

**Vocational Higher Secondary  
Education (VHSE)**

**Second Year**

**MARINE TECHNOLOGY**

*Reference Book*



Government of Kerala  
Department of Education

State Council of Educational Research and Training (SCERT),  
KERALA  
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## **Foreword**

Dear Learners,

This book is intended to serve as a ready reference for learners of vocational higher secondary schools. It offers suggested guidelines for the transaction of the concepts highlighted in the course content. It is expected that the learners achieve significant learning outcomes at the end of the course as envisaged in the curriculum if it is followed properly.

In the context of the Right- based approach, quality education has to be ensured for all learners. The learner community of Vocational Higher Secondary Education in Kerala should be empowered by providing them with the best education that strengthens their competences to become innovative entrepreneurs who contribute to the knowledge society. The change of course names, modular approach adopted for the organisation of course content, work-based pedagogy and the outcome focused assessment approach paved the way for achieving the vision of Vocational Higher Secondary Education in Kerala. The revised curriculum helps to equip the learners with multiple skills matching technological advancements and to produce skilled workforce for meeting the demands of the emerging industries and service sectors with national and global orientation. The revised curriculum attempts to enhance knowledge, skills and attitudes by giving higher priority and space for the learners to make discussions in small groups, and activities requiring hands-on experience.

The SCERT appreciates the hard work and sincere co-operation of the contributors of this book that includes subject experts, industrialists and the teachers of Vocational Higher Secondary Schools. The development of this reference book has been a joint venture of the State Council of Educational Research and Training (SCERT) and the Directorate of Vocational Higher Secondary Education.

The SCERT welcomes constructive criticism and creative suggestions for the improvement of the book.

With regards,

**Dr. P. A. Fathima**  
**Director**  
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## ABOUT THE COURSE

'Marine Technology' has great relevance among the different vocational courses. India being a country with a vast coastline of about 8000 Km, fishing, water transportation and allied industries play an important role, in providing employment to a majority of the coastal population and also in sustaining the economy with foreign exchange, earned from the export of various fisheries products.

Among the maritime status of India, Kerala holds a remarkable position in fisheries sector. The coast of Kerala constitutes approximately 10 percent of India's total coastline. This coastline of 590 km and the Exclusive Economic Zone (EEZ) extends up to 200 nautical miles far beyond the continental shelf, which covers an area of 2,18,536 sq km, providing opportunities for ages in traditional fishing in inshore waters. Kerala has a large number of boats, ships and vessels and thus provides job opportunities for lakhs.

The course 'Marine Technology' enables a VHS student to acquire the skill to do maintenance, different service works, fault finding and rectification in different On board and In board engines. He may work as a technician/supervisor in marine workshops or plants, or he can start a service centre of his own.

This two year course has 4 modules. After the completion of **first module** he gets a skill certificate in '**Basic Marine Work shop practice**'.

The **second module** deals with servicing of out board motors and after completion he will get a Skill certificate as '**Out Board Motor Servicing**'.

The **third module** is about servicing of Marine diesel engines and earns a skill certificate in '**Marine Diesel Engine Servicing**'.

The **last module** is about marine equipments and navigational aids. The certificate issued will be a skill certificate in '**Marine vessel equipment servicing, Welding and NDT**'.

### Major Skills (With Sub Skills)

#### 1. The ability to do Marine Diesel Engine Servicing

- a) Decarbonization
- b) Injector Testing and Servicing
- c) Fault Diagnosis and Rectification
- d) Identification of Pipe Lines

## 2. Marine Equipment Servicing, Welding And Non-destructive Testing

- a) Maintenance of Auxiliary Machines
- b) Handling of Deck Equipments
- c) Handling of Navigation Aids
- d) Various welding Techniques
- e) Analysis of welding defects
- f) Major NDT Techniques

## SYLLABUS

### Module-3

#### Unit 3.1- Introduction to Marine Diesel Engine (20 - Period)

Diesel engine Cycle- Diesel engine description - working of 2 - stroke and 4 Stroke CI engines. - Differences between SI & CI engines

#### Unit 3.2- Marine Low Speed Engine Construction (60 - Periods)

Categorization of Marine engines - Low, medium & High Speed engines - Necessity of Main & Auxiliary engines in Ships & Vessels - Advantages of 2 - stroke low speed engine as Main engine in Marine Ships & Vessels.- Heavy vessel diesel engine construction

#### Unit 3.3- Marine Diesel Engines Systems (140 - Periods)

Fuel system - electronic injector - Starting system- Air starting system - Cooling system - Lubrication system - Air intake and Exhaust systems - Transmission System - Steering system governor, decompression mechanism, blow past mechanism.

#### Unit 3.4- Marine Diesel Engines: Maintenance and Trouble Shooting (60 - Periods)

Daily maintenance - Periodic maintenance - Preventive maintenance - Break down maintenance - Fault diagnosis and rectification - Propeller efficiency low - Smoke colour -Blue, White and Black - Cavitations in propeller - Engine temperature high - Low mileage - Detonation inside the engine - Decarburization - Valve Clearance

adjustment - Cylinder piston clearance - Compression pressure checking low/ high  
- Crank case explosion - Oil mist detection - Engine oil quality checking - Visual,  
Viscosity, water, microbial degradation

**Unit 3.5- Gauges and Meters (40 - Periods)**

Different gauges and meters used in marine engines - Pressure gauge, temperature  
gauge, tachometer - Different gauges and meters used in marine engines -Ammeter,  
flow meter, pyrometer, Inclinator, gauge glass, hour meter

**Unit 3.6- Vessel and Vessel Terminology (20 - Periods)**

Vessel terminology - Engine room layout - Colour lights and code used in ships

**Module- 4**

**Unit 4.1 - Marine Auxiliary Machines (60 - Period)**

Auxiliary Machines-Pumps (Centrifugal pump, reciprocating pump, Gear pump and  
Hand Pump) -Compressor (Reciprocating compressor Single stage, Multi-stage,  
Centrifugal compressor) - AC Generator - Power take off (Mechanical, Electrical  
and Hydraulic)

**Unit 4.2- Deck Equipments and Fishing Accessories (40 - Periods)**

Deck Equipments and fishing Accessories- Mechanical Trawl winch, fishing  
Accessories- Line Hauler, Power block (open and closed) - Net drum-Gallows -  
Mast -Derrick and pulleys

**Unit 4.3 - Navigation Aids (20 - Periods)**

Navigation aids - GPS, Gyroscope, AIS, VHF Radio, RADAR, Ultra sonic devices  
(Fathometer, SONAR, Fish finder), Magnetic compass and Gyro compass

**Unit 4.4 - Life Saving Equipments (10 - Periods)**

Life - saving Equipments - Life raft, Life buoy, Life Jacket and Life Boat

**Unit 4.5- Welding and Welding Defects (110 - Periods)**

Welding Methods - Fusion welding, Pressure welding and Thermo chemical welding  
- Gas Welding (Oxy-Acetylene), Arc Welding Methods- SMAW,GMAW/MIG,  
GTAW/TIG and Submerged arc welding - Different welding positions-Flat,

Horizontal, vertical and Overhead - Under water welding and its two types such as Wet (Metal Arc) and Dry (Flux cored arc) - Welding defects - Lack of penetration, Lack of fusion, Porosity, Slag inclusion, undercut, Overlays, Cracking, Blowholes, Burn through, Excessive penetration, spatter and arc strike

**Unit 4.6 Non-Destructive Tests**

**(Periods-100)**

Types of weld tests - destructive and non destructive - Different types of non - destructive testing - visual inspection, liquid penetrant test, magnetic particle test, radiographic test and ultra sonic test



## Overview of the Module 3

### Marine Diesel Engine Servicing

A course in marine technology is incomplete without heavy diesel engine/ ship engine servicing. In this module the learner acquires the skills for servicing multi - cylinder diesel engine, its different systems, maintenance works and trouble shooting. He gets familiar with different gauges and meters found on the engine / control room / bridge. He also gets a fair idea about vessel terminology, engine room layout and the colour codes used in Marine vessels.

### Unit - 1

#### INTRODUCTION TO MARINE DIESEL ENGINE

An introduction to diesel engine begins with diesel cycle. The diesel cycle is explained on the basis of P-V diagram and T-S diagram. This gives a clear picture of the processes taking place in a diesel cycle. Thereafter the working of two- stroke marine diesel engine and four - stroke diesel engines are detailed and a comparison between spark ignition (S.I.) engine and compression ignition (C.I.) engine is done.

#### Learning Outcomes

- Describes thermodynamic cycle behind the working of diesel engines.
- Explains working of 2 - stroke & 4 - stroke CI engines.
- Differentiates between SI & CI engines.

#### Detailing of the Concepts

##### 3.1.1 Diesel Engine Cycle

A diesel engine's working is based on diesel cycle. It consists of four processes.

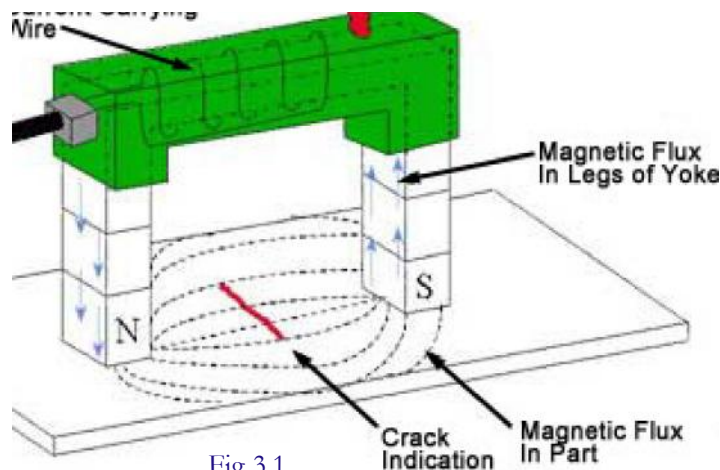


Fig 3.1

**Process 1-2**

Volume decreases from  $V_1$  to  $V_2$ , Pressure increases from  $P_1$  to  $P_2$ , Temperature also increases  $T_1$  to  $T_2$  and Entropy is constant  $S_1=S_2$ , it is adiabatic process and work is input into the system. So process 1-2 is adiabatic work input process.

**Process 2-3**

Volume increases from  $V_2$  to  $V_3$ , Temperature increases from  $T_2$  to  $T_3$ , Entropy also increases from  $S_2$  to  $S_3$  and Pressure remains constant  $P_2 = P_3$ , it is a constant pressure process and heat is input into the system. So it is a constant pressure heat addition process.

**Process 3-4**

Pressure decreases from  $P_3$  to  $P_4$ , Temperature also decreases from  $T_3$  to  $T_4$ , Volume increases from  $V_3$  to  $V_4$ , and entropy remains constant  $S_3=S_4$ , it is a adiabatic process and work is output from the system. So it is adiabatic work output process.

**Process 4-1**

Pressure decreases from  $P_4$  to  $P_1$ , Temperature decreases from  $T_4$  to  $T_1$ , Entropy decreases from  $S_4$  to  $S_1$  and Volume remains constant  $V_4=V_1$  and heat rejection from the system. So it is constant volume heat rejection process.

**3.1.2 Diesel Engine Description**

4 - stroke Compression Ignition (CI) engine works as same as the 4 - Stroke SI engine. Only difference in spite of spark plug here it is fuel injector. But in the case of 2 - stroke CI engine here the pressurised air is entered into the cylinder (above the piston), no transfer port, only inlet port and exhaust valve

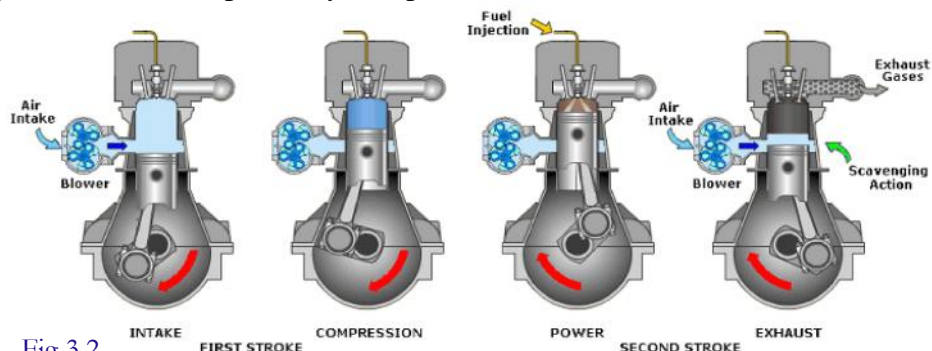


Fig 3.2

**3.1.2.1 Working of 2 - stroke Marine Diesel Engine**

2 - stroke internal combustion engines are more simple mechanically than four-stroke engines, but more complex in thermodynamic and aerodynamic processes, according to SAE (Society of Automotive Engineers) definitions. In a 2-stroke engine,

the four "processes" of internal combustion engine theory (intake, compression, ignition, exhaust) occur in one revolution, 360 mechanical degrees, whereas in a 4-stroke engine these occur in two complete revolutions, 720 mechanical degrees. In a 2-stroke engine, more than one function occurs at any given time during the engine's operation.

- Intake begins when the piston is near the bottom dead center. Air is admitted to the cylinder through ports in the cylinder wall (there are no intake valves). All 2-stroke Diesel engines require artificial aspiration to operate, and will either use a mechanically driven blower or a turbo-compressor to charge the cylinder with air. In the early phase of intake, the air charge is also used to force out any remaining combustion gases from the preceeding power stroke, a process referred to as scavenging.
- As the piston rises, the intake charge of air is compressed. Near top dead centre, fuel is injected, resulting in combustion due to the charge's extremely high pressure and the heat created by compression, which drives the piston downward. As the piston moves downward in the cylinder, it will reach a point where the exhaust port is opened to expel the high-pressure combustion gases. However, most current 2-stroke diesel engines use top-mounted poppet valves and uniflow scavenging. Continued downward movement of the piston will expose the air intake ports in the cylinder wall, and the cycle will start again.

### 3.1.2.2 Working of 4-Stroke Marine Diesel Engine

A 4-stroke engine is an internal combustion (IC) engine in which the piston completes four separate strokes while turning the crankshaft twice. A stroke refers to the full travel of the piston along the cylinder, in either direction. The four separate strokes are termed:

- **Intake:** This stroke of the piston begins at top dead centre (T.D.C.) and ends at bottom dead centre (B.D.C.). In this stroke the intake valve must be in the open position while the piston pulls air into the cylinder by producing vacuum pressure into the cylinder through its downward motion.

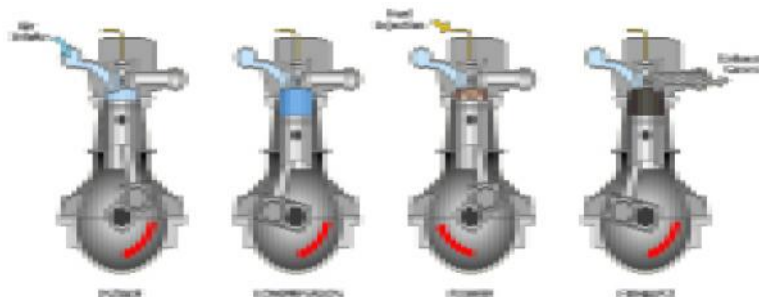


Fig 3.3

- **Compression:** This stroke begins at B.D.C, or just at the end of the suction stroke, and ends at T.D.C. In this stroke the piston compresses the air in preparation for ignition during the power stroke (below). Both the intake and exhaust valves are closed during this stage.
- **Combustion:** While the piston is at T.D.C. (the end of the compression stroke) the injector sprays diesel into the combustion chamber. The rise in temperature of the air caused by its compression results in instantaneous burning of diesel with in an explosion. This causes heat to release resulting in the generation of expanding forces known as power. Piston moves from TDC to BDC.
- **Exhaust:** During the exhaust stroke, the piston once again returns from B.D.C. to T.D.C. while the exhaust valve is open. This action expels the spent air-fuel mixture through the exhaust valve.

### 3.1.3 Differences between SI & CI Engines

SI No	SI	CI
1	Otto Cycle	Diesel Cycle
2	Spark plug, Ignition system	Injector, Injection pump
3	Less initial cost	High initial cost
4	High running cost	Less running cost
5	Less power	High Power
6	Low weight	High weight

### Detailing of Practicals

#### 1. Identify and categorize the SI & CI engines parts.

Mix the SI & CI engine parts and placed on the workshop floor. Teacher asked students to identify and categorize the SI & CI engine parts.

### Assessment Activities

- Class test
- Identification of engine parts
- Seminar
- Flow chart preparation
- Assignment
- Quiz • Collection

### TE Questions

- 1) Identify the CI engine thermodynamic cycle. ( Otto, diesel, auto, dual, Carnot)
- 2) Explain the working of 2 - stroke diesel engine with neat sketch
- 3) Arrange and categories the following IC engine parts under SI and CI engine  
Piston, diesel injector, inlet valve, fly wheel, spark plug, carburettor, injection pump, exhaust valve, turbo charger.

## Unit - 2

### MARINE LOW-SPEED ENGINE CONSTRUCTION

Before one should go in detail about marine diesel engines, he should know about the categorization of diesel engines into high speed engines, medium speed engines, low speed engines and their differentiation criteria. Eventually the topic leads to the use of low speed engines as Main engines and 4 - stroke engines as auxiliary engines. This paves way to the relevance of the topic-advantages of two stroke engines over four stroke engines as main engines onboard ship. The parts of two stroke diesel engines such as exhaust valve, piston and piston rod, cross head, piston rings, fuel injector, fuel pump, turbocharger, fuel cam etc. are covered in detail.

#### Learning Outcomes

- Categorization of marine engines such as low, medium & high speed
- Describe the needs of main & auxiliary engines in ships & vessels
- Describe the advantages of 2 - stroke low speed engine as main engine in marine ships & vessels.
- Identify heavy vessel diesel engine parts such as exhaust valve, piston rod, cross head, piston rings, fuel injection pump, no transfer port, air induction by turbo charger, direct drive, two sets of fuel cams for reversing the engine rotation.

#### Detailing of the Concepts

##### 3.2.1 Categorization of diesel engines

Within the diesel engine industry, engines are often categorized by their rotational speeds into three unofficial groups:

1. High-speed engines (> 1,000 rpm),
2. Medium-speed engines (300-1,000 rpm), and
3. Low-speed engines (< 300 rpm).

#### High-speed engines

High-speed (approximately 1,000 rpm and greater) engines are used to power trucks (lorries), buses, tractors, cars, yachts, compressors, pumps and small electrical generators. Now a days most high-speed engines have direct injection. Many modern engines, particularly in on-highway applications, have common rail direct injection, which is cleaner burning.

### Medium-speed engines

Medium-speed engines are used in large electrical generators, ship propulsion and mechanical drive applications such as large compressors or pumps. Medium speed diesel engines operate on either diesel fuel or heavy fuel oil by direct injection in the same manner as low-speed engines.

Engines used in electrical generators run at approximately 300 to 1000rpm and are optimized to run at a set synchronous speed depending on the generation frequency (50/60hertz) and provide a rapid response to load changes. Typical synchronous speeds for modern medium-speed engines are 500/514 rpm (50/60Hz), 600 rpm (both 50 and 60Hz), 720/750rpm, and 900/1000rpm.

### Low-speed engines

Also known as slow-speed, or traditionally oil engines, the largest diesel engines are primarily used to power ships, although there are a few land-based power generation units as well. These extremely large two-stroke engines have power outputs up to approximately 85 MW (114,000 HP), operate in the range from approximately 60 to 200rpm and are up to 15m (50ft) tall, and can weigh over 2,000 short tons (1,800t). They typically use direct injection running on cheap low-grade heavy fuel, also known as bunker C fuel, which requires heating in the ship for tanking and before injection due to the fuel's high viscosity.

Large and medium marine engines are started with compressed air directly applied to the pistons.

### 3.2.2 Main & Auxiliary Engines in Ships

Main or propulsion engines are used to turn the ship's propeller and move the ship through the water.

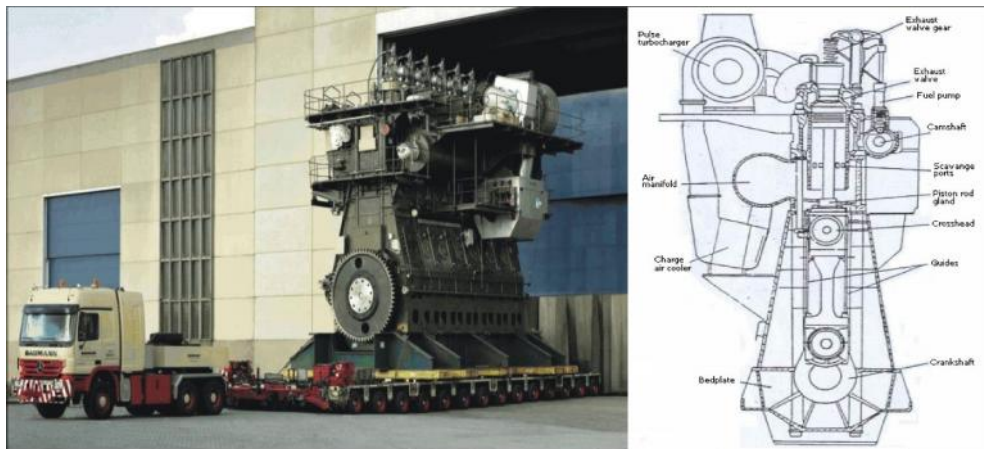


Fig 3.4

### Main engine

They typically burn diesel oil or heavy fuel oil, and may be able to switch between the two. In ships mostly 2-stroke diesel engines are used as main engines. 4-stroke diesel engines are also used as main engines in smaller vessels, but this requires a bigger reduction gear box.

### Auxiliary engine

Auxiliary engine is normally a 4 stroke engine which is coupled with a generator to produce electricity. There will be 2 or 3 auxiliary engines in a ship, at least two will be present.



Fig 3.5

### 3.2.3. Advantages of 2 - stroke low speed engine as main engine

1. No gear box required
2. Less number of moving parts when compared to 4 stroke engine
3. Low quality fuel can be burned
4. Produce high power compared to 4 stroke engines

### 3.2.4 Heavy Vessel Diesel Engine Construction

#### Exhaust valve

Exhaust valves open inwards into the cylinder, so that the gas pressure in the cylinder will ensure positive closing.

Two - stroke cross-head engines have a single exhaust valve mounted in the centre of the cylinder head. The opening and closing of the valve is controlled by a cam mounted on the camshaft. On older engines the cam follower lifts a push rod, which operates a rocker arm and opens the valve.

Modern two - stroke cross-head engines have a hydraulically operated air sprung exhaust valve. The cam operates a hydraulic pump instead of a push rod. Oil (from the engine Lube Oil system) displaced by the pump operates a piston in the exhaust valve which pushes the valve open.

Instead of mechanical springs, the valve has an "air spring". Air at 7 bar is led via a non return valve to the underside of a piston attached to the valve spindle. As the valve opens, the air underneath the piston is compressed. The expansion of this compressed air, when the hydraulic pressure is relieved, assists in the closing of the valve.

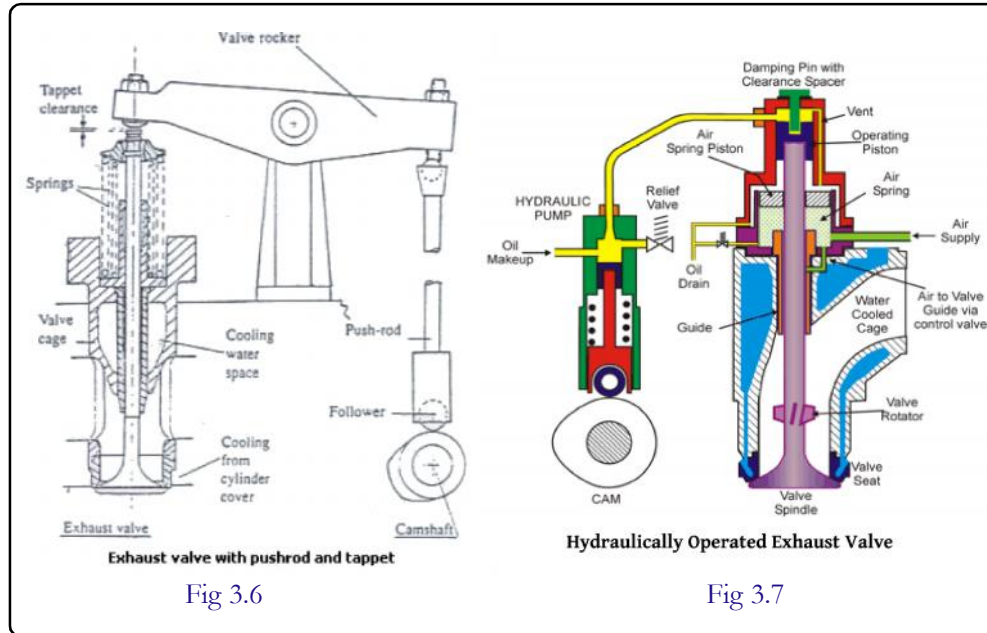


Fig 3.6

Fig 3.7

The air is supplied with a small amount of oil for lubrication purposes. Air is also led down the exhaust valve guide. This keeps the guide cool and lubricated, and prevents the exhaust gas leaking up the guide. Excess oil which collects at the bottom of the air spring cylinder is drained to a collecting tank.

To prevent the possibility of an air lock, the hydraulic system has a small leak off at the top of the exhaust valve hydraulic cylinder. Oil is made up via a non return valve. A relief valve is also fitted. A damping arrangement on top of the piston in the exhaust valve prevents hammering of the valve seating.

The valve spindle is fitted with a winged valve rotator. The kinetic energy in the exhaust gas rotates the valve a small amount as it passes. This keeps the valve at an even temperature and helps to reduce the build up of deposits on the valve seat.

When the valves are overhauled, the valves and seats are not lapped together. Instead special grinding equipment is used to grind the seat and spindle to the correct angles.

### Piston and Piston Rod

The Piston comprises of two pieces; the crown and the skirt. The crown is subject to the high temperatures in the combustion space and the surface is liable to be eroded /burnt away. For this reason the material from which the crown is made must be able to maintain its strength and resist corrosion at high temperatures. Steel, alloyed with chromium and molybdenum is used, and some pistons have a special alloy welded onto the hottest part of the crown to try and reduce the erosion caused



by the burning fuel. The crown also carries the 4 or 5 piston ring grooves which may be chrome plated. The cast iron skirt acts as a guide within the cylinder liner. It is only a short skirt on engines with an exhaust valve (known as uni-flow scavenged engines), as unlike a trunk piston engine, no side thrust is transmitted to the liner (that's the job of the cross-head guides).

A forged steel piston rod is bolted to the underside of the piston. The other end of the piston rod is attached to the cross-head pin. Pistons are cooled either using water or the crankcase oil. Water has a better cooling effect than oil, but there is a risk of leakage of water into the crankcase.

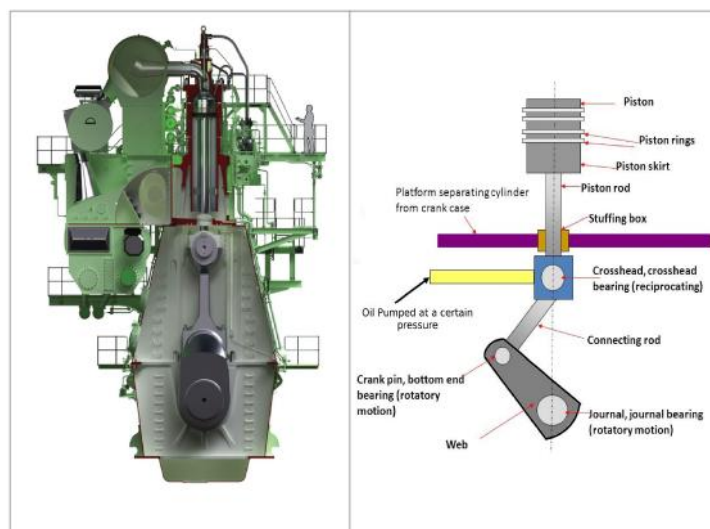


Fig 3.8

Modern engines have oil cooled pistons. The piston rod is utilized to carry the oil to and from the piston. The rod is hollow, and has a tube running up its centre. This gives an annular space which, with the central bore, allows a supply and return.

### Piston rings

Piston ring is an important part of the engine. Yet the rings tend to be neglected because they are a consumable item. Often they can be found in the corner of a storeroom covered in dirt and rust, and in severe cases they have been painted. Piston rings should be kept in a dry place and stored flat. A light coating of protective lubricant will prevent them from rusting. If they are covered, make sure they are checked regularly to ensure they are in satisfactory condition.

The functions of piston rings are:

- Provide a seal to the combustion chamber to prevent gases and combustion products passing the piston.

- Control the lubricating oil.
- Conduct heat away from the piston to the liner.

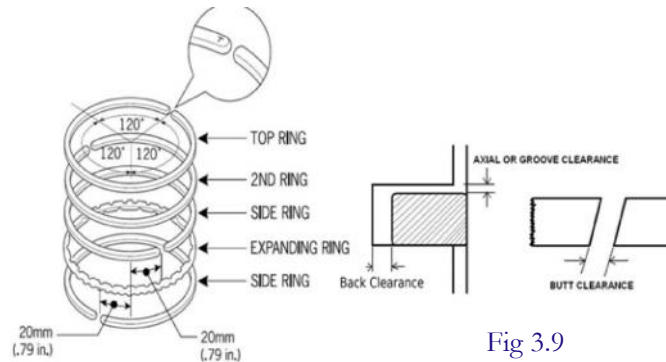


Fig 3.9

### Types of Piston Rings

- Compression ring- Provides a gas seal.
- Scraper or Oil Control ring- Distributes oil on the cylinder liner preventing the oil passing upwards into the combustion chamber. These rings are normally found on trunk piston engines.

The piston ring sits in a machined groove, located such that the ring operates at an acceptable temperature. If the rings were fitted too high, the high temperature would rapidly burn off the oil and the rings would seize in their grooves. The piston ring must be free to move in its groove, therefore, a clearance is required. Ring clearances are shown in the figure above.

### Effect of Clearances

#### Groove Clearance

- Allows pressure to build up behind the ring
- Allows oil to flow into the groove
- Allows pressure to build up behind the ring

This may also be termed gap clearance and is required to accommodate the ring expansion as it heats up.

#### Too small Groove Clearance

- Ring will stick in the groove. This will result in poor sealing and possible blow by which will burn away the oil and cause scuffing. Insufficient gas pressure behind the ring will affect sealing.

#### Too large Groove Clearance

- Ring flutter and possible breakage

### Too small Butt Clearance

- As the ring expands the butt will come together. This will exert a large radial pressure on the liner, breaking down the oil film and increasing scuffing wear. Ring seizure may occur.

### Too large Butt Clearance

- Excessive gas leakage

The piston rings operate in a hostile environment. The load is fluctuating and at top dead centre the rings are at their slowest speed and highest temperature. The rings must withstand corrosive combustion products. Piston rings must therefore have high tensile strength to resist breakage, combined with good anti-corrosive properties. Rings must also maintain tension at lower combustion pressures and be compatible with the liner material.

### Cross-head

The 2 - stroke diesel cross-head engine works on exactly the same principle and cycle as the 2 stroke diesel trunk piston engine. The piston rod is bolted to the piston and passes through a stuffing box mounted in the diaphragm plate. To ensure that the cross-head reciprocates in alignment with the piston in the cylinder, guide shoes are attached either side of the cross-head pin. These shoes are lined with white metal, a bearing material and they reciprocate against the cross-head guides, which are bolted to the frame of the engine. The cross-head guides are located in between each cylinder. Cross-head design allows engines to be built with very long strokes - which means the engine can burn a greater quantity of fuel/stroke and develop more power. The most powerful diesel engines in the world are two stroke cross-head engines.

The function of the fuel injection system is to provide the right amount of fuel at the right moment and in a suitable condition for the combustion process.

### The fuel oil injection system for a diesel engine

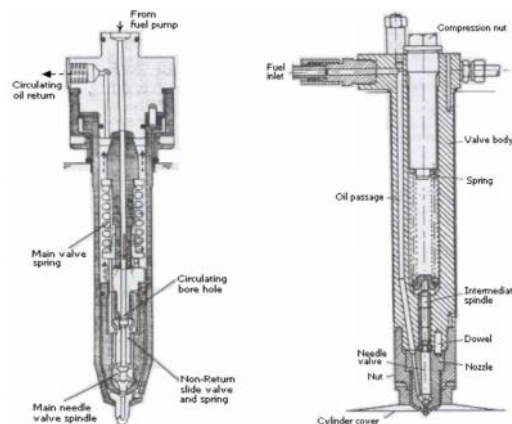


Fig 3.10

The injection of the fuel is achieved by the location of cams on a camshaft. This camshaft rotates at engine speed for a two-stroke engine and at half engine speed for a four-stroke engine. There are two basic systems in use, each of which employs a combination of mechanical and hydraulic operations. The most common system is the jerk pump; the other is the common rail.

A typical fuel injector is shown in Figure. It has two basic parts, the nozzle and the nozzle holder or body. The high-pressure fuel enters and travels down a passage in the body and then into a passage in the nozzle, ending finally in a chamber surrounding the needle valve.

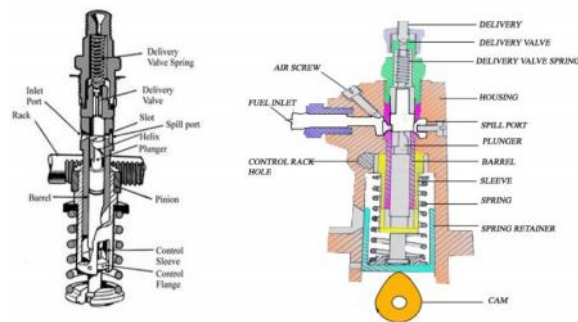
The needle valve is held closed on a mitred seat by an intermediate spindle and a spring in the injector body. The spring pressure, and hence the injector opening pressure, can be set by a compression nut which acts on the spring. The nozzle and injector body are manufactured as a matching pair and are accurately ground to give a good oil seal. The two are joined by a nozzle nut.

The needle valve will open when the fuel pressure acting on the needle valve tapered face exerts a sufficient force to overcome the spring compression. The fuel then flows into a lower chamber and is forced out through a series of tiny holes. The small holes are sized and arranged to atomize, or break the fuel into tiny drops, all of the fuel oil, which will then readily burn. Once the injector pump or timing valve cuts off the high pressure fuel supply the needle valve will shut quickly under the spring compression force.

All slow-speed two-stroke engines and many medium-speed four stroke engines are now operated almost continuously on heavy fuel. A fuel circulating system is therefore necessary and this is usually arranged within the fuel injector. During injection the high-pressure fuel will open the circulation valve for injection to take place. When the engine is stopped the fuel booster pump supplies fuel and the circulation valve directs around the injector body.

Older engine designs may have fuel injectors which are circulated with cooling water.

### Fuel Injection Pump



Fuel Injection Pump

Fig 3.11

Fuel has to be injected into the engine at a high pressure so that it atomizes correctly. Injection takes place over a short period of time and this period of time must be accurately controlled; late or early injection will lead to a lack of power and damage to the engine. Because the timing of injection is crucial, cams mounted on the camshaft, which is driven by the crankshaft are used to operate the fuel pumps, one of which is provided for each cylinder.

As the cam rotates it operates a spring loaded ram (or plunger) which moves up and down in a cylinder (or barrel). As the plunger moves up the barrel, the pressure of the fuel in the barrel above the plunger rises very quickly. The high pressure fuel then opens the fuel valve (injector) and is sprayed into the cylinder in tiny droplets known as atomization. It is important to note that the injection only takes place when the plunger is moving up the cam slope.

This is the principle behind the operation of the fuel pump. Once started, the engine would over speed. A process which will infinitely vary the amount of fuel injected into the engine can be controlled by a governor.

Two different methods are used. In the first, the plunger has a helix machined into it which also forms a vertical groove and an annular groove at the base of the helix. The plunger reciprocates in a barrel, located in the pump body which has spill ports, connected to the suction side of the pump, drilled so that they are above the top of the plunger when the cam is on the base circle. The plunger is keyed to a sleeve which has a gearwheel (pinion) machined into it. The pinion meshes with a rack which can rotate the plunger relative to the barrel. The rack is connected to the engine governor.

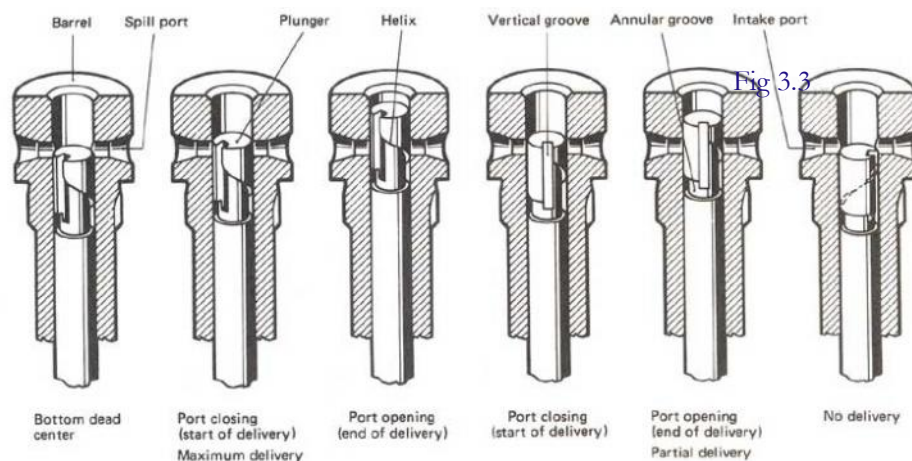


Fig 3.12

As the plunger moves upwards in the barrel, injection will commence once the plunger has closed off the spill ports and the pressure builds up. As soon as the helix or scroll passes the spill ports the pressure above the plunger will immediately drop, even though the plunger is still moving upwards. It should therefore be evident that the amount of fuel injected into the cylinder is dependent on the position of the helix relative to the spill port. When the vertical groove is lined up with the spill port, then no injection will take place and the engine will stop.

### Air induction by turbo charger

About 35% of the total heat energy in the fuel is wasted to the exhaust gases. The Turbocharger uses some of this energy (about 7% of the total energy or 20% of the waste heat) to drive a single wheel turbine. The turbine is fixed to the same shaft as a rotary compressor wheel. Air is drawn in, compressed,

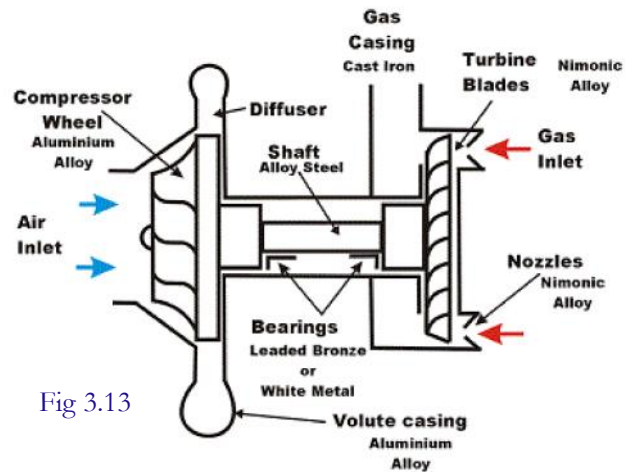


Fig 3.13

and compression raises the temperature of the air, it is cooled down to reduce its volume. It is then delivered to the engine cylinders via the air manifold or scavenge air receiver.

The speed of the turbocharger is variable depending on the engine load. At full power the turbocharger may be rotating at speeds of 10000RPM.

### Direct Drive

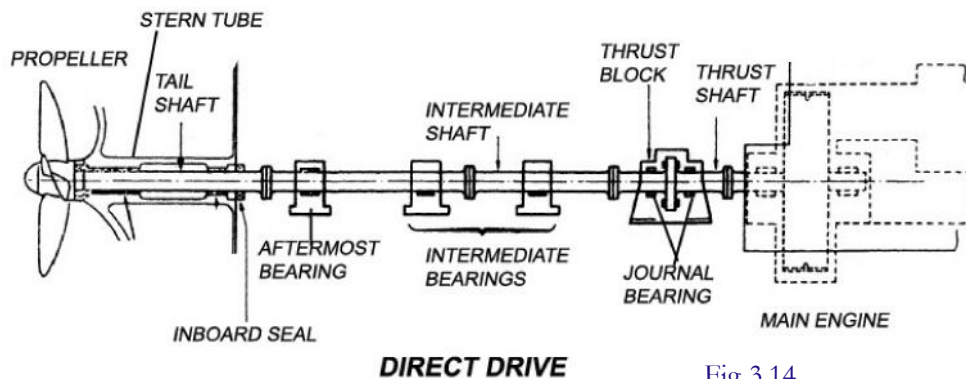


Fig 3.14

## Cam Shaft Reversing

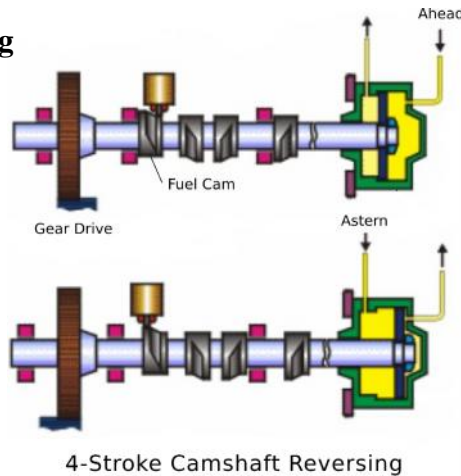


Fig 3.15

## Detailing of Practicals

1. **Dismantling and assembling of boat diesel engine and identification of parts such as exhaust valve, piston rod, cross head, separate fuel injection.pump for each cylinder, no transfer port, air induction by turbocharger, direct drive, two set of fuel cams for reversing the engine rotation**
  - After removing all the fuel supply lines, electrical connection from battery and lube oil lines.
  - Remove the cylinder cover.
  - Mark the cylinder from flywheel end by using chalk.
  - Remove the fuel injector.
  - Remove the cylinder head stud nuts and dismantle the cylinder head.
  - Remove the cylinder block window nuts and then remove it.
  - Remove the connecting rod big end nuts, big end cap from crank shaft.
  - Remove the piston, cross head (if present), connecting rod assembly.
  - Then identify and study the diesel engine parts such as exhaust valve, piston rod, cross head, minimum 4 piston rings only, separate fuel injection pump for each cylinder, no transfer port, air induction by turbo charger, direct drive, two set of fuel cams for reversing the engine rotation.
  - Assemble the diesel engine in the reverse order of dismantling.
  - Dismantle and assemble the fuel injection pump.
  - After removing the fuel supply lines from service tank and fuel injector
  - Remove the fuel injection pump fixing nuts from the engine.
  - Then remove the injection pump and placed on the work table.
  - Dismantle the injection pump delivery pipe and remove the nuts.

- Dismantle the delivery valve spring, delivery valve.
- Dismantle the rack from the pump.
- Dismantle cam follower, spring, plunger etc.
- Dismantle the pinion, sleeve etc.
- Then identify all the parts like, delivery spring, delivery valve, inlet port, spill port, barrel, plunger, plunger groove, rack, pinion, cam follower, sleeve etc.
- After studying its working, assemble the pump in the reverse order of dismantling.

## 2 Dismantling and assembling of fuel injector

- After removing the fuel supply lines from service tank and fuel injector, remove the injector fixing nuts.
- Remove the injector from the engine and placed on a work table.
- Dismantle the injector cap nut, remove lock nut, adjusting screw, valve spring one by one.
- Remove nozzle body nut and separate injector body and nozzle.
- Dismantle valve with valve rod.
- Identify all the parts such as cap nut, lock nut, adjusting screw, valve spring, inlet passage, leak off passage, nozzle valve, nozzle body, valve rod, nozzle etc.
- After studying its working assemble the injector in the reverse order of dismantling.

## 3 Assembling of piston rings in the piston

- Remove piston from the cylinder.
- Separate piston from connecting rod.
- Spread piston rings gently by using piston ring extractor, so that they can be removed or fitted over the piston crown
- The marking 'top' must be upper most.
- Piston rings must be fitted so that the gaps in the rings are offset.

### Assessment Activities

- 1 Class test
- 2 Assignment
- 3 Group discussion
- 4 Seminar

### TE Questions

- 1 Differentiate low, medium and high speed engines
- 2 List advantages of 2- stroke marine diesel engines over 4 - stroke engines
- 3 What is the purpose of an auxiliary and main engine onboard ship?
- 4 From the given figure identify and mark the following 2 - stroke marine diesel engine parts.

Exhaust valve, piston rod, cross head, piston rings, fuel injection pump, turbo charger, direct drive, cams.



## Unit - 3

### MARINE DIESEL ENGINES SYSTEMS

This unit deals with the different types of systems onboard ships and boats. The systems mainly consists of fuel system, starting air system, cooling system, lubrication system, air intake and exhaust system, propulsion system, transmission system, steering system. The fuel system covers the types of fuel oils onboard ship and a detailed study of fuel oil line in ships and boats. The topics such as injector testing and servicing, fuel injection pump diesel governor etc. are included. Starting system and its classifications like manual, electric and air starting systems, blow past, de-compression mechanisms are detailed. A detailed study about indirect sea water cooling system is included in cooling system. Lubrication, its importance and the lube oil system with line diagram gives a clear view about the lubrication of engines, machinery, stern tube, etc. air intake and exhaust system deals with the engine air intake and exhaust lines as well as machinery included in it, the role of turbocharger and its lubrication. The transmission system cover topics like transmission onboard ships, gearboxes such as epi-cyclic, differential, hydraulic gearboxes used. Propeller, its nomenclature and its types are detailed in propulsion system. The manoeuvrability of the vessel and the steering gear arrangements are covered in steering system.

#### **Detailing of The Concepts**

##### **3.3.1. Fuel system - Fuels used in marine engines**

Marine Diesel Oil (MDO) is a type of fuel oil and is a blend of gasoil and heavy fuel oil, with less gasoil than intermediate fuel oil used in the maritime field. Marine Diesel Oil is also called Distillate Marine Diesel. MDO is widely used by medium speed and medium/high speed marine diesel engines. It is also used in the larger slow speed and medium speed propulsion engine which normally burn residual fuel, those fuels resulting from a catalytic cracking/visbreaking refinery, due to its lower price compared to more refined fuel

##### **3.3.2 Fuel system in fishing boats**

Fuel supply system in marine diesel engine is made of the following components:

#### **1. Diesel tank or reservoir:**

Whenever you supply fuel to a marine diesel engine, it is stored in the diesel tank. Diesel tank temporarily stores diesel that is to be supplied to the engine.

#### **2. Low pressure pump:**

It pumps the diesel at a low pressure to the fuel injection pump through a filter.

**3. Filter:**

Before diesel is supplied to an engine, it must be filtered to remove any unwanted impurities. Filter is used for this purpose.

**4. Fuel injection pump:**

This is the most important component of the fuel injection system. Fuel injection pump pressurizes the fuel to the required level and injects it correctly at the end of the compression stroke, during each cycle of operation of the engine.

**5. Fuel injectors:**

Injectors are devices used to inject the fuel to the cylinder. In diesel engine, when fuel is injected, it is automatically atomized

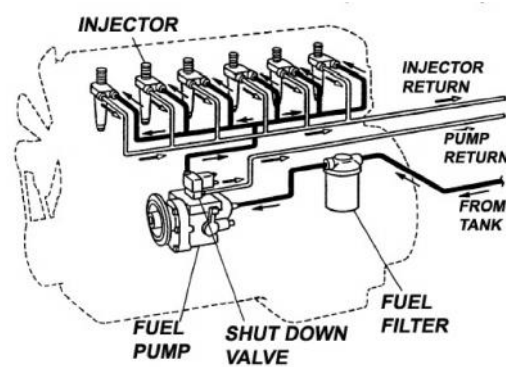


Fig 3.16

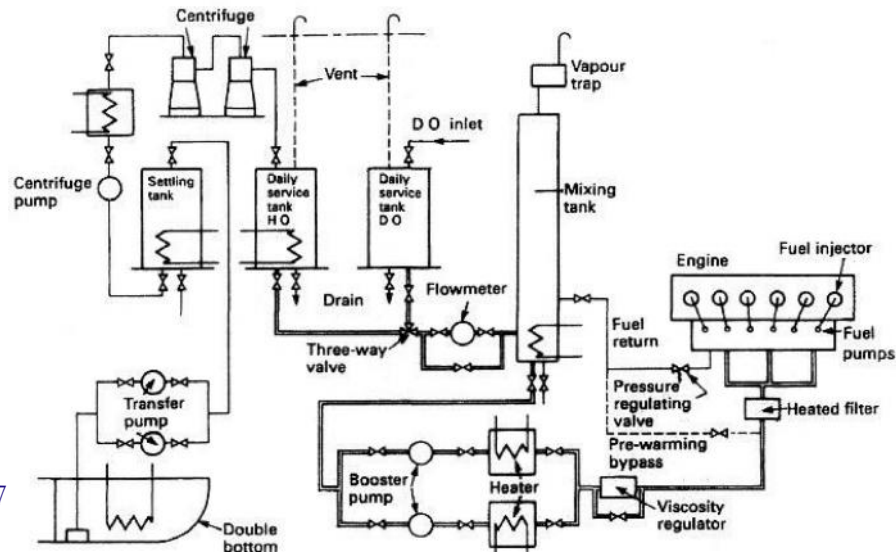
**3.3.3 Fuel system in Ships and Vessels**

Fig 3.17



When the plunger rises, it opens a valve and the injector sends fuel through the spray tip and into either the intake manifold, just upstream of the intake valve, or directly into the cylinder. The former system is called multipoint fuel injection and the latter is direct injection.

### 3.3.6 Starting systems

#### Manual starting

Hand or manual starting system is the one in which the crankshaft is rotated mechanically by manpower. Hand or manual starting system may be further classified as starting by pulling rope, kick starting and starting by using lever. Rope is wound on the flywheel which when pulled rotates the crank shaft and the engine is started. The handle method of hand starting is commonly applied in marine engines. This system is used for small engines up to 60 HP. Before starting the decompression lever of the engine is put in the ON position which keeps the exhaust valve in open condition always.

#### Electric starting

This method is adopted in engines having power up to 200HP. Here the external force required to rotate the crank shaft is supplied by an electric motor. Diagram below shows the schematic arrangement of electrical starting system. The components of this system are a starting motor connected with bendix and starter pinion, a dynamo, a battery, cut out, switch etc. when the switch is pushed on the current from battery flows to the motor and rotates it. At the same time the current also flows to the bendix and pushes it up so that the starter pinion will become mesh with the flywheel and rotates it, hence the engine is started. When the engine gets sufficient speed the bendix pull back the starter pinion to its original position. As the engine working the dynamo connected to it through belt drive produces DC current and it flows to the battery through the cut out. The cut out protecting the battery from over charging.

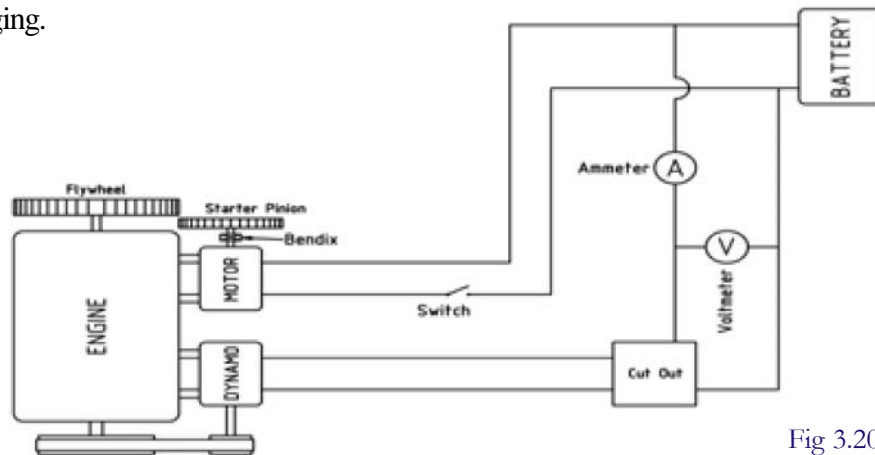


Fig 3.20

## Bendix drive

A Bendix drive is a type of engagement mechanism used in starter motors of internal combustion engines. The device allows the pinion gear of the starter motor to engage or disengage the flywheel of the engine automatically when the starter is powered or when the engine fires, respectively. It is named after its inventor, Vincent Hugo Bendix.

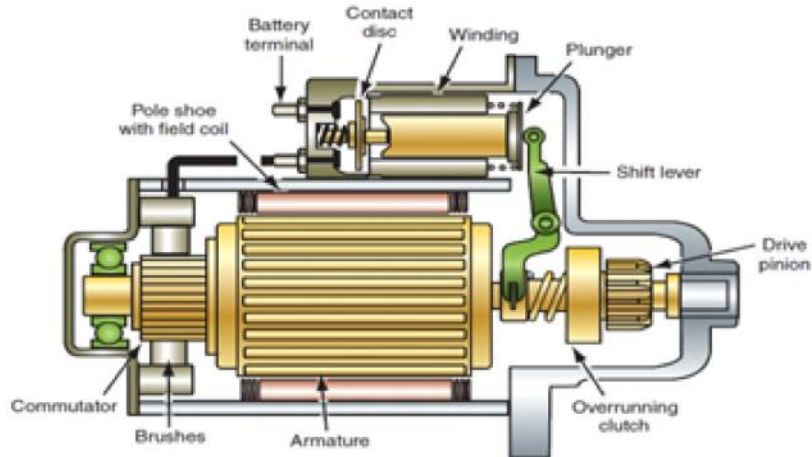


Fig 3.21

## Operation

The Bendix system places the starter drive pinion on a helical drive spring. When the starter motor begins to turn, the inertia of the drive pinion assembly causes it to wind the spring forcing the length of the spring to change and engage with the ring gear. When the engine starts, back drive from the ring gear causes the drive pinion to exceed the rotation speed of the starter, at which point the drive pinion is forced back and out of mesh with the ring gear.

## Air Starting System

Large Marine Diesel Engines are started using high pressure compressed air. In the air distribution starting system, main component is the starting air tank or air bottle. Normally the starting air inside the tank is stored at 30 kg/cm<sup>2</sup>. The pressure relief valve is provided on the tank to enable release of excess pressure inside the tank. The compressed air is admitted on the top of the cylinder in which the piston is in just after TDC position. This compressed air pushes the piston down and gives a starting torque on the crank shaft. Shaft is thus rotated. When the shaft rotates the air present in some of the cylinders will get compressed to provide a temperature sufficient enough to ignite the fuel. The schematic diagram of a distributor type air starting system for a four cylinder engine is given below.

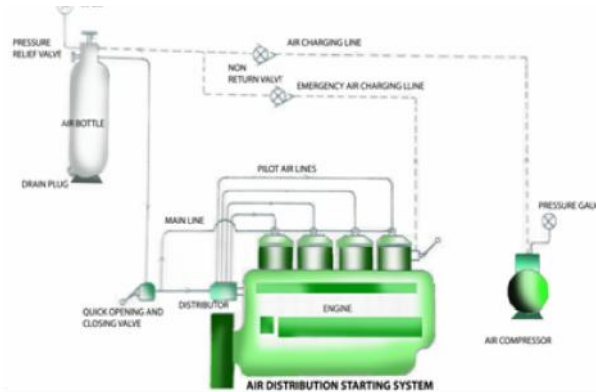


Fig 3.22

Here the air from the bottle goes to the quick opening and closing valve and from the valve, one connection is given to the distributor and a main line of air is connected to the valves on the top of each cylinder. These valves are operated by air lines (pilot air lines) coming from the distributor. When the valve on the cylinder is opened by the air coming through the pilot air line, the main air line supplies the air required to push down the piston of the respective cylinder. The distributor is operated by the cams which are arranged according to the firing order.

### 3.3.7 Cooling system

#### Indirect sea water cooling

Although there is an abundance of free sea water available, marine diesel engines do not use it directly to keep the hottest parts of the engine cool. This is because of the corrosion which would be caused in the cooling water spaces, and the salts which would be deposited on the cooling surfaces interfering with the heat flow.

Instead, the water circulated around the engine is fresh water (or better still, distilled water) which is then itself cooled using sea water. This fresh water is treated with chemicals to keep it slightly alkaline (to prevent corrosion) and to prevent scale formation. Of course, if distilled water, which some ships can make from sea water using evaporators, is used then there is a reduced risk of scale formation.

The cooling water pump which may be engine driven or be a separate electrically driven pump pushes the water around the circuit. After passing through the engine, where it removes the heat from the cylinder liners, cylinder heads, exhaust valves and sometimes the turbochargers, it is cooled by seawater and then returns to the engine. The temperature of the cooling water is closely controlled using a three way control valve. If the water is allowed to get too cold then it will cause thermal shocking which may lead to component failure and will also allow water and acids to condense

on the cylinder bores washing away the lubricating film and causing corrosion. If it gets too hot then it will not remove the heat effectively causing excessive wear and there is a greater danger of scale formation. For this reason the cooling water outlet temperature is usually maintained at about 78-82°C. Because it is at a higher temperature than the cooling water used for other purposes (known as the LT cooling), the water for cooling the engine is known as the HT (High Temperature) cooling water.

Cooling can be achieved by using a dedicated cooler or by mixing in some of the water from the LT cooling circuit. The LT cooling water is then cooled in the sea water coolers. The temperature is controlled using cascade control which monitors both the inlet and outlet temperatures from the engine. This allows a fast response to any change in temperature due to a change in engine load.

To make up for any leaks in the system there is a header tank, which automatically makes up any deficiency. Vents from the system are also led to this header tank to allow for any expansion in the system and to get rid of any air (if you are familiar with a domestic central heating system then you will see the similarities). The header tank is relatively small, and usually placed high in the engine room. It is deliberately made to be manually replenished, and is fitted with a low level alarm. This is so that any major leak would be noticed immediately. Under normal conditions, the tank is checked once per watch, and if it needs topping up, then the amount logged.

The system will also contain a heater which is to keep the cooling water hot when the engine is stopped, or to allow the temperature to be raised to a suitable level prior to starting.

Some ships use a central cooling system, whereby the same cooling water is circulated through the main engine(s) and the alternator engines. This system has the advantage whereby the engines which are stopped are kept warm ready for immediate starting by the engines which are running.

A fresh water generator (FWG) which is used to produce fresh water from sea water is also incorporated.

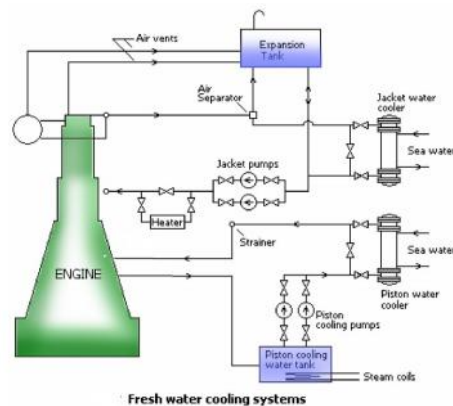


Fig 3.23

A drain tank has been included. This is for when the engine is drained down for maintenance purposes. Because of the quantities of water involved and the chemical treatment, it is not economically viable or environmentally responsible to dump the treated water overboard each time. This way the water can be re used

### 3.3.8 Lubrication system (in ships)

#### Forced lubrication system

Lubricating oil for a marine diesel engine achieves two objectives: it must cool and lubricate. The oil is taken from the drain tank usually underneath the engine by a gear type pump. It is cooled, filtered and supplied to the engine via the oil inlet pipe or inlet rail at a pressure of about 4bar. On a medium speed 4-stroke engine the oil is supplied to the main bearings through drillings in the engine frame to the crankshaft main bearings. Drillings in the crankshaft then take the oil to the crankpin or bottom end bearings. The oil is then led up the connecting rod to the piston or gudgeon pin and from there to the piston cooling before returning to the crankcase.

Oil is also supplied to lubricate the rocker gear operating the inlet and exhaust valves, and to the camshaft and camshaft drive. The oil then drains from the crankcase into the drain tank or sump. The oil in the drain tank is being constantly circulated through a centrifugal purifier. This is to remove any water and products of combustion and any foreign particles which may be present in the oil.

The cylinder liner must be lubricated as well. This is so there will be a film of oil between the piston rings and the liner and also so that any acid produced

by combustion of the fuel is neutralized by the oil and does not cause corrosion. Some of this lubrication will be supplied by so called "splash lubrication" which is the oil splashed up into the liner by the rotating crankshaft. However larger medium speed marine diesel engines also use separate pumps to supply oil under pressure to the cylinder liner. The oil is led through drillings onto the liner surface where grooves distribute it circumferentially around the liner, and the piston rings spread it up and down the surface of the liner.

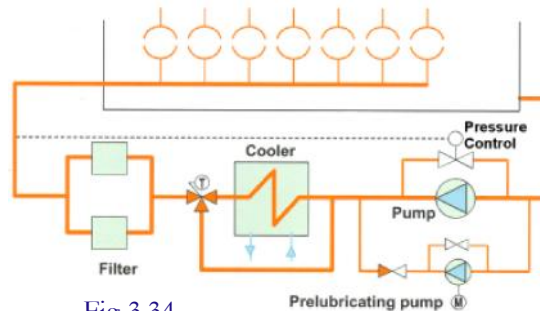


Fig 3.34



On a two stroke crosshead engine lubricating oil is supplied to the main bearings and camshaft and camshaft drive. A separate supply is led via a swinging arm or a telescopic pipe to the crosshead where some of it is diverted to cool the piston (travelling up and back through the piston rod), whilst some is used to lubricate the crosshead and guides, and the rest led down a drilling in the connecting rod to the bottom end or crankpin bearing. Oil is also used to operate the hydraulic exhaust valves.

On some engines, the oil supply to the crosshead bearing is boosted in pressure to about 12bar by a second set of pumps. This oil is also used to operate the hydraulic reversing gear for the engine.

The cylinder liners on a two stroke engine are lubricated using separate injection pumps which use a different specification of oil. The oil which is led to drillings in the liner is able to deal with the acids produced by the burning of high sulphur fuels.

### Grading of Lubricating Oil

The main function of lubricating oil is to reduce wear on moving parts; they also clean, inhibit corrosion, improve sealing, and cool the engine by carrying heat away from moving parts.

The Society of Automotive Engineers (SAE) has established a numerical code system for grading motor oils according to their viscosity characteristics. SAE viscosity gradings include the following, from low to high viscosity: 0, 5, 10, 15, 20, 25, 30, 40, 50 or 60. The numbers 0, 5, 10, 15 and 25 are suffixed with the letter W, designating they are "winter" (not "weight") or cold-start viscosity, at lower temperature. Oils can be separated into multigrade oils and monograde oils. Multigrade oils must fulfil two viscosity specifications, their viscosity grade consists of two numbers, e.g. 10W-40: 10W refers to the low-temperature viscosity ("Winter"), 40 refers to the high-temperature viscosity ("Summer"). Currently, most automotive engine oils are multigrade oils, while oils for restricted usage.

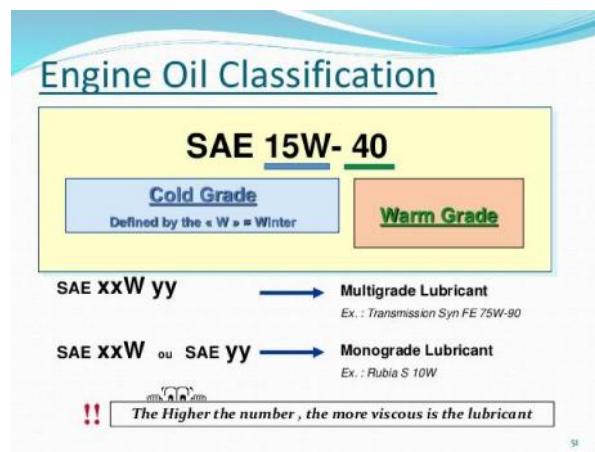


Fig 3.25

### 3.3.9 Air intake and Exhaust systems

#### Turbo charger

The turbocharger consists of a single stage impulse turbine connected to a centrifugal impeller via a shaft.

The turbine is driven by the engine exhaust gas, which enters via the gas inlet casing. The gas expands through a nozzle ring where the pressure energy of the gas is converted to kinetic energy. This high velocity gas is directed onto the turbine blades where it drives the turbine wheel, and thus the compressor at high speeds (10000 - 15000 rpm). The exhaust gas then passes through the outlet casing to the exhaust uptakes.

On the air side air is drawn in through filters, and enters the compressor wheel axially where it is accelerated to high velocity. The air exits the impeller radially and passes through a diffuser, where some of the kinetic energy gets converted to pressure energy. The air passes to the volute casing where a further energy conversion takes place. The air is cooled before passing to the engine inlet manifold or scavenge air receiver.

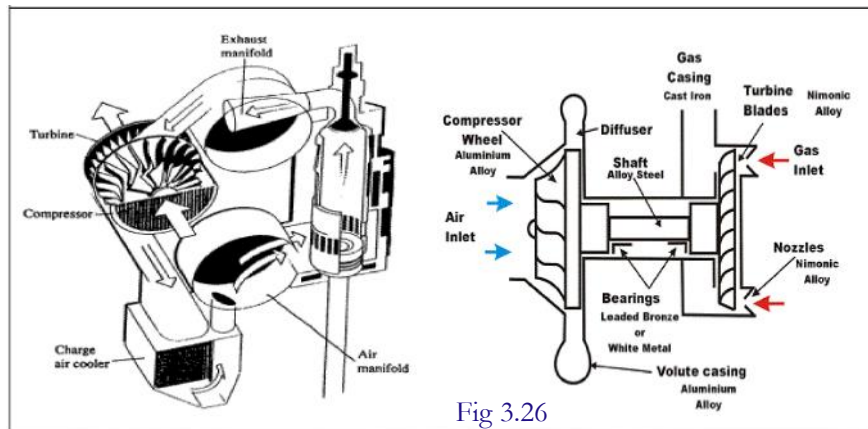


Fig 3.26

#### 3.3.10 Transmission system

The diesel engine is a type of internal combustion engine which ignites the fuel by injecting it into hot, high-pressure air in a combustion chamber. In common with all internal combustion engines the diesel engine operates with a fixed sequence of events, which may be achieved either in four strokes or two, a stroke being the travel of the piston between its extreme points. Each stroke is accomplished in half a revolution of the crankshaft.

Where the shaft speed of a medium-speed diesel engine is not suitable for its application, e.g. where a low speed drive for a propeller is required, a gearbox must

be provided. Between the engine and gearbox it is usual to fit some form of flexible coupling to dampen out vibrations. There is also often a need for a clutch to disconnect the engine from the gearbox.

### Epi-cyclic Reverse Gear

In this type, the drum which is supported by the driving shaft by means of roller bearing carries planet wheels. There are inner and outer planet wheels in the drum. The outer wheels are meshed with sun wheels provided to grip the drum during the reverse direction. The drum face is made as a male part of a cone clutch. The driven shaft carries the male portion of the cone clutch. The conical sliding piece is used to engage the cone clutch for the forward direction.

When the control lever is moved to the ahead position, the male cone is engaged with the female cone. So that the complete unit of the system is rotated along with the engine direction, when the control lever is moved to the stern position, the brake band is hold in the drum. Now the drum is stationary. So the power is transmitted from the driving to driven shaft through the gear wheel.

If the sun wheel rotates in clockwise direction, the inner planet wheel rotates in the anti clockwise direction; hence the outer planet wheel rotates in clockwise direction making the driven shaft to rotate in an anti clockwise direction. Thus the direction is changed. During the neutral position the drum is free from brake band. So that it is rotating along with the engine, and due to the load and friction in the propeller the drum is kept stationary.

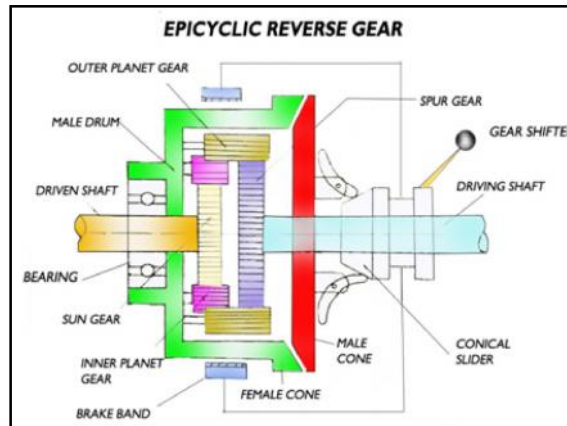


Fig 3.27

### Differential Gear box

In this type engine output shaft and the driven shaft are fitted with bevel gears in between the bevel gears a number of star wheels are provided. The star wheel spindles are held by means of two roller bearings. On the other side of the hollow drum the female portion of the cone clutch is fitted. The male portion of the cone is provided around the hollow drum so as to have a grip with the operating lever.

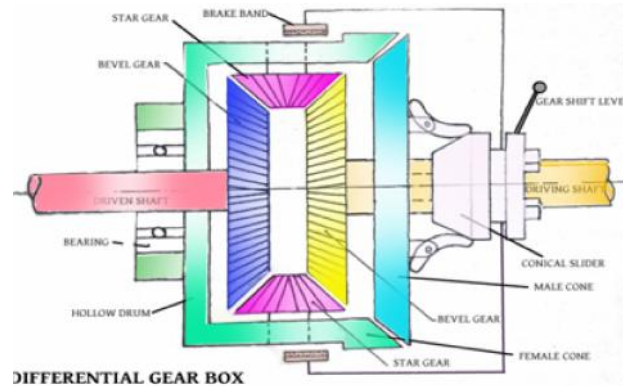


Fig 3.28

When the reverse gear operating is put in the ahead position, the male portion of cone clutch engages with the female portion of the drum. So the complete unit rotates in the direction of the engines as a solid mass due to the arrangement of the bevel gears. When the reverse gear operating handle is engaged in stern position, the brake band, grips the hollow drum and makes it stationary. At the same time the star wheel rotates the driven shaft bevel gear and thus the output shaft. So the output shaft is rotated in the opposite direction of the engine rotation.

During the neutral position the cone clutch will be in the disengaged position and brake band will be loose over the drum. Now the bevel gear fitted in the driven shaft is stationary due to the load on the propeller. So the hollow drum is rotating along with the engine shaft bevel gear in the direction of the rotation of the engine.

### Reverse and Reduction Gear box

Reduction gear box consists of a hollow shaft, solid shaft, clutch assembly, propeller shaft, idle gear, spur gears etc.

The clutch assembly is attached with the fly wheel and it consists of friction plates and pressure plates. When the gear lever is moved to ahead position, the friction plate engages with the flywheel. Then the solid shaft

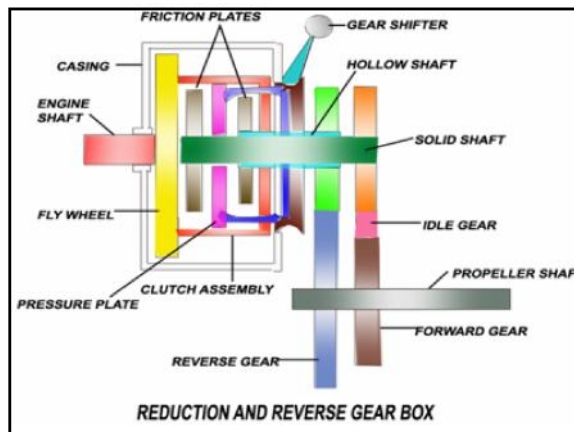


Fig 3.29

rotates and the propeller shaft rotates in the direction of engine shaft. When the lever is moved to astern position, the friction plate engages with the clutch assembly. Then the hollow shaft rotates along with the engine direction. Even though the hollow shaft gear rotates in same direction of the engine shaft, the propeller shaft rotates in the opposite direction. While in the neutral position, the two friction plates are free from the pressure plates.

### Hydraulic Gear Box

(1) and (2) are multi-plate hydraulic clutch. Clutch is mounted on the ahead shafts with gear (4) on the input side and (5) on the output side. The input shaft houses gear (3), the clutch (2) and gear (6). This shaft also acts as reverse shaft. The output shaft is situated down below the input shaft. The output shaft is situated down below the input shaft. The output shaft houses gear (7) which is also the output gear. The gear pump is used to direct the flow as per the clutches. Direction control valve is used to direct the flow as per the requirement. A pressure regulation valve used to maintain the constant pressure in the system. The working pressure of the clutch may be about 10 - 15 Kg/cm<sup>2</sup> and the working oil pressure for the gear box lubrication is approximately 2 Kg/cm<sup>2</sup>.

### Working principle

When the clutch (1) ie. Ahead clutch is engaged, the power is transmitted from the driving shaft to driven shaft through the gear wheels 3,4,5 and 7. When the clutch is engaged, the direction of the driving shaft and driven shaft is same. When the clutch (2) ie, astern clutch is engaged, the power is transmitted from the driving shaft to driven shaft through the driving shaft and driven shaft is changed. The driven shaft is rotating in anti clockwise direction. Thus reverse direction is obtained.

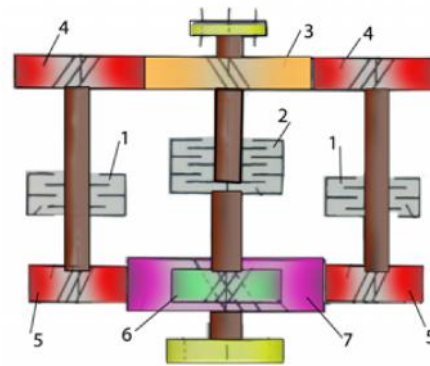


Fig 3.30

In the neutral position both the clutches are disengaged to then power will not be transmitted from driving shaft to driven shaft.

### Transmission System in ships

Reversing is done in many ways. In ships using 2 stroke diesel engines for propulsion the propeller rotation can be reversed by using variable pitch propeller, reversing the engine.

The engine rotation can be reversed by engaging another set of cams which momentarily changes the firing order of the engine, hence when starting air is admitted to the cylinder the engine cranks in reverse direction and is fired up with fuel.

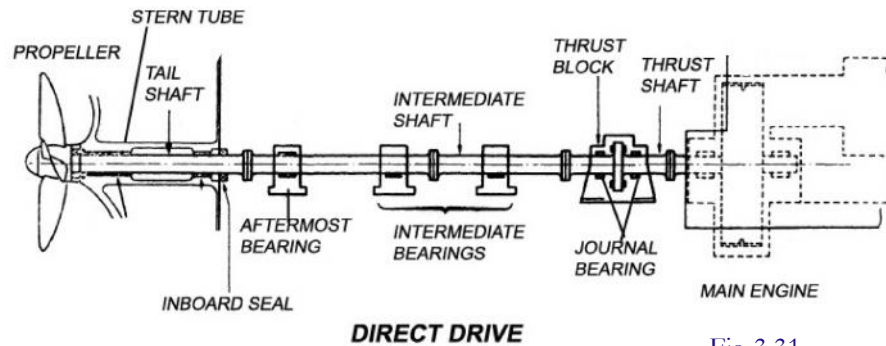


Fig 3.31

### 3.3.11 Propulsion System

A propeller transmits power by converting rotational motion into thrust. A pressure difference is produced between the forward and rear surfaces of the airfoil-shaped blade, and a fluid (such as air or water) is accelerated behind the blade. A marine propeller of this type is sometimes colloquially known as a screw propeller or screw.

#### Propeller nomenclature

##### Fixed pitch

A propeller transmits power by converting rotational motion into thrust. A pressure difference is produced between the forward and rear surfaces of the airfoil-shaped blade, and a fluid (such as air or water) is accelerated behind the blade. A marine propeller of this type is sometimes colloquially known as a screw propeller or screw.

The propeller consists of a boss with several blades of helicoidal form attached to it. When rotated it 'screws' or thrusts its way through the water by giving momentum to

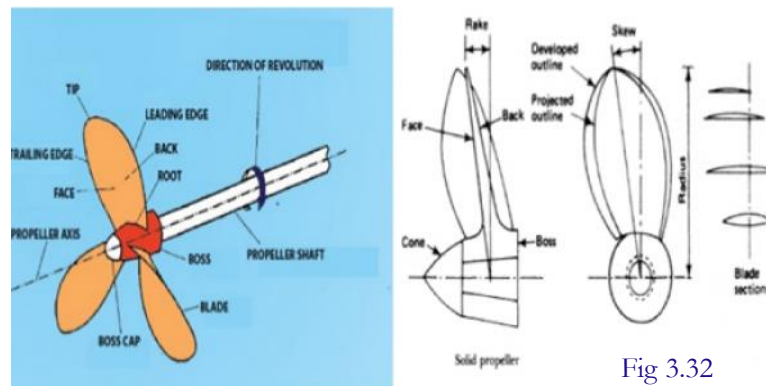


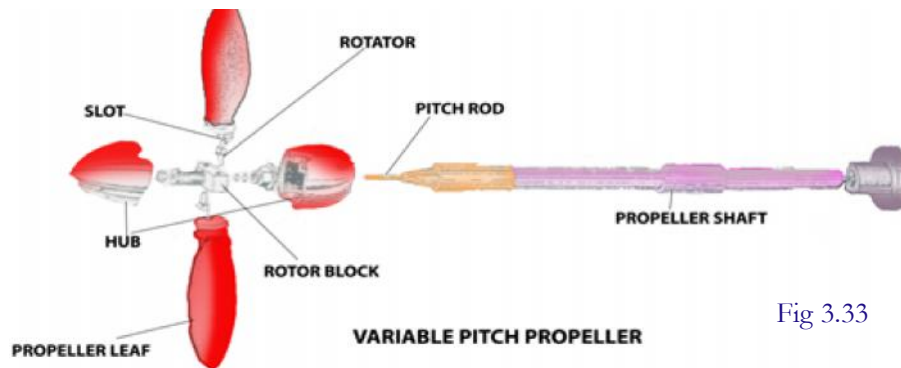
Fig 3.32

the column of water passing through it. The thrust is transmitted along the shafting to the thrust block and finally to the ship's structure. A solid fixed-pitch propeller is shown in Figure above. Although usually described as fixed, the pitch does vary with increasing radius from the boss. The pitch at any point is fixed, however, and for calculation purposes a mean or average value is used.

A propeller which turns clockwise when viewed from aft is considered right-handed and most single-screw ships have right-handed propellers. A twin-screw ship will usually have a right-handed starboard propeller and a left-handed port propeller.

### Variable Pitch Propeller (Controllable-Pitch Propeller)

A controllable-pitch propeller (CPP) or variable-pitch propeller is a type of propeller with blades that can be rotated around their long axis to change the blade pitch. Reversible propellers those where the pitch can be set to negative values can also create reverse thrust for braking or going backwards without the need to change the direction of shaft revolution.



### Voith Schneider propeller

The Voith Schneider propeller (VSP), also known as a cycloidal drive, is a specialized marine propulsion system (MPS). It is highly maneuverable, being able to change the direction of its thrust almost instantaneously. It is widely used on tugs and ferries.

#### 3.3.12 Steering system used in boats and ships

Every ocean going cargo ship need to be provided with a main steering gear and an auxiliary steering gear unless the main steering gear comprises two or more identical power units. The main steering gear is to be capable of turning the rudder over from  $35^\circ$  on one side to  $35^\circ$  on the other side with the ship at its deepest draft and running ahead at maximum service speed, and under the same conditions from  $35^\circ$

on either side to  $30^\circ$  on the other side in not more than 28 seconds. It is to be power operated where necessary to meet the above conditions and where the stock diameter exceeds 120mm.

The auxiliary steering gear is to be capable of putting the rudder over  $15^\circ$  on one side to  $15^\circ$  on the other side in not more than 60 seconds with the ship at its deepest draft and running ahead at half the maximum service speed or 7 knots whichever is greater. Power operated auxiliary steering gear is required if necessary to meet the forgoing requirement or where the rudder stock diameter exceeds 230 mm.

Steering gear control for power operated main and auxiliary steering gears is from the bridge and steering gear compartment, the auxiliary steering gear control being independent of the main steering gear control (but not duplication of the wheel or steering lever)

Steering gear on ocean-going ships is generally of the electro-hydraulic type. The steering gear provides a movement of the rudder in response to a signal from the bridge. The total system may be considered made up of three parts, control equipment, a power unit and a transmission to the rudder stock. The control equipment conveys a signal of desired rudder angle from the bridge and activates the power unit and transmission system until the desired angle is reached. The power unit provides the force, when required and with immediate effect, to move the rudder to the desired angle. The transmission system, the steering gear, is the means by which the movement of the rudder is accomplished.

Steering gears can be arranged with hydraulic control equipment known as a 'telemeter', or with electrical control equipment. The power unit may in turn be hydraulic or electrically operated. Each of these units will be considered in turn, with

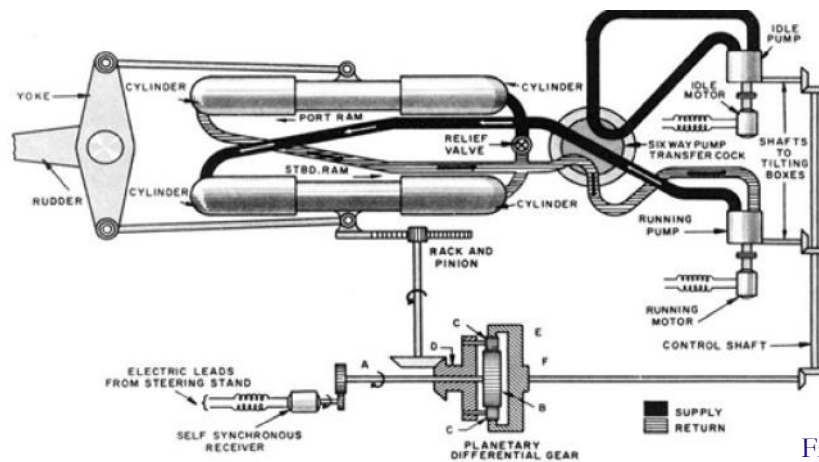


Fig 3.34



the hydraulic unit pump being considered first. A pump is required in the hydraulic system which can immediately pump fluid in order to provide a hydraulic force that will move the rudder. Instant response does not allow time for the pump to be switched on and therefore a constantly running pump is required which pumps fluid only when required. A variable delivery pump provides this facility.

Generally, work should not be done on steering gear when a ship is under way. If it is necessary to work on steering gear when the vessel is at sea, the ship should be stopped and suitable steps taken to immobilize the rudder by closing the valves on the hydraulic cylinders or by other appropriate and effective means.

### **3.3.13 Important mechanisms in a diesel engine**

#### **3.3.13.1 Governor**

##### **Diesel Engine Speed Governor**

The speed control mentioned above is achieved with the help of a governor and we will study about this device here. I would just like to clarify one confusion here that the main role of the governor is not to increase or decrease the speed which can be done via fuel control system (similar to an accelerator on your car) but once the speed of the engine has been set, the job of the governor is to maintain that speed despite the variations in load. In other words the governor controls the speed variation and keeps the speed within restrained limits despite these variations.

The variations could arise from several factors such as say rough weather. A ship rolling and pitching in heavy weather may temporarily come in such position that its propeller is literally out of water and without the governor the speed of the engine could shoot up to such an extent that it could damage the engine itself.

Governors are also fitted in auxiliary diesel engines on the ship used for power generation, and their function remains the same in this situation as well. The power delivered by the alternator needs to be constant despite load variations and this depends to a great degree on the speed at which the prime mover of the generator diesel engine is rotating since the alternator is getting its movement from that engine only. Hence the role of the governor is equally important in this case as well.

#### **3.3.13.2 Decompression mechanism**

The compression ratio of diesel engine is so high such that a huge torque is required to crank the engine. In smaller manual starting engines a decompression lever is provided. While cranking this engine the decompression lever is pushed into decompression position which in turn opens the exhaust valve, thereby allowing the

air to escape from the cylinder by which it is made easy to crank for the worker. After attaining the required normal engine momentum the decompression valve is closed and eventually engine starts and runs on fuel. Now engine develops compression and ignition temperature and when fuel is injected it is started.

### 3.3.13.3 Blow past mechanism

Blow past valve is provided on cylinder head of each unit of a main engine. If an engine is kept shut down for a long period, there can be unwanted dust or carbon deposits and waste particles inside the cylinder. So before starting the engine, the blow past valves of all units are opened and compressed air is fed into cylinders, this compressed air will go through blow past valve clearing all smaller waste particles or carbon deposit present in the cylinder .

Blow past valves are kept opened while turning the crankshaft using turning gear for inspection or overhauling purpose. Here blow past valve acts as a decompression valve as it allow the air in the cylinder to escape while compression stroke.

## Detailing of Practicals

### ■ Hands on experience on injector servicing

With nozzle tester the injector is tested and calibrated as per the working pressure of the injection system. The nozzle tester is one kind of hand operated pressure pump which consists of a fuel pump from which the fuel is fed to the injector. The pump is operated manually by means of a hand lever. A pressure gauge is connected to the pressure pipe which is provided with a shut-off cock. An air-vent screw is provided to release the air from the tester and the injector at the beginning of the test.

When the hand lever is operated, pressure of fuel increases inside the pump, and the high pressure pipe thereby reaches the injector and the pressure gauge shows the actual injection pressure. The pressure can be adjusted by the nozzle pressure adjusting screw provided at the top of the injector. After obtaining the desired pressure the adjusting screw is locked by means of locknut.

The too high pressure indicates that the nozzle is seized up, the valve is sticking or the opening is blocked with dirt. The too low nozzle pressure indicates that the nozzle spring is broken.

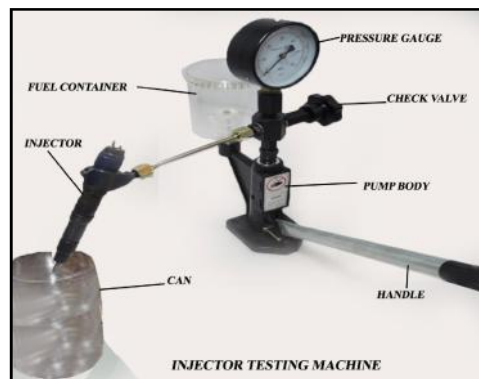


Fig 3.35

### *Nozzle tests*

**Seat tightness** - For this test open the check valve and operate the hand lever so that a pressure about 10 atmosphere should be read on the pressure gauge. This pressure must be below the opening pressure of the nozzle. Under this condition there should not be any fuel blob on the tip of the nozzle.

**Pressure Testing** - For this test operate the hand lever slowly downwards and note the highest pressure built before the nozzle valve opens. If this pressure is not correct then correct it with the help of adjusting screw and finally lock with locknut. To increase the pressure, move the adjusting screw of the injector inwards and to decrease the pressure, move it outwards.

**Spray test** - For this operate the hand lever quickly at the rate of about 100 strokes per minute. Under this condition atomized spray should occur from all holes at the same quantity. Visual inspection is enough. A cylindrical glass bowl to be attached to the nozzle tip area for this purpose.

*Care To Be taken that The Fuel Spray Should Not Make Any Contact With Your Body. Use Goggles For Eye Protection.*

**Leak off test or Back leakage test** - For this test clamp the injector, open the check valve and operate the hand lever. Set the nozzle opening pressure to about 160 atmospheres with the help of adjustment screw. Now operate the hand lever quick so that an enough pressure may be build u to open the nozzle valve. Release the hand lever and note the time taken for the pressure to fall from 150 to 100 atmospheres. This time period should be about 6 second for a nozzle of good condition. Under this test check all the conditions and joint of the injector, there should not be any leakage of the fuel.

### ■ **Hands on experience on injection pump servicing**

#### **Setting of fuel injection pump**

It should deliver fuel in equal quantity and at equal interval, failing which the engine shall run with jerks and jolts. The pump should be calibrated and phased, on a proper test bench.

#### **Calibration**

Measurement of quantity of fuel, delivered by each element of an injection pump at a fixed control setting and adjusting these settings, so as to deliver equal quantities of fuel per stroke of each plunger to all cylinders is known as calibration.

Adjustment is usually made by changing the relative positions of control sleeve of each pump element. Clockwise movement of control sleeve increases and anticlockwise decreases the quantity of fuel delivered, on a right hand driven pump and vice versa.

### Phasing

The testing and adjustment of an injection pump for the accuracy of its firing -interval is known as phasing

In phasing, the exact firing or critical point is spotted where injection starts at the closure of spill port, at the beginning of upward stroke of the plunger. For this the pump is installed on a test bench; fuel line connections are made and air is bled out from the supply system and pump after that proceed as given below:-

- Detach delivery valve holder.
- Remove only valve and place it safely away in a tray containing some clear diesel oil.
- Replace delivery valve holder alone and turn on fuel.
- Move the control rod to maximum delivery position.
- Rotate the pump shaft in the direction of rotation, until the plunger is at the bottom of its stroke and that the fuel flows freely through the delivery valve orifice. Further rotation of the pump shall diminish fuel flow which will finally cease as ports are closed. This point of port closure, which is the beginning of effective part of pumping stroke, is the exact firing point.
- Mark the 'firing point' at the graduated disc of the test bench.
- Repeat the above process on the other elements of the pump, one by one, in the sequence of firing order.
- Rotating the camshaft through the required angle i.e.  $360^\circ / \text{number of elements}$ , and see that the point of port-closure coincides. The tappet should be adjusted for correct phasing. Decrease the length of tappet if firing is early and increase if late
- Fit back the delivery valve and make a final check. The delivery valves should not be mixed up, as these are not interchangeable. Tappet clearance (free lift) at the end of plunger stroke should also be checked up. (normal clearance is 0.3mm)

### ■ Hands on experience on manual starting systems

Hand or manual starting system is one in which the crankshaft is rotated mechanically by manpower. Hand or manual starting system may be further classified as starting by pulling rope, kick starting and starting by using lever.

Rope is wound on the flywheel which when pulled rotates the crank shaft and the engine is started. This method is used in OBMS.

The handle method of hand starting is commonly applied in marine diesel engines. This system is used for small engines up to 60 HP.

Before starting the decompression lever of the engine is put in the ON position which keeps the exhaust valve in open condition always. Then the lever is placed on the rotating handle/ flywheel. Rotate the lever in the direction of engine rotation after attaining the starting speed close the decompression lever and immediately remove the rotating lever from the engine. Otherwise the lever damage the operator, others and machineries etc.

■ **Heat exchanger servicing.**

- Dismantle the head.
- Drive out tube bundle from shell.
- Clean tube bundle with brush and fuel.
- Inspect the soldered connections.
- Renew all gaskets and 'o' rings (seals).
- Refitting in reverse sequence.

■ **Dismantling and assembling of turbo charger.**

- From the turbocharger dismantle all hose pieces and intake bends.
- Dismantle the oil pipe.
- Unscrew the fixing screws from the exhaust bend and take away the turbo-charger.
- Before dismantling turbo charger apply marks on the compressor casing, bearing housing and turbine casing.
- Clamp the turbocharger complete at the turbine casing flange in a bench vice in the upward direction.
- Loosen the nut from the clamp and screw back to the threaded bolt end.
- Lift the body group with compressor casing and keep it on the work bench.
- Clamp the body group at the hub pin of the turbine wheel in a vice.
- Clean the turbine blades.
- Refitting in reverse sequence

■ **Dismantling and assembling of fishing boat transmission system epicyclic**

- Remove the flywheel housing nuts
- Remove the gear shifter
- Remove the gear box cover nuts and then the cover
- Dismantle the bake bands

- Dismantle the mole cone with driving shaft ,conical slider assembly
- Then remove the conical slider
- Dismantle the mole cone from driving shaft
- Then dismantle the spur gear
- Dismantle the 2 outer planet gears and 2 inner planet gears
- Dismantle the sun gear from the driven shaft.
- Identify the parts as shown in the figure and studying its working
- Then assemble the gear box in the reverse order of dismantling
- **Dismantling and assembling of fishing boat transmission system differential.**
- Remove the flywheel housing nuts
- Remove the gear shifter
- Remove the gear box cover nuts and then the cover
- Dismantle the bake bands
- Dismantle the mole cone with driving shaft ,conical slider assembly
- Then remove the conical slider
- Dismantle the mole cone from driving shaft
- Then dismantle the bevel gear from driving shaft
- Dismantle the 2 star gears
- Dismantle the bevel gear from the driven shaft.
- Identify the parts as shown in the figure and studying its working.
- Then assemble the gear box in the reverse order of dismantling.
- **Dismantling and assembling of fishing boat transmission system reverse and reduction**
- Remove the flywheel housing nuts
- Remove the gear shifter
- Remove the gear box cover nuts and then the covers.
- Remove the clutch assembly nuts from flywheel and dismantle this.
- Dismantle the hollow shaft gears, solid shaft gears.
- Remove hollow and solid shafts.

- Identify the parts and studying its working.
- Assemble the gear box in the reverse sequence.

### **Assessment Activities**

- Class room test
- Assignment
- Flow chart
- Seminar
- Group discussion

### **Portfolio**

- Activity log, charts and seminar report on propulsion system used in ships.
- Practical Activity log - indirect sea water cooling system
- Practical Activity log -fuel system and lubrication system used in ships
- Practical Activity log - types of propeller
- Practical Activity log - types of starting system
- Chart preparation on propeller nomenclature.
- Chart preparation on stern tube assembly
- Chart preparation on fuel injector.

### **TE Questions**

- 1 What are the types of fuels used on board ships?
- 2 What is the role of fuel injector in fuel system?
- 3 Explain bendix starting system
- 4 Which starting method is used in ships?  
a) Air      b) electric      c) manual
- 5 What is the use of a turbocharger?
- 6 List the different types of gearboxes?
- 7 Explain the role of stern tube
- 8 Explain briefly about steering system

## Unit - 4

# MARINE DIESEL ENGINES MAINTENANCE AND TROUBLE SHOOTING

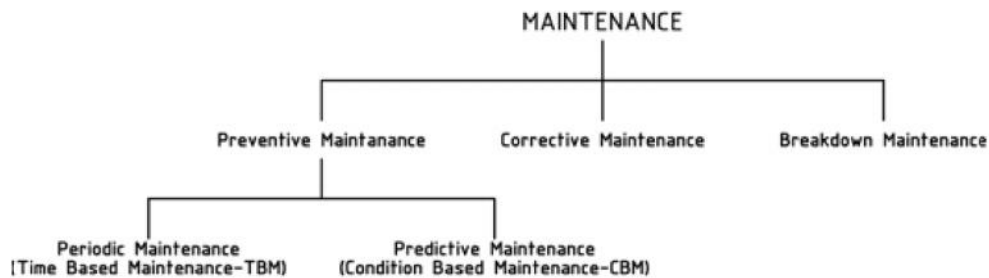
Maintenance is the most critical job in a ship. Maintenance includes daily, periodic, preventive and breakdown maintenances. In addition this unit goes in detail about fault diagnosis and rectification. The reasons and rectification methods for blue, black and white smoke, cavitation, engine temperature high/low, low mileage, detonation, compression pressure high and low, etc. are covered in detail. Maintenance procedures for decarburization, valve clearance adjustment, cylinder piston clearance, etc. are discussed. In addition a detailed study about crankcase explosion, oil mist detector and lubrication oil quality checking are also discussed in this unit

### Detailing of The Concepts

#### 3.4.1 Maintenance

Maintenance is an important and essential thing for any machine for its proper working and efficient performance. Maintenance is a set of compulsory operations carried out to keep the engine safe and good serviceable condition. It includes inspection, testing, removal, replacement, repair, etc. Improper maintenance will cause the following effect on the engine or machine.

- Higher fuel consumption
- higher lubricating oil consumption
- Higher operational cost
- Reduce life of the machinery
- Leads to sudden break down
- Leads to accidents





## Types of Maintenance

### 1. Break down maintenance

It means that people usually wait for an equipment to fail and then repair it. Such a thing could be used when the equipment failure does not significantly affect the operation or production or generate any significant loss other than repair cost. Break down maintenance will be time consuming and expensive.

### 2. Preventive Maintenance

It is the 'Stitch in time saves nine' daily maintenance (cleaning, inspection, oiling and re-tightening), designed to retain the healthy condition of equipment and prevent failure through the prevention of deterioration, periodic inspection or equipment condition diagnosis, to measure deterioration. It is further divided into periodic maintenance and predictive maintenance. Just like human life is extended by preventive medicine, the equipment service life can be prolonged by doing preventive maintenance.

#### 2(a). Periodic Maintenance ( Time based maintenance - TBM)

Time based maintenance consists of periodically inspecting, servicing and cleaning equipment and replacing parts to prevent sudden failure and process problems.

#### 2(b). Predictive Maintenance (Condition based maintenance - CBM)

This is a method in which the service life of an important part is predicted based on inspection or diagnosis, in order to use the parts to the limit of their service life. Compared to periodic maintenance, predictive maintenance is condition based maintenance. It manages trend values, by measuring and analyzing data about deterioration and employs a surveillance system, designed to monitor conditions through an on-line system.

### 3. Corrective Maintenance

It improves equipment and its components so that preventive maintenance can be carried out reliably. Equipment with design weakness must be redesigned to improve reliability or improving maintainability.

#### 3.4.2 Guidelines for scheduled maintenance

##### Daily Maintenance

Daily maintenance in ship is done by watch keeping officer or engineer on duty. They are listed below. These observations are to be entered in the log book.

- Check the colour of smoke coming out of the funnel.
- Check the air compressor outlet pressure

- Observe the air compressor for any unwanted noise or vibrations.
- Check the air bottle pressure
- Open the drain cock of the air bottle to remove water content inside
- Check the boiler gauge glass level
- Check the feed to the boiler and control the feed if necessary
- Note the fuel oil flow meter reading
- Check the lube oil pump inlet and outlet pressure
- Check the fuel oil pump inlet and outlet pressure
- Check the jacket cooling water pump inlet and outlet pressure
- Check the jacket cooling water inlet and outlet temperature
- Check the sea water pump inlet and outlet pressure
- Check the sea water inlet and outlet temperature
- Check the main engine lube oil inlet pressure
- Check the main engine cylinder lubrication oil level in the sight glass provided
- Ensure turbo charger lubrication, observe splashing lube oil in the sight glass provided
- Check the heat exchanger inlet and outlet temperature
- Check the inlet manifold pressure and temperature
- Check the auxiliary engine's unit temperature that are working at that instant
- Note oil purifier pressure, temperature readings and rpm.
- Note voltmeter, ammeter readings from electrical control panel
- Check stern tube lubrication and stern tube lube oil gravity tank level

### **Maintenance Chart**

#### **After 50 hours**

- Inspect and clean, adjust or replace fuel lines.
- Check the gear oil level
- Manual greasing or oiling of parts.
- Check the battery and starter connection.
- Remove water if found in fuel system

**After 100 hours**

- Clean fuel and lubricating oil filter
- Inspect the v-belt for tightness
- Inspect the ignition timing

**After 250 hours**

- Replacement of engine lubricating oil.
- Test the injector for proper spray and pressure.

**After 500 hours**

- Replacement of engine lubricating oil
- Test the injector for proper spray and pressure
- Adjust the valve tappet clearance.

**After 1000 hours**

- Clean the air filter.
- Inspection of tightness of cylinder head bolt and connecting rod bolt.
- Cleaning of heat exchangers
- Cleaning and grinding of exhaust valve.
- Cleaning of valve tappet clearance.

**After 3000 hours**

- De-carbonisation or top over hauling
- Cleaning of exhaust system.
- Inspection of thrust bearings.

**Inspection after 6000 hrs.**

- Major overhauling

**3.4.3 Break down maintenance**

If due care and consideration are not given to preventive maintenance, the engine may break down during the course of its operation. The maintenance which is carried out after the engine breakdown is called breakdown maintenance. The breakdown maintenance will be time consuming and expensive.

### 3.4.4 Fault diagnosis and rectification

#### 3.4.4.1 Propeller- maintenance

When a ship is in dry dock the opportunity should be taken to thoroughly examine the propeller, and any repairs necessary should be carried out by skilled dockyard staff.

A careful examination should be made around the blade edges for signs of cracks. Even the smallest of cracks should not be ignored as they act to increase stresses locally and can result in the loss of a blade if the propeller receives a sharp blow. Edge cracks should be welded up with suitable electrodes.

Bent blades, particularly at the tips, should receive attention as soon as possible. Except for slight deformation the application of heat will be required. This must be followed by more general heating in order to stress relieve the area around the repair.

Surface roughness caused by slight pitting can be lightly ground out and the area polished. More serious damage should be made good by welding and subsequent heat treatment. A temporary repair for deep pits or holes could be done with a suitable resin filler.

### 3.4.5 Smoke colour

#### 3.4.5.1 Blue

Component	Cause	Action
Engine oil	Combustion of lube oil inside the engine	Check for the leaky piston rings and change the rings. Check for improper assembling of lube oil ring and fix them properly.
exhaust turbocharger, cylinder head, piston rings, cylinder liner	Too much oil in the engine	Drain engine Oil
	Oil separator of crankcase breather contaminated.	Replace
	Faculty	Replace/repair

**3.4.5.2 White**

Component	Cause	Action
Engine	Not at operating temperature.	Run up to operating temperature.
fuel system	Water in fuel.	Check fuel system or fuel filter
	Late ignition	Drain fuel filter, Adjust the injection timing
Inter cooler	Leaking	Repair

**3.4.8.3 Black**

Component	Cause	Action
Air supply	Air filter clogged	Check and service intake system
Fuel injection equipment	Injector faulty	Replace
	Insufficient air for combustion	Check and service intake system
	More fuel present when combustion chamber for combustion	Check fuel injector and fuel compared to air in the pump
Engine	Overload	Reduce load

**3.4.6 Cavitation in propeller**

Cavitation, the forming and bursting of vapour-filled cavities or bubbles, can occur as a result of pressure variations on the back of a propeller blade. The results are a loss of thrust, erosion of the blade surface, vibrations in the after body of the ship and noise. It is usually limited to high-speed heavily loaded propellers and is not a problem under normal operating conditions with a well designed propeller

**3.4.7 Engine temperature high**

Component	Cause	Action
Valve train	faulty valve timing	Adjust the valve timing
Engine	faulty injection timing Less lube oil in the crank case	Adjust the injection timing Fill the crank case oil to the appropriate level
Cooling system	Wrong grade oil	Use the correct grade oil
	Faulty thermostat	Clean/Adjust the thermostat

**3.4.9 Engine knocking**

Component	Cause	Action
Fuel system	fuel injection too early timing	Adjust the injection timing
	Very high injection pressure	Adjust the injector to the correct pressure
	Sticking of needle valve	Service/ replace
	Quantity of fuel injection	Readjust the fuel pump excessive
	Fuel oil is contaminated with water	Check the fuel/ rectify the defect
Cooling system	Improper cooling	Check the cooling system

**3.4.10 Engine rotates but not continue to run**

Component	Cause	Action
Cooling system	Over cooled	Pre heat the engine
Fuel system	Shortage of fuel	Fill the fuel in the service tank
	Air in the fuel system	Bleed out the air from the fuel system

### 3.4.10 Engine rotates but no ignition takes place

Component	Cause	Action
Fuel system	No fuel in the fuel tank	Fill the fuel
	Air In the fuel line	Bleed out the air from the fuel system
	Clogging of filter	Clean the filter
	Worn/broken injection	Repair the pump plunger
Engine	Wrong injection timing	Correct the timing
	Poor compression pressure	Service the engine

### 3.4.11 Engine does not rotate

Component	Cause	Action
Starting system electrical	Faulty wiring	Check and rectify
	Trouble in brush and commutator	Check the commutator and replace
	Battery not charged	Recharge the battery
	Insufficient air in the air bottle	Recharge air bottle
	Faulty air starting valve	Service/ replace
	Chocked filter in the air starting line	Clean the filter

### 3.4.12 Engine stops suddenly

Component	Cause	Action
Fuel system	No fuel in the fuel system	Check the service tank and fill the fuel
Engine	Clogging fuel filter	Clean the filter
	Timing gear teeth loose or broken	Check and rectify
	Main or connecting rod	Check and replace the defect bearing Check the lubricating system and rectify the defect Check the lube pump for bearing seizer proper functioning Check the cooling system for blockage Check the cooling pump
	Seizer of piston	Check and rectify the piston skirt clearance
Check and rectify the lubricating system		
Check and repair lubrication oil pump		

### 3.4.13 Crank case explosion

Early detection of over-heating and the immediate stopping or slowing down of the main (or auxiliary) engine, as circumstances permit, will avoid conditions which might form an explosive atmosphere in the crankcase.

Oil mist detectors and / or bearing temperature monitors are fitted to engine crankcases to detect any build-up of a potentially explosive oil mist. All alarms from oil mist detectors and bearing temperature monitors, (no matter how suspect the instrument may be), are to be treated as an emergency situation and the engine stopped.

The most likely cause of such an alarm will be an overheating bearing, but could also be caused by the possibility of heavily leaking piston rings and / or piston rod stuffing



boxes. Great care must be taken if the main engine has been stopped due to a positive alarm from an oil mist detector or bearing monitor. Under no circumstances should anyone approach the engine or open a crankcase door until sufficient time has been allowed for cooling and mist dispersal.

#### **3.4.14 Oil mist detector**

The presence of an oil mist in the crankcase is the result of oil vaporization caused by a hot spot. Explosive conditions can result if a build-up of oil mist is allowed. The oil mist detector uses photoelectric cells to measure small increases in oil mist density. A motor driven fan continuously draws samples of crankcase oil mist through a measuring tube. An increased meter reading and alarm will result if any crankcase sample contains excessive mist when compared to either clean air or the other crankcase compartments. The rotary valve which draws the sample then stops to indicate the suspect crankcase. The comparator model tests one crankcase mist sample against all the others and once a cycle against clean air. The level model tests each crankcase in turn against a reference tube sealed with clean air. The comparator model is used for cross-head type engines and the level model for trunk piston engines.

#### **3.4.15 Engine oil quality checking**

A number of simple oil condition tests may be carried out on board ship with portable equipment. A flash point test will warn of possible fuel oil contamination. Color titration test can indicate loss in alkalinity. A variety of viscosity tests are available. Water present can be detected, but special equipment is required if actual percentage are to be measured. Inspection of the sludge/ water discharge at the purifier will give a good indication of condition. In blotter tests the slow migration of a drop of oil on blotting paper will indicate the oxidation, carbon present and dispersive properties when compared with similar drops of fresh oil.

#### **Microbial degradation of oil**

This is the possible infection of an oil system by micro - organisms. These live by consuming hydrocarbons in the base oil together with nitrogen, sulphur, and phosphorous from additives. If water is present, they will multiply in the warm agitated conditions in the oil system. Contamination may occur from cooling water leaks, condensation in humid climates, or accidental entry of dirt and water during overhaul. Infection by micro - organisms will form acids and more water depleting the additives. This will cause corrosion and wear of metal surfaces and will create sludge and

slime that choke oil filters. The oil may be prone to emulsification and saponification.

Tests for microbial infection make use of a special gel which is either dipped in the oil or has oil poured over it and is incubated to develop a growth or culture. The appearance of this culture is then compared visually with a standard colored chart, to indicate the degree of contamination if any. If the oil does not wet the gel, it may be necessary to mix sample with a small quantity of sterile water.

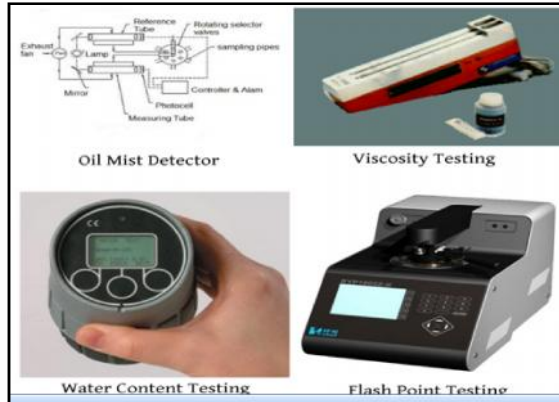


Fig 3.36

## Detailing of Practicals

### ■ On hand experience of Decarburization in boats.

- Place the cylinder head on the work table.
- Carry out visual inspection of the cylinder head and mountings.
- Dismantle all the mountings.
- Remove carbon, oil and sludge from the cylinder head and mountings
- Inspect cylinder head for any cracks visually.
- Inspect all the valves for any scratches, bends, dents and pitting.
- Inspect valve spring for bends, springiness, and free length.
- Inspect valve guides for pitting and scratch marks, check bushes for intactness.
- Dismantle rocker assembling, bushes, lubrication holes and tappet adjusting screws.

### ■ Hands on experience on engine Valve Clearance adjustment.

- Find out the exact clearance required for intake and exhaust valve from the Engine maker's Service manual.
- Bring the respective unit to TDC at fuel injection position by turning the fly wheel. TDC and cylinder number is marked on the fly wheel
- At this position both intake and exhaust valves will be closed.
- Check the clearance using feeler gauge.

### ■ Adjustment of tappet Clearance

- Keep the unit TDC at fuel injection position.

- Loosen the lock nut of the tappet adjusting screw on the rocker arm.
  - Turn the adjusting screw using screw driver.
  - Check the clearance using feeler gauge and adjust.
  - Hold the screw at the same position and tightened the lock nut.
  - Check the clearance and confirm.
- **Hands on experience on engine cylinder - piston clearance checking by using feeler gauge**

#### Calibration Of Piston And Piston Rings

- Inspect piston crown for cracks and dents.
- Remove piston rings.
- Clean piston ring grooves.
- Measure height and depth of piston ring grooves.
- Compare this data with Engine maker's Calibration chart.
- Measure butt clearance (piston ring end gap)
  - a) Clean the respective cylinder liner.
  - b) Insert piston ring horizontally in the liner top area (where maximum liner wear can be occurred).
  - c) Measure the ring gap using feeler gauge.

Compare all this data as per Engine maker's Service manual and carry out servicing or renewal of parts accordingly.

Piston ring from top	Groove height	Groove depth

Piston ring	End gap mm
Top ring	
Second ring	
Third ring	
Oil ring	

- **Hands on experience on engine Compression pressure checking low/high**
- Unscrew bleed line and fuel delivery line
  - Remove injector

- Unscrew the starting air connection sleeve nut and remove starting air line from connection
- Provide adapter instead of injector
- Connect the compression tester to the adapter
- Run out the chart using the transport lever, clamp chart in the holder and push chart holder back into recorder
- Turn engine 3-5 turns whilst cold. Check all cylinders.
- **Hands on experience on Engine oil quality checking - Water Content test, pH Test, Viscosity Test, Spot test, Flash point test, Water Crackle test**

### 1. Water Content test

5 ml of sample is taken inside digital water content meter mixed with 15 ml of reagent containing paraffin or toluene. Before closing the lid of the digital meter, a sealed sachet containing calcium Hydride is kept and container closed tight. The meter is shaken by hand and the pressure rise due to the chemical reaction in the test container is shown as water percentage in the digital display.

### 2. pH Test

It is done by using a pH paper which changes colour once in contact with oil and it is then compared with standard values. This test determines the reserve alkalinity of the oil sample.

### 3. Viscosity Test

This test is performed by using a Flow stick in which two paths are provided for flow of oil side by side. In one path fresh oil is filled and in other side path used sample oil is filled. Now the flow stick is tilted allowing oil on both paths flowing in the direction of the tilt due to gravity. A finish point is provided along with reference points along the flow stick and the position of used oil is checked when fresh oil reaches the finish point. This method shows the contamination of lube oil which may be due to diesel oil, heavy oil or sludge resulting in change in viscosity.

### 4. Spot test

In this test a drop of lube oil is put on the blotter paper and it is then dried for few hours. The dry spot is then compared with the standard spot available which determines the insoluble components in lube oil.

### 5. Flash point test

This is performed by using Pensky Martin closed cup apparatus which determines the temperature at which the vapour will flash up when an external ignit-

able source is provided. As per the regulation, this apparatus generally carried on passenger ships.

### 6. Water Crackle test

It is another method of determining water presence in the lube oil where the oil sample drops are heated in an aluminium container over a flame. If water is present crackling sound will come.

### Assessment Activities

- Class room test
- Assignment
- Flow chart
- Seminar
- Group discussion

### Portfolio

- Activity log, charts and seminar report on types of maintenance and its importance
- charts and seminar report on oil mist detector
- Practical Activity log - decarburization
- Practical Activity log - valve clearance adjustment
- Chart preparation- daily maintenance
- Chart preparation- lube oil quality checking

### TE Questions

- Explain the importance of maintenance
- Explain cavitation in propeller and its remedy
- What is the reason for blue smoke emission from engine?
- How oil mist detector prevents crank case explosion?
- Explain different types of lube oil tests

## UNIT - 5

### GAUGES AND METERS

The unit on gauges and meters is small but vital. The need and applications of different gauges and meters are discussed under this title. The devices like temperature gauge, pressure gauge, tachometer, inclinometer, ammeter, flow meter, gauge glass, hour meter are detailed.

#### Detailing of The Concepts

##### 3.5.1 Gauges

A gauge or gage, in science and engineering, is a device used to make measurements or in order to display certain information, like time. A wide variety of tools exist which serve such functions, ranging from simple pieces of material against which sizes can be measured to complex pieces of machinery. Depending on usage, a gauge can be described as "a device for measuring a physical quantity".

All gauges can be divided into four main types, independent of their actual use.

1. Analogue instrument meter with analogue display ("needles"). Until the later decades the most common basic type.
2. Digital instrument meter with analogue display. A screen that shows an "analogue meter", commonly used in modern aircraft cockpits, and some hospital equipment etc.
3. Digital instrument meter with digital display. Only numbers are shown at a digital display.
4. Analogue instrument meter with digital display. Only numbers are displayed, but through a mechanical or electro-mechanical display (today very rare but has existed for clocks, certain Doppler meters and informational screens at all kinds of stations and airports)

##### 3.5.1.1 Bimetal temperature gauge

Bimetal temperature gauges operate with a measuring system in the form of a helical or spiral tube. The measuring system consists of two sheets with different expansion coefficients, which are inseparably joined. The mechanical deformation of the bimetal strips into the tube shapes mentioned above results in a rotational movement, caused by temperature changes. If one end of the bimetal measuring system is firmly clamped, the other end will rotate the pointer shaft. Bimetal temperature gauges are available with a scale range of  $-70 \dots +600 \text{ }^\circ\text{C}$ .

### 3.5.1.2 Gas-actuated temperature gauge

With a gas-actuated temperature gauge the stem, the capillary and the Bourdon tube are joined together into one unit. The instrument is filled with inert gas. If the temperature changes, the internal pressure also changes. The pointer is moved by the action of the pressure via a measuring tube. To compensate for the ambient temperature, a bimetal element is mounted between the movement and the measuring tube. Gas-actuated temperature gauges are available with scale ranges between -200 ... +700 °C

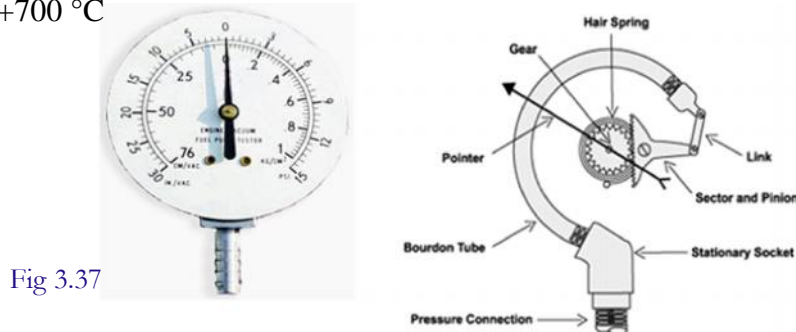


Fig 3.37

### 3.5.1.3 Bourdon Tube pressure gauge

The Bourdon tube pressure gauge uses the principle that a flattened tube tends to straighten or regain its circular form in cross-section when pressurized. It consists of a hollow bourden tube that is fastened at one end and free at the other. The oil pressure is applied to the curved tube through an oil line from the engine which causes the tube to straighten out. This movement is transmitted to a needle by linkage and gears from the end of the tube. The needle moves across the face of dial indicating the oil pressure.

### 3.5.1.4 Gauge Glass (sight glass)

A sight glass or water gauge is a transparent tube through which the operator of a tank or boiler can observe the level of liquid contained within. Simple sight glasses may be just a plastic or glass tube connected to the bottom of the tank at one end and the top of the tank at the other. The level of liquid in the sight glass will be the same as the level of liquid in the tank. Today, however, sophisticated float switches have replaced sight glasses in many such applications.

## 3.5.2 Meters

### 3.5.2.1 Tachometer

A tachometer (revolution-counter, tach, rev-counter, RPM gauge) is an instrument measuring the rotation speed of a shaft or disk, as in a motor or other machine. The

device usually displays the revolutions per minute (RPM) on a calibrated analogue dial, but digital displays are increasingly common.

### 3.5.2.2 Ammeter

An ammeter is a measuring instrument used to measure the current in a circuit. Electric currents are measured in amperes (A), hence the name. Instruments used to measure smaller currents, in the milli ampere or microampere range, are designated as milli ammeters or micro ammeters.

### 3.5.2.3 Flow measurement

Flow measurement is the quantification of bulk fluid movement. Flow can be measured in a variety of ways. Positive-displacement flow meters accumulate a fixed volume of fluid and then count the number of times the volume is filled to measure flow. Other flow measurement methods rely on forces produced by the flowing stream as it overcomes a known constriction, to indirectly calculate flow. Flow may be measured by measuring the velocity of fluid over a known area.

### 3.5.2.4 Inclinometer

An inclinometer or clinometer is an instrument for measuring angles of slope (or tilt), elevation or depression of an object with respect to gravity. It is also known as a tilt meter, tilt indicator, slope alert, slope gauge, gradient meter, gradiometer, level gauge, level meter, declinometer, and pitch & roll indicator. Clinometers measure both inclines (positive slopes, as seen by an observer looking upwards) and declines (negative slopes, as seen by an observer looking downward) using three different units of measure: degrees, percent, and topo.

### 3.5.2.5 Engine-Hour Meter

A device that records the operating time of an engine, machine, or mechanism; it is used to monitor and log the service life of the engine.

The main components of an engine-hour meter are an indicator of the engine's operating conditions, which records such data as the speed of rotation of shafts, the temperature of exhaust gases, or the torque; a timer; and a recorder, usually a mechanical counter with digital drums. Electric clocks, or



GAUGES & METERS

Fig 3.38



semiconductor or magnetic devices driven by constant-frequency quartz or other master oscillator, may be used as timers for aircraft engines. The simpler engines of tractors and harvesters have indicators that are driven mechanically by the engine shaft through a reduction gear. In this case, the hours of operation are determined from the number of revolutions of the engine. Self-winding spring driven clocks are also used as timers for such engines.

### **Detailing Of Practicals**

- **Dismantling and assembling of bourden tube Pressure gauge.**
  - Disconnect inlet line and remove the gauge from engine and placed on the work table.
  - Remove glass cover and needle or pointer.
  - Identify elliptical tube and rack and pinion.
  - Refit the needle on pinion without dial.
  - Allow the air enter inside the bourden tube with high pressure.
  - Note the deflection on the needle and shape changing of bourden tube.
  - Re- assemble the gauge and re-fit into engine in reverse order of dismantling

### **Assesment Activities**

- Classroom test
- Assignment
- Flow chart
- Seminar
- Group discussion

### **PORTFOLIO**

- Activity log, charts and seminar report on bourdon tube pressure gauge
- charts and seminar report on different types of gauges
- Practical Activity log - Bourdon pressure gauge

### **TE QUESTIONS**

- 1 Explain the working of bourdon tube pressure gauge, with a neat sketch
- 2 What is the use of temperature gauge, list the names of any two?
- 3 Which device is used to measure angles of slope ?
  - a) Tachometer      b) ammeter      c) inclinometer
- 4 What is the use of a gauge glass?
- 5 If a person wants to measure the quantity of fluid passing through a pipe, which device he will use?

## UNIT - 6

### VESSEL AND VESSEL TERMINOLOGY

This unit deals with the terms used in maritime industry. A few terms from the glossary which are used most frequently are introduced here. A detailed explanation on navigation lights, ballasting and de ballasting, pipe line colour code and engine room layout are discussed in detail.

#### Detailing Of The Concepts

##### 3.6.1 VESSEL TERMINOLOGY

###### 3.6.1.1 Ahead

The forward motion of a ship is termed as ahead.

###### 3.6.1.2 Astern

The backward motion of a ship is termed as astern.

###### 3.6.1.3 Bow

The bow is the forward part of the hull of a ship or boat, the point that is usually most forward when the vessel is underway. The bow is designed to reduce the resistance of the hull cutting through water and should be tall enough to prevent water from easily washing over the top of it. The forward part of the bow, usually on the ship's centreline, is called the stem. Traditionally, the stem was an upright timber or metal bar into which side planks or plates were joined.

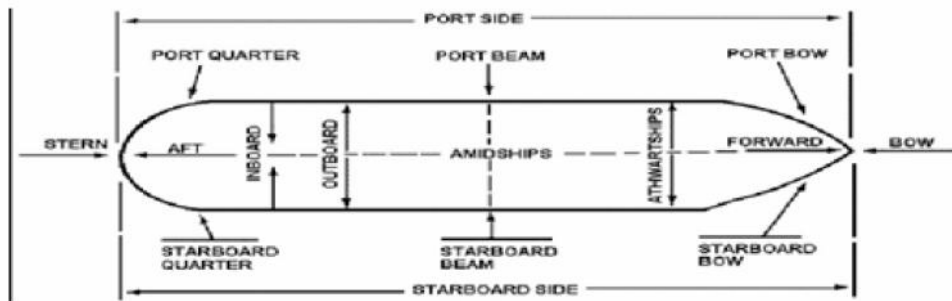


Fig 3.39

###### 3.6.1.4 Stern

The stern is the back or aft-most part of a ship or boat, technically defined as the area built up over the sternpost. The stern lies opposite of the bow, the foremost part of a ship. Originally, the term only referred to the aft port section of the ship, but

eventually came to refer to the entire back of a vessel. The stern end of a ship is indicated with a white navigation light at night.

### 3.6.1.5 Port And Starboard

Port and starboard are nautical terms for left and right, respectively. Port is the left-hand side of or direction from a vessel, facing forward. Starboard is the right-hand side, facing forward.

### 3.6.1.6 Bridge

The bridge of a ship is the room or platform from which the ship can be commanded. When a ship is underway the bridge is manned by an OOW (officer of the watch) aided usually by an AB (able seaman) acting as lookout. During critical manoeuvres the captain will be on the bridge supported, perhaps, by an OOW as an extra set of hands, an AB on the wheel and sometimes a pilot if required.

### 3.6.1.7 Gangway

Gangways are used to embark and disembark passengers.

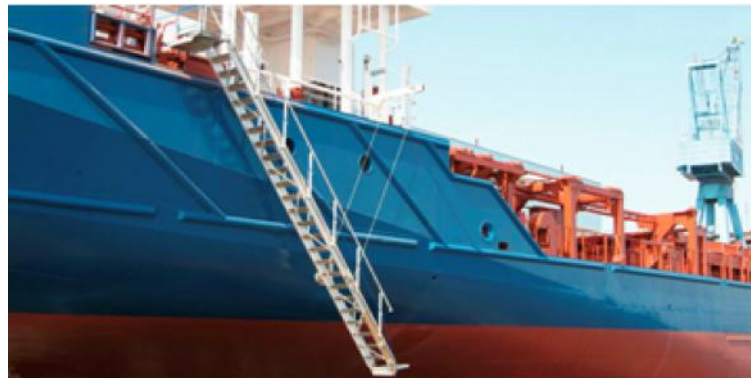


Fig 3.40

## 3.6.2 Ballasting and deballasting

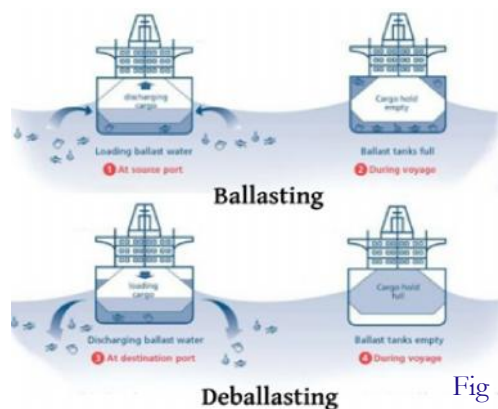


Fig 3.41

Ballasting or de-ballasting is a process by which sea water is taken in and out of the ship when the ship is at the port or at the sea. The sea water carried by the ship is known as ballast water. Ballast or ballast water is sea water carried by a vessel in its ballast tanks to ensure its trim, stability and structural integrity. Ballast tanks are constructed in ships with piping system and high capacity ballast pumps to carry out the operation.

When no cargo is carried by the ship, the later becomes light in weight, which can affect its stability. For this reason, ballast water is taken in dedicated tanks in the ship to stabilize it. Tanks are filled with ballast water with the help of high capacity ballast pumps and this process is known as Ballasting.

However, when the ship is filled with cargo, the stability of the ship is maintained by the weight of the cargo itself and thus there is no requirement of ballast water. The process of taking out ballast water from the ballast tanks to make them empty is known as de-ballasting.

### 3.6.3 Engine room layout

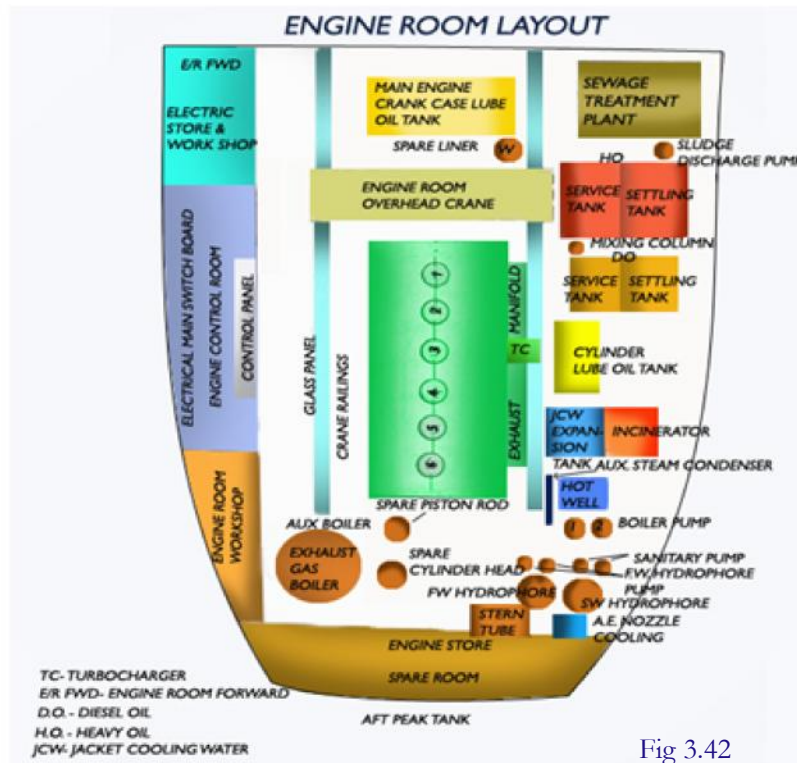


Fig 3.42

### 3.6.4 Colour lights and code used in ships

#### 3.6.4.1 Marine Navigation Lights

To avoid collisions, vessels mount navigation lights that permit other vessels to determine the type and relative angle of a vessel, and thus decide if there is a danger of collision. In general sailing vessels are required to carry a green light that shines from dead ahead to two points ( $22\frac{1}{2}^\circ$ ) abaft the beam on the starboard side (the right side from the perspective of someone on board facing forward), a red light from dead ahead to two points abaft the beam on the port side (left side) and a white light that shines from astern to two points abaft the beam on both sides. Power driven vessels, in addition to these lights, must carry either one or two (depending on length) white masthead lights that shine from ahead to two points abaft the beam on both sides. If two masthead lights are carried then the after one must be higher than the forward one.

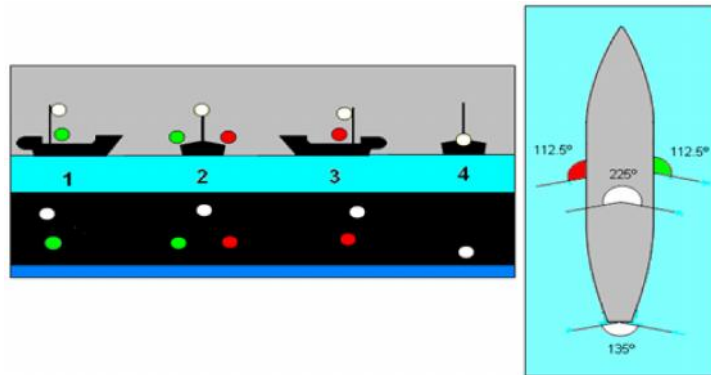


Fig 3.43

In addition to red, white and green running lights, a combination of red, white and green Mast Lights placed on a mast higher than all the running lights, and viewable from all directions, may be used to indicate the type of craft or the service it is performing.

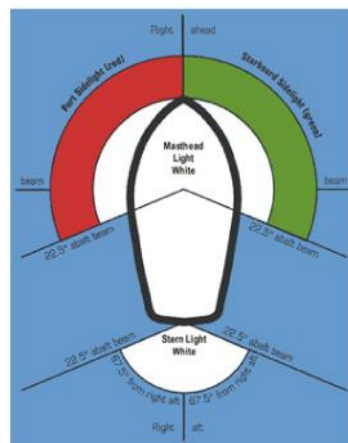


Fig 3.44

- Ships at anchor display one or two white anchor lights (depending on the vessel's length) that can be seen from all directions. If two lights are shown then the forward light is higher than the aft one.
- Boats classed as "small" are not compelled to carry navigation lights and may make use of a handheld torch.

#### 3.6.4.2 Color codes for ships pipe line

##### Color Codes For Pipelines..!









• Lubricating Oil	
• Fuel Oil	
• Diesel Oil	
• Steam	
• Compressed Air	
• Sea Water	
• Fresh Water	
• Fire Main line	

Fig 3.45

#### 3.6.5 Types of ships

##### Passenger ship

Passenger ships also known as cruise vessels are used for luxury tours and sea voyages carrying passengers, as well as their belongings.

##### Container ship

Container ships are meant to carry cargoes that are contained in containers. Containers are handled either by cranes on ship or that are present on ports.

##### Bulk carrier

Bulk carriers are ships which carry cargoes in bulk, which means those cargoes which are not packed in any form. These include iron ore, rice, sulphur etc. these cargoes are loaded into big cargo holds through conveyor belts. These cargo holds have large hatch doors, which in turn protect the cargo.

##### Tanker

Tanker vessels are used to ship crude oil or petroleum products, edible oils, apple juice etc. These vessels have only one third portion of it above the sea.

##### LPG carrier

These vessels are exclusively used to carry liquid petroleum gas.

##### Car carrier

Car carriers are used to ship cars from one country to the other in large numbers. Cars enter through a ramp that can be retracted while in voyage.

### Chemical tanker

Chemical tankers are used to carry highly concentrated chemicals, polymers etc.



Fig 3.46 TYPES OF SHIPS

The workers in this ship must undergo a chemical tanker familiarization course before joining the vessel.

### Barge

Barges are used to carry cargoes or fuel for ships. Barges usually ply near coastal areas.

### **Project vessel**

Project vessels are meant to complete a particular project. These ships will have machinery and equipment that are required to complete the work or assist during the project.

### **Dredger vessel**

Dredgers are used to dredge or increase the depth of ships channel. Dredgers suck mud through large pipes from the floor of the ocean thereby clearing sea channel and makes enough depth.

### **Assessment Activities**

- Class room test
- Assignment
- Flow chart
- Seminar
- Group discussion

### **PORTFOLIO**

- Activity log and seminar report on vessel terminology
- charts and seminar report on navigation lights used in ships
- Chart preparation on engine room layout

### **TE QUESTIONS**

- Explain navigation lights used onboard ship
- List any four piping system and their colour code used onboard ship
- Name any five types of ships.

### **Extended Activities**

#### **List of Practicals**

- Identify and categorize the SI & C I engines parts.
- Dismantling and assembling of boat diesel engine and Identification of parts such as exhaust valve, piston rod, cross head, minimum 4 piston rings only, separate fuel injection pump for each cylinder, no transfer port, air induction by turbo charger, direct drive, two set of fuel cams for reversing the engine rotation.
- Dismantling and assembling of fuel injection pump.
- Dismantling and assembling of fuel injector



- Assembling of piston rings in the piston
- Hands - on experience on injector servicing
- Hands- on experience on injection pump servicing
- Hands on experience on manual starting systems
- Dismantling and assembling of Bendix starting system
- Heat exchanger servicing
- Dismantling and assembling of turbo charger
- Dismantling and assembling of fishing boat transmission system epi - cyclic
- Dismantling and assembling of fishing boat transmission system differential.
- Dismantling and assembling of fishing boat transmission system reverse and reduction.
- On hand experience of lube oil changing.
- On hand experience of Decarburization in boats.
- Hands - on experience on engine Valve Clearance adjustment.
- Hands - on experience on engine Cylinder piston clearance checking by using feeler gauge
- Calibration of piston and piston rings
- Hands - on experience on engine Compression pressure checking low/ high
- Hands - on experience on Engine oil quality checking - Water Content test, pH Test, Viscosity Test, Spot test, Flash point test, Water Crackle test
- Dismantling and assembling of bourden tube Pressure gauge.

## OVERVIEW OF THE MODULE

### **Module 4 - Marine Equipment Servicing, Welding and Non Destructive Testing**

The final module is named as marine equipment servicing, welding and non destructive test. The condition of an engine is assessed by reading on different meters. In this module the learner is familiarized with each and every meter and gauges found in most of the marine vessels. He is also introduced to deck equipments, navigation aids, auxiliary machines and life saving equipments. He is also skilled to service deck equipments like winches, centrifugal pump, reciprocating pumps, compressors etc. Welding and NDT in this module empowers the learner to explore job opportunities in corresponding area.

#### UNIT - 1

### MARINE AUXILIARY MACHINES

All machinery excluding main engine in a ships engine room comes under the topic marine auxiliary machinery. This includes pumps, compressor, A.C. Generator, etc. The study of pumps comprises of the working and operation of centrifugal pump, reciprocating pump, gear pump, hand pump. The need of a compressor onboard ship and types of compressor used are explained in detail. The role of AC generator and its working is also covered. In addition different types of power take off and batteries onboard are also discussed.

#### Detailing of The Concepts

##### 4.1.1 Pump

##### 4.1.1.1 Centrifugal pump

A pump is a machine used to raise liquids from a low point to a high point. In a centrifugal pump liquid enters the centre or eye of the impeller and flows radially out between the vanes, its velocity being increased by the impeller rotation. A diffuser or volute is then used to convert most of the kinetic energy in the liquid into pressure.

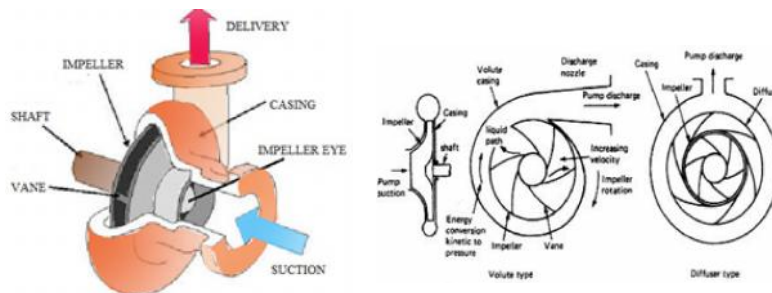


Fig 4.1

#### 4.1.1.2 Reciprocating pump

If the mechanical energy is converted into hydraulic energy by sucking the liquid into a cylinder in which a piston is reciprocating, which exerts the thrust on the liquid and increases its hydraulic energy is known as reciprocating pump. A reciprocating pump is a positive plunger pump. It is often used where relatively small quantity of liquid is to be handled and where delivery pressure is quite large. Reciprocating pump consists of following parts.

##### Single acting reciprocating pump:-

A single acting reciprocating pump, which consists of a piston which moves forwards and backwards in a close fitting cylinder. The movement of the piston is obtained by connecting the piston rod to crank by means of a connecting rod. The crank is rotated by means of an electric motor. Suction and delivery pipes with suction valve and delivery non return valves are connected to the cylinder. Suction valve allows water from suction pipe to the cylinder which delivery valve allows water from cylinder to delivery pipe.

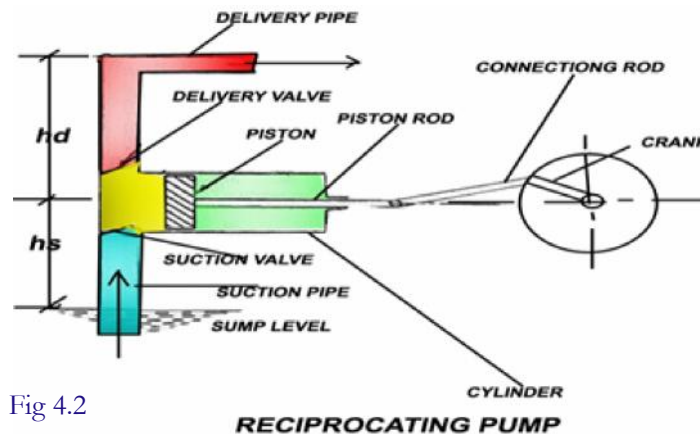


Fig 4.2

The rotation of the crank brings about an outward and inward movement of the piston in the cylinder. During the suction stroke the piston is moving towards right in the cylinder, this movement of piston causes vacuum in the cylinder. The pressure of the atmosphere acting on the sump water surface forces the water up in the suction pipe. The forced water opens the suction valve and the water enters the cylinder. The piston from its extreme right position starts moving towards left in the cylinder. The movement of the piston towards left increases the pressure of the liquid inside the cylinder more than atmospheric pressure. Hence suction valve closes and delivery valve opens. The liquid is forced into the delivery pipe and is raised to a required height.

For one revolution of the crank, the quantity of water raised up in the delivery pipe is equal to the stroke volume in the cylinder in the single acting pump and twice this volume in the double acting pump.

### Double-acting reciprocating pump

In a Double-acting reciprocating pump, each stroke of the piston carries out both the functions, suction as well as delivery. Thus it requires two suction pipes and two delivery pipes for double-acting pump. When there is a suction stroke on one side of the piston, there is at the same time a delivery stroke on the other side of the piston. Thus for one complete revolution of the crank there are two delivery strokes and water is delivered to the pipes by the pump during these two delivery strokes.

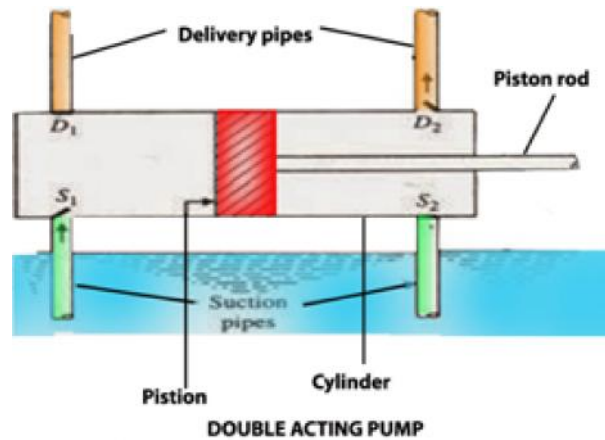


Fig 4.3

#### 4.1.1.3 Gear pump

These gear pumps are rotary displacement or rotary positive displacement pumps. Two toothed wheels shown mesh together and are a close fit in casing. Initially the air or gas is trapped between each pair of consecutive teeth and the same is dragged along the casing from suction to discharge side till no more air is left on the suction side. Liquid from the tank will thus rise up into suction line under atmospheric pressure, subsequently this liquid will now be trapped between each pair of two consecutive teeth and dragged along the casing into the discharge side and pumping of liquid will commence.

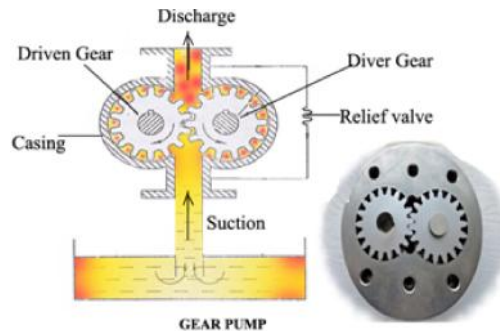


Fig 4.4

The working principle just explained is what makes the pump a self priming pump. Further if liquid level on suction side is at a higher level, the liquid will flow into the suction side on its own at first instant itself.

Usually the gear pumps are electric motor driven through a chain or wheel drive. Control of flow rate is achieved by a bypass valve or controlling speed of prime mover. A number of such pumps in series can be used to develop high pressure. Such pumps are efficient and smooth running.

### **Applications**

Gear pumps are used for duties as a lube oil pump, boiler fuel oil pump, fuel oil transfer pump, main engine driven lube oil pump. As a main engine driven lube oil pump it will have a set of suction and discharge valve to give same side discharge at all times irrespective of ahead or astern movement of the main engine.

#### **4.1.1.4 Hand pumps**

Hand pumps are manually operated pumps; they use human power and mechanical advantage to move fluids or air from one place to another. They are widely used in every country in the world for a variety of industrial, marine, irrigation and leisure activities. There are many different types of hand pump available, mainly operating on a piston, diaphragm or rotary vane principle with a check valve on the entry and exit ports to the chamber operating in opposing directions. Most hand pumps have plungers or reciprocating pistons, and are positive displacement.

#### **4.1.2 Compressor**

Compressor is one such device which is used for several purposes on a ship. As the main aim of the compressor, as the name suggests, is to compress air or any fluid in order to reduce its volume. Some of the main applications of compressors are main air compressor, deck air compressor, AC compressor and refrigeration compressor.

Air Compressor produces pressurized air by decreasing the volume of air and in turn increasing its pressure. Different types of air compressors are used according to the usage

### **Uses of Air Compressor on Ship**

On board a ship, compressed air is used for several purposes. On the basis of application, different air compressors are kept for a particular usage. Normally, air compressors on board ships are:

- main air compressor
- topping up compressor
- deck air compressor
- Emergency air compressor

### **Main air compressor**

Main air compressor is used for supplying high pressurized air for starting of main and auxiliary engines. The pressurized air generated by the air compressor is stored in air storage bottle. These are high capacity compressors and the air pressure that is required from these compressors to start the main engine is 30 bars.

Control air is also supplied from air bottle through a pressure reducing valve and a control air filter. Normally they are twice in number and can be more than that for redundancy.

### **Topping up compressor**

Topping up compressor takes up the lead to cover up for the leakage in the system. This means that as soon as the air pressure in the system goes below a particular level, the topping up compressor replenished the system with pressurized air.

### **Deck air compressor**

Deck air compressor is used for deck use and as service air compressor and might have a separate service air bottle for the same. These are lower capacity pressure compressors as pressure required for service air is in between the range of 6 to 8 bar.

### **Emergency air compressor**

Emergency air compressor is used for starting auxiliary engine at the time of an emergency or when the main air compressor has failed for filling up the main air receiver. This type of compressor can be motor driven or engine driven. If motor driven, it should be supplied from emergency source of power.

#### **4.1.2.1 Single stage Reciprocating Air Compressor:**

In single stage reciprocating air compressor the entire compression is carried out in a single cylinder. If the compression is affected in one end of the piston & cylinder then it is known as single acting & if the compression is affected in both ends of piston & cylinder then it is known as double acting reciprocating air compressor.

The opening & closing of simple check valve (plate or spring valve) is depend upon difference in pressure, if mechanically operated valves are used for suction & discharge then their functioning is controlled by cams.

The weight of air in the cylinder will be zero when the piston is at top dead centre, if we neglect clearance volume. When piston starts moving downwards, the pressure inside the cylinder falls below atmospheric pressure & suction valve/inlet valve opens.

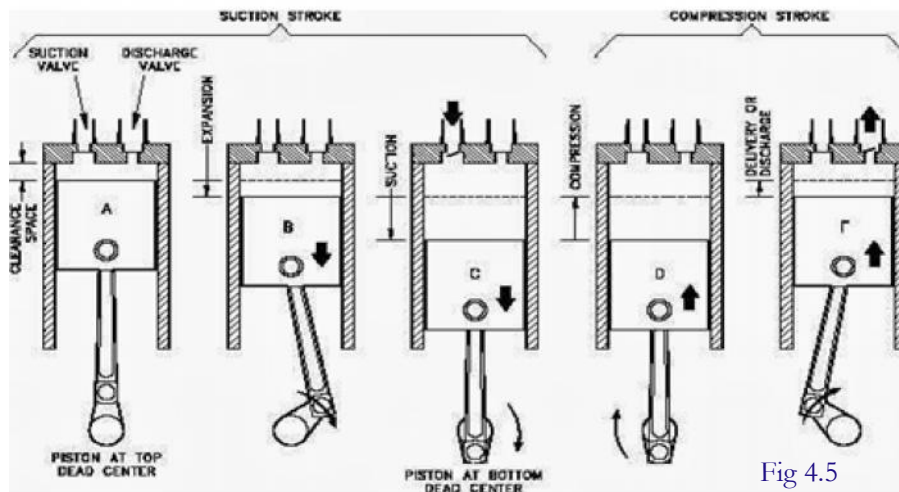


Fig 4.5

The air is drawn into the cylinder through suction filter element. This operation is known as suction stroke.

When piston moves upwards, compresses the air in cylinder & inlet valve closes when pressure reaches to atmospheric pressure. Further compression follows as the piston moves towards the top of its stroke until, when the pressure in the cylinder exceeds that in the receiver. This is compression stroke of compressor. At the end of this stroke discharge/delivery valve opens & air is delivered to receiver.

### Two - stage air compressor

#### On the suction stroke

- First-stage piston, air at atmospheric pressure enters the cylinder through the inlet filter and valve located in the airhead.
- Second stage piston, this cooled air enters the second stage Cylinder through the inlet valve.

#### On the compression stroke of the:

- First stage piston, the air is compressed to an intermediate pressure and discharged through the valve in to a common manifold.
- From the manifold, the air passes through the intercooler tubes where the heat of first stage compression is removed by the action of the fan passing cool air over the intercooler tubes.
- Second stage piston compresses the air to the final discharge pressure and forces it out through the valve in to the receiver or system.

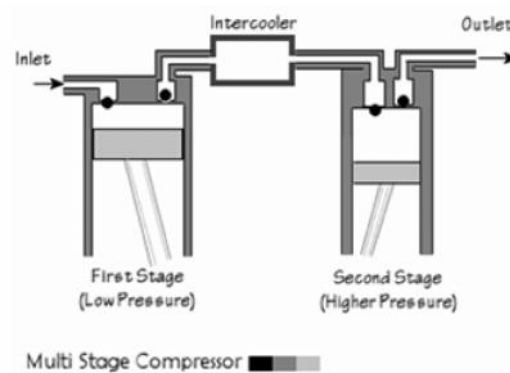


Fig 4.6

#### 4.1.2.2 Centrifugal compressor

In a centrifugal compressor, energy is transferred from a set of rotating impeller blades to the gas. The designation "centrifugal" implies that the gas flow is radial, and the energy transfer is caused from a change in the centrifugal forces acting on the gas. Centrifugal compressors deliver high flow capacity per unit of installed space and weight, have good reliability, and require significantly less maintenance than reciprocating compressors. However, the performance characteristic of centrifugal compressors is more easily affected by changes in gas conditions than is the performance of reciprocating compressors

Very large (i.e., high-volume) flow compressors may operate at speeds as low as 3,000 rpm. Conversely, low-volume flow compressors may operate at speeds up to 30,000 rpm. Power requirement is related to mass flow, head, and efficiency. Depending on the particular application, centrifugal compressor powers can range from as low as 500 hp (400 kW) to more than 50,000 hp (40 MW).

#### 4.1.3 AC generator

In DC generator, the conductors are rotated in a stationary magnetic field and current flow in the same direction. But in AC generator, the magnetic field is rotated and the conductors remain stationary. The current flows first on one direction and then in other alternately. The same electricity generating effect is produced if the reverse occurs, that is, the field coils rotate and the armature is stationary. This is in fact the arrangement adopted for large, heavy duty alternators.

The field current supply in older machines comes from a low-voltage direct current generator or exciter on the same shaft as the alternator. Modern machines, however, are either statically excited or the high speed brushless type. The exciter is required to operate to counter the effects of power factor for a given load.



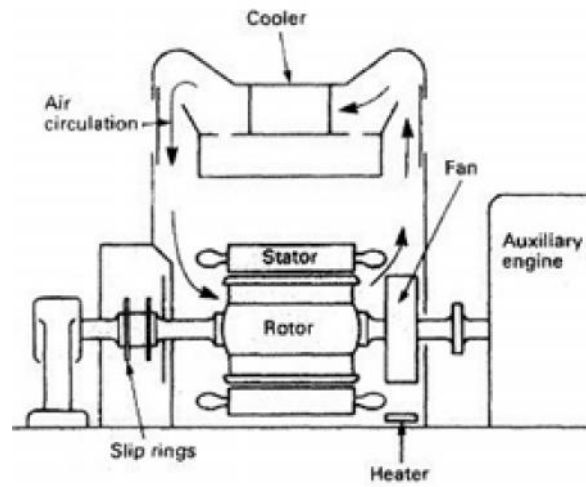


Fig 4.7

The construction of an alternator can be seen in figure above. The rotor houses the poles which provide the field current, and these are usually of the salient or projecting-pole type. Slip rings and fan are also mounted on the rotor shaft, which is driven by the auxiliary engine. The stator core surrounds the rotor and supports the three phase windings. Heat is produced in the various windings and must be removed by cooling. The shaft fan drives air a water-cooled heat exchanger.

In addition to auxiliary engine driven alternator a ship may have a shaft driven alternator. In this arrangement a drive is taken from the main engine or the propeller shaft and use to rotate the alternator.

A hydraulic pump and gear box arrangement may be used to provide a constant speed drive, or alternator output may be fed to a static frequency converter. In the static frequency converter the ac output is first rectified into dc voltage and the inverted back into a three phase ac voltage. A feedback system in oscillator inverter produces a constant output ac voltage and frequency.

#### 4.1.3.1 Electrical system used in ships

An a.c. distribution system is provided from the main switchboard which is itself supplied by the alternators (Figure below). The voltage at the switchboard is usually 440 volts, but on some large installations it may be as high as 3300 volts. Power is supplied through circuit breakers to larger auxiliaries at the high voltage. Smaller equipment may be supplied via fuses or miniature circuit breakers. Lower voltage supplies used, for instance, for lighting at 220 volts, are supplied by step down transformers in the distribution network.

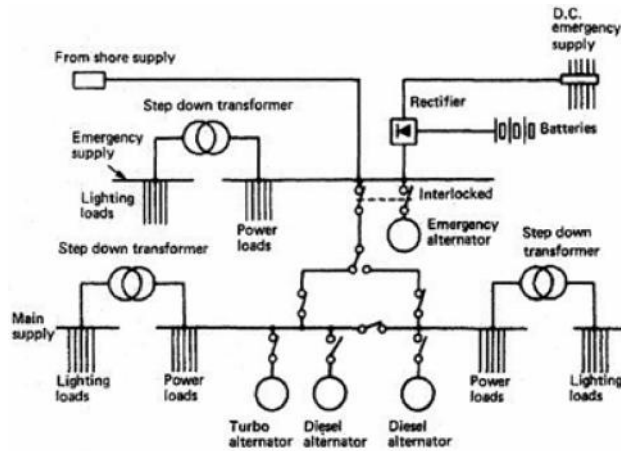


Fig 4.8

#### 4.1.4 Power take off

Fishing vessels are equipped with a number of fishing accessories like winch, gurdies, line hauler, etc. To operate such accessories power is required. In some vessels there will be an additional engine called auxiliary engine for this purpose. In some other vessels this is achieved by taking power from the main engine by using some arrangements. This method is called power take off.

Power take off are three types Mechanical, Electrical and Hydraulic power take off

##### 4.1.4.1 Mechanical power takeoff

In mechanical power takeoff, drive is taken from the extension shaft attached to the forward side of the main engine and supported by suitable bearings. A counter shaft from the winch led along the lower edge of the beam and supported by suitable bearings from these beams

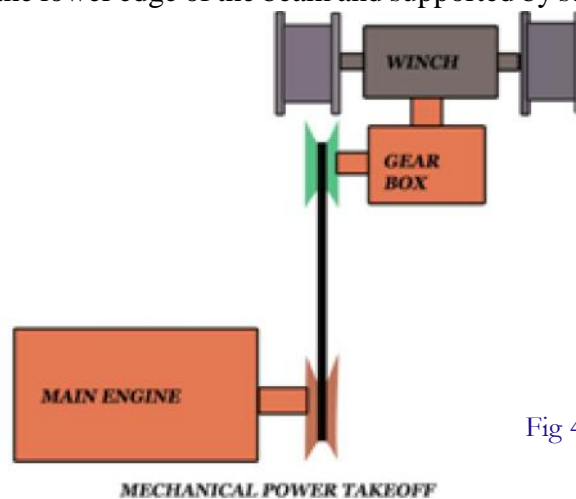


Fig 4.9

This counter shaft is coupled to the engine shaft by pulleys. A power takeoff clutch provided at the end of the engine and is used to transmit the power as and when required. The main disadvantages are noisy operation and very difficult to engage and disengage.

#### 4.1.4.2 Electrical Power takeoff

In electrical power takeoff the power generated in the engine is first converted into electrical energy by using a generator coupled to the engine. This electrical energy is again converted into mechanical energy by using an electric motor. A reduction gearbox is provided between the electric motor and winch for changing the speed and torque.

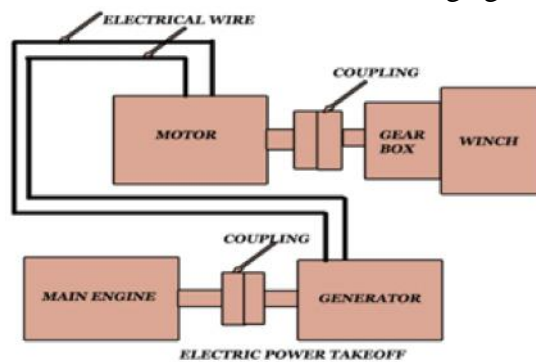


Fig 4.10

#### 4.1.4.3 Hydraulic Power takeoff

In hydraulic power takeoff the main engine of the ship drives the hydraulic pump, through a suitable speed up arrangement. It consists of a hydraulic pump, oil tank, control valve, servo motor, and reduction gear box.

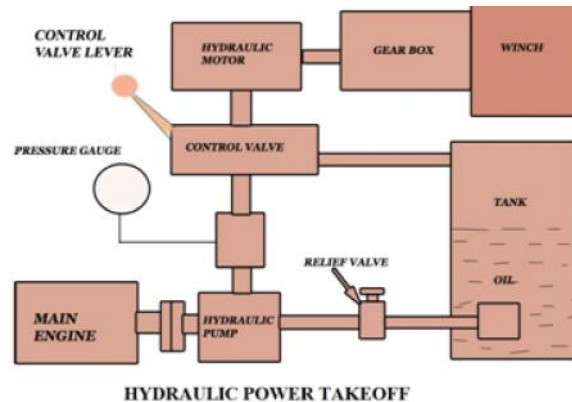


Fig 4.11

The main engine is coupled with hydraulic pump through a clutch. Hydraulic pump pressurize the oil and it supply to the servo motor through control valve. The direction of rotation of servo motor can be change by a hand lever attached with the control

valve. A reduction gearbox is provided between the servo motor and winch for changing the speed and torque.

#### 4.1.5 Batteries for ships machinery spaces

The battery is a convenient means of storing electricity. It is used on many ships as an instantly available emergency supply. It may also be used on a regular basis to provide a low-voltage d.c. supply to certain equipment. To provide these services the appropriate size and type of battery must be used and should be regularly serviced. Two main types of battery are used on board ship: the lead acid and the alkaline type, together with various circuits and control gear.

##### 4.1.5.1 Lead-acid battery

The lead - acid battery is made up of a series of cells. One cell consists of a lead peroxide positive plate and a lead negative plate both immersed in a dilute sulphuric acid solution. The sulphuric acid is known as the 'electrolyte'. A wire joining these two plates will have a potential or voltage developed across it and a current will flow. This voltage is about 2.2V initially with a steady value of about 2V. A grouping of six separate cells connected in series will give a 12V battery.

##### 4.1.5.2 Alkaline battery

The basic cell of the alkaline battery consists of a nickel hydroxide positive plate and a cadmium and iron negative plate immersed in a solution of potassium hydroxide. The cell voltage is about 1.4V. A grouping of five cells is usual to give about seven volts.

In the charged condition the positive plate is nickel hydroxide and the negative plate cadmium. During discharge oxygen is transferred from one plate to the other without affecting the specific gravity of the potassium hydroxide solution. The negative plate becomes cadmium oxide and the positive plate is less oxidised nickel hydroxide. Charging the battery returns the oxygen to the positive plate.

### Detailing of Practicals

- **Dismantling and assembling of Centrifugal pump.**
  - Stop and safely isolate the pump.
  - Disconnect the delivery pipe and suction pipe.
  - Remove the foundation bolts.
  - Then hoist the pump from its foundation.

- Dismantle casing.
- Unscrew the impeller nut and take out the impeller by careful tapping of soft hammer or use a puller. Take out and secure the impeller key.
- Loosen the gland nut and take out gland packing. In case of mechanical seal, safely remove it. Then identify all the parts like impellers, eye, shape etc. casing and its shape, delivering line and valve, suction line, foot valve etc.
- Identify the parts- Volute casing, Impeller, Key, Impeller nut & lock washer, Wear rings, Gland & gland packing, Foot valve and Priming plug.
- After studying its working, then assemble the pump in the reverse order of dismantling

#### ■ **Dismantling and assembling of Reciprocating pump.**

Before dismantling the pump,

- Release pressure from air vessel
- Remove suction and delivery pipes
- Remove the head nuts and dismantle the head
- Check the valves, piston and seal
- Identifies the pump parts such as piston, piston rod, connecting rod, suction and delivery pipes and valves
- After study its working assemble the pump in the reverse sequence

#### ■ **Dismantling and assembling of Gear pump.**

- Dismantle the suction and delivery lines
- Remove the fixing nut and remove the pump
- Placed on the worktable
- Unscrew the casing bolts and remove the casing
- " Dismantle the gear wheels and check it
- Identify the parts such as delivery port, suction port, driver wheel, driven wheel, casing, relief valve, by pass line etc
- Study its working and assemble in the reverse order of dismantling

#### ■ **Dismantling and assembling of Hand Pump.**

- Remove the head nuts and dismantle the plunger with connecting rod and head assembly

- Remove the plunger from connecting rod end
  - Check the plunger washer
  - Remove the suction non return valve
  - Check the non return valve
  - Identify the pump parts such as plunger, washer, connecting rod, non return valve, suction pipe and handle.
  - After studying its working assemble the pump in the reverse sequence
- **Dismantling and assembling of Reciprocating compressor (Single stage and Multistage).**
- Disconnect the electric connection
  - Remove the air filter and suction line.
  - Dismantle the delivery line and moisture/oil trap.
  - Then remove the cylinder head stud's nuts using the socket spanner.
- **Dismantle the belt from the prime mover.**
- Remove piston and the connecting rod.
  - Dismantle the connecting rod, cylinder block, crank shaft.
  - And identify all the parts along with air bottle, inter cooler, after cooler etc.
  - After the identification of parts and studying its working, then assemble all the part in reverse order of dismantling.
- **Dismantling and assembling of Centrifugal compressor.**
- Dismantle casing
  - Unscrew the impeller nut and take out the impeller by careful tapping of soft hammer or use a puller. Take out and secure the impeller key.
  - Then identify all the parts like impellers, eye, shape etc. casing and its shape, delivering line and valve, suction line, air filter etc.
  - After studying its working, then assemble the pump in the reverse order of dismantling

**Assessment Activities**

- Class room test
- Assignment
- Flow chart
- Seminar
- Group discussion

**Portfolio**

- Activity log and seminar report on AC generator
- charts and seminar report on centrifugal pump
- Chart preparation reciprocating pump
- Practical Activity log- centrifugal pump
- Practical Activity log- hand pump
- Chart preparation on different types of power take off

**TE Questions**

- What is the need of an AC generator onboard ship?
- List any two types of rotary pumps used onboard ship?
- Explain hydraulic power take off with a neat sketch.
- Which equipment is used to pressurize air?  
a) Centrifugal pump      b) Centrifugal compressor      c) AC generator

## UNIT - 2

### DECK EQUIPMENTS AND FISHING ACCESSORIES

Fishing accessories and deck equipment covers the machinery which are used exclusively for fishing purposes. These machinery includes mechanical trawl winch, line hauler, power block, gurdy, gallows, pulleys etc.

#### Detailing Of The Concepts

##### 4.2.1 Deck Equipments and fishing Accessories-

Winches may be one of the first machinery fitted on fishing vessels, when fishing vessels were mechanised. There are different types of winches to suite trawl fishery, purse-seining, deep sea anchoring etc.

Trawl winches can be single drum, two drum on one shaft, two or more drums on parallel shafts. Also they may be mechanically driven, hydraulically or electric driven winches.

Mechanically driven trawl winches are common in small fishing boats. Power from the main engine is taken by chain drive or pulley belt drive. A power take off unit is used to take power from the main engine. The construction of the winch is by welded and bolted sections of sufficient strength which enable it to withstand shocks or load. It is fixed on the deck by nuts or bolts avoid yielding under heavy strains. A mechanically driven winch consists of bed plate, warp head, warp drum, brake operating wheel, worm wheel housing etc.

The bed plate is a solid plate and the base is perfectly flat for strength and solid fastening. The worm reduction gear box is a semi steel casting. The worm is cut right or left hand according to the rotation needed. The main shaft is attached to the worm wheel and is suspended in roller bearings. The two warp drums are keyed to the main shaft. Oil seals are fitted to the worm wheel housing to prevent leakage of oil. The gear ratios are selected as per the work. Clutches and brakes are provided to stop the winch. Mechanical winches have more frictional loss and occupies more space. But hydraulic winch is more efficient. It is same as that of hydraulic power take off unit. The hydraulic winches are provided with hydraulic motor. The direction control valve available on the winch directs the flow to the motor so that motor rotates in clockwise or anti clockwise. The hydraulic power required for the motor



is fed from the hydraulic pump. The hydraulic pump is fitted on the forward side of the engine.

#### 4.2.1.2 Gurdy

Gurdy is a gear handling equipment used on trollers for hauling troll lines. They are used in gill netters also. There are mechanical, electrical and hydraulic gurdies. The figure shows mechanically operated gurdy with a capstan. It has a reduction gear box with worm wheel, vertical shaft, V sleeve pulley and a capstan. The construction of the gurdy is by welded or bolted plates. It is rigidly fixed on the deck by means of nuts and bolts. The vertical shaft is pressed and keyed to the worm wheel. The capstan and the V sheave pulley are keyed to the main shaft. An operating lever is provided on the deck to engage power to the gurdy.

Gurdies used in small line haulers to haul troll lines. They have reels on it. Instead of just being pulled through as in a line hauler gurdies wound the lines on.

#### 4.2.1.3 Line Hauler

Line hauler is the deck equipment used on long liners. Tuna liners are commonly electrically driven. Line haulers have three main parts i) lower part- consisting of driving mechanism- driving shaft, two gears for changing speed etc. ii) Middle part - speed governing mechanism and clutch iii) Upper part - Pulley mechanism.

The upper part consists of three pullies which wind the lines automatically. The main pulley is the driving pulley. Pressure pulley presses the lines to the main pulley while the guide pulley guides the lines to the driving pulley.

The lower part of the line hauler contains oil which is automatically fed to the working parts. The whole body of the line hauler is made of cast steel and pullies are out of gun metal to prevent wear of lines. Rubber coated pullies are also used. The line hauler is firmly fastened by nut and bolts to the deck. The bed plate is a strong structure which is fastened to the deck.

#### 4.2.1.4 Net drums

In bigger trawlers and gill netters, the size of the nets are large, so more manual labour is required to handle them. Also the nets are likely to sag while handling. These difficulties are overcome by providing a net drum. The net is completely wound on the drum during handling.

#### 4.2.1.5 Power blocks

A power block was used in purse-sein vessels at the time of introducing. Now they are used in all vessels including small fishing boats. They are multipurpose such as i) leading rope to convenient position ii) leading rope to lowering point as in trawlers iii) for lifting heavy loads.

A simple pulley doesn't provide mechanical advantage. But it can change the direction of the force into a convenient direction. Also now a days motorized power blocks helps to handle leads with least manual effort.

The construction of the power block is shown. Blocks are fitted in wooden or metal case with one or more sheaves. The pulley is mounted on a shaft. The shaft may drive with hydraulic or electric power.

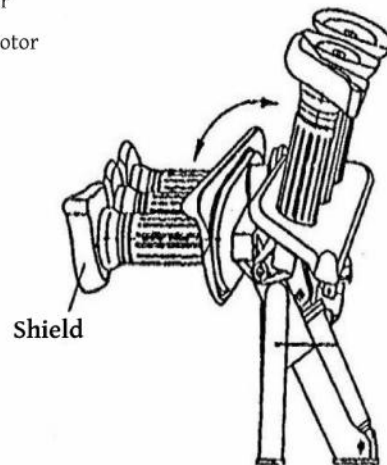
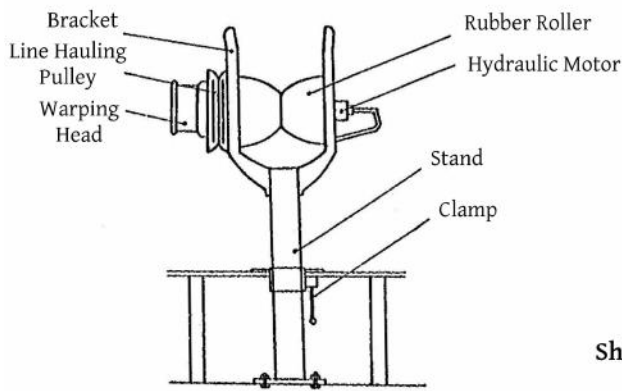
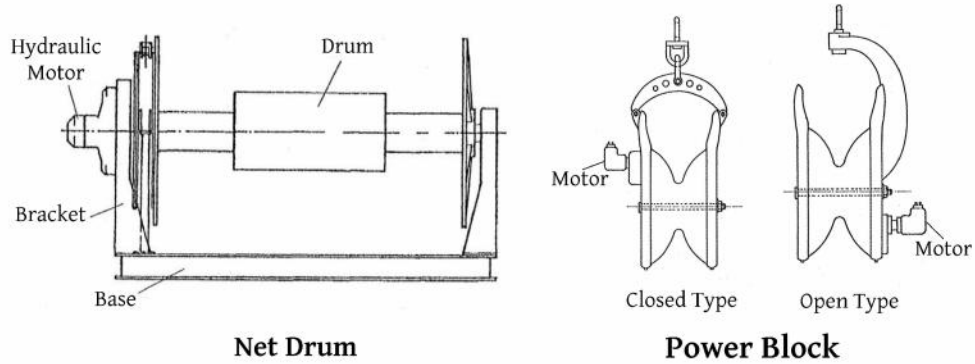
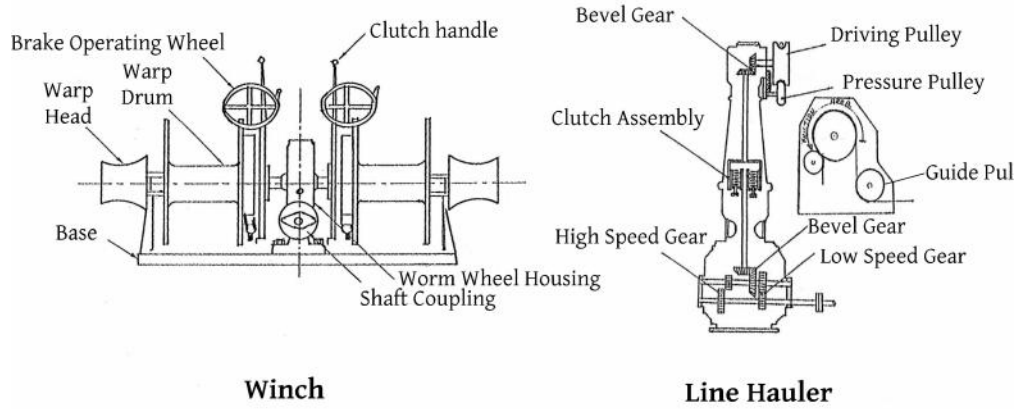
The hydraulic motor is mounted on the side of the pulley cover. The shaft of the motor is connected to the pulley shaft through gears. Thus speed of the pulley can be controlled. The sheave is designed with optimum V groove so that net can be handled easily. Rubber coating is given on the sheave to give smooth friction. The power blocks are two types open type and closed type. The power blocks are held on an elevated position such as from the end of a boom, crane etc.

#### 4.2.1.6 Gill net hauler

Gill net haulers are used for hauling the gill net especially on bigger vessels. They are operated with the help of hydraulic power. These haulers are also provided with rubber grooved rollers for hauling the nets with more grip and less damage. In vessels performing combined gill netting and line fishing there are long line cum gill net haulers.

#### 4.2.1.7 Purse-seine winch and Triplex rollers

Purse-seine operation mainly needs purse-seine winch. Power blocks are employed to haul the nets. Triplex rollers are another method for passing net to the winch and from there to bin. It consists of three parallel rollers with independent shaft. The rollers are hydraulically operated.



Lone Line Cum Gillnet Hauler

Triplex Roller

Fig 4.12

FISHING ACCESSORIES

**Detailing Of Practicals**

- Dismantling and assembling of Mechanical Trawl winch.
- Remove warp head both sides.
- Remove warp drum both sides.
- Remove the drain plug of gear housing and drain the oil.
- Remove the housing and dismantle the gears.

**Detailing of Practicals**

- Dismantling and assembling of Mechanical Trawl winch.
- Remove warp head both sides.
- Remove warp drum both sides.
- Remove the drain plug of gear housing and drain the oil.
- Remove the housing and dismantle the gears.
- Identify and study the parts then greasing the gears and reassemble in the reverse order of dismantling.

**Assessment Activities**

- Class room test
- Assignment
- Flow chart
- Seminar
- Group discussion

**Portfolio**

- Activity log and seminar report on winches
- charts and seminar report on fishing accessories
- Practical Activity log- winch
- Chart preparation on deck equipments

**TE Questions**

- What is a power block, explain its use?
- List any three fishing accessories
- Draw a neat sketch and mark the important parts of a trawl winch and explain the working?

## UNIT - 3

### NAVIGATION AIDS

Besides engine side, the deck department plays an equal role in navigation as well as manoeuvring. This is accomplished by a lot of navigation equipment, which assist the officer for a safe and efficient journey. The unit covers a detailed study and use of automatic identification system (AIS), SONAR, RADAR, etc.

#### Detailing of the Concepts

##### 4.3.1 Navigation Aids

###### 4.3.1.1 Global Positioning System (GPS)

The Global Positioning System (GPS) is a satellite-based navigation system made up of a network of 24 satellites placed into orbit by the U.S. Department of Defense. GPS was originally intended for military applications, but in the 1980s, the government made the system available for civilian use. GPS works in any weather conditions, anywhere in the world, 24 hours a day. There are no subscription fees or setup charges to use GPS.

##### How it works

GPS satellites circle the earth twice a day in a very precise orbit and transmit signal information to earth. GPS receivers take this information and use trilateration to calculate the user's exact location. Essentially, the GPS receiver compares the time a signal was transmitted by a satellite with the time it was received. The time difference tells the GPS receiver how far away the satellite is. Now, with distance measurements from a few more satellites, the receiver can determine the user's position and display it on the unit's electronic map.

A GPS receiver must be locked on to the signal of at least 3 satellites to calculate a 2-D position (latitude and longitude) and track movement. With four or more satellites in view, the receiver can determine the user's 3-D position (latitude, longitude and altitude). Once the user's position has been determined, the GPS unit can calculate other information, such as speed, bearing, track, trip distance, distance to destination, sunrise and sunset time and more.

###### 4.3.1.2 AIS

The Automatic Identification System (AIS) is an automatic tracking system used on ships and by vessel traffic services (VTS) for identifying and locating vessels by electronically exchanging data with other nearby ships, AIS base stations, and satellites.

When satellites are used to detect AIS signatures then the term Satellite-AIS (S-AIS) is used. AIS information supplements marine radar, which continues to be the primary method of collision avoidance for water transport.

Information provided by AIS equipment, such as unique identification, position, course, and speed, can be displayed on a screen.. AIS is intended to assist a vessel's watch standing officers and allow maritime authorities to track and monitor vessel movements. AIS integrates a standardized VHF transceiver with a positioning system such as a GPS or LORAN-C receiver, with other electronic navigation sensors, such as a gyrocompass or rate of turn indicator. Vessels fitted with AIS transceivers can be tracked by AIS base stations located along coast lines or, when out of range of terrestrial networks, through a growing number of satellites that are fitted with special AIS receivers which are capable of deconflicting a large number of signatures.

#### **4.3.1.3 VHF Radio**

Marine VHF radio refers to the radio frequency range between 156.0 and 162.025 MHz, inclusive. In the official language of the International Telecommunication Union the band is called the VHF maritime mobile band.

Marine radio equipment is installed on all large ships and most seagoing small craft. It is also used, with slightly different regulation, on rivers and lakes. It is used for a wide variety of purposes, including summoning rescue services and communicating with harbours, locks, bridges and marinas, and operates in the very high frequency (VHF) range, between 156 and 162.025 MHz. Although it is widely used for collision avoidance, its use for that purpose is contentious and is strongly discouraged by some countries, including the UK.

#### **4.3.1.4 RADAR**

Marine radars are X band or S band radars to provide bearing and distance of ships and land targets in vicinity from own ship (radar scanner) for collision avoidance and navigation at sea.

Radar is a vital component for safety at sea and near the shore. Captains need to be able to maneuver their ships within feet in the worst of conditions and to be able to navigate "blind". This means inside a dark room with no visibility they need to safely navigate their way through waters in the worst of weather. Radars are rarely used alone in a marine setting. In commercial ships, they are integrated into a full system of marine instruments including chart plotters, sonar, two-way radio communication devices, and emergency locators (SART).

The integration of these devices is very important as it becomes quite distracting to look at several different screens. Therefore, displays can often overlay charting, radar, sonar into a single system. This gives the captain unprecedented instrumentation to maneuver the ship. With digital backbones, these devices have advanced greatly in the last years. For example, the newer ones have 3D displays that allow you to see above, below and all around the ship, including overlays of satellite imaging. In port or in harbour, shore-based vessel traffic service radar systems are used to monitor and regulate ship movements in busy waters.

#### **4.3.1.5 ECHO SOUNDER**

Echo sounding is a type of SONAR used to determine the depth of water by transmitting sound pulses into water. The time interval between emission and return of a pulse is recorded, which is used to determine the depth of water along with the speed of sound in water at the time. This information is then typically used for navigation purposes or in order to obtain depths for charting purposes. Echo sounding can also refer to hydro acoustic "echo sounders" defined as active sound in water (sonar) used to study fish. Hydro acoustic assessments have traditionally employed mobile surveys from boats to evaluate fish biomass and spatial distributions. Conversely, fixed-location techniques use stationary transducers to monitor passing fish.

#### **4.3.1.6 SONAR**

Sonar (originally an acronym for Sound Navigation And Ranging) is a technique that uses sound propagation (usually underwater, as in submarine navigation) to navigate, communicate with or detect objects on or under the surface of the water, such as other vessels. Two types of technology share the name "sonar": passive sonar is essentially listening for the sound made by vessels; active sonar is emitting pulses of sounds and listening for echoes. Sonar may be used as a means of acoustic location and of measurement of the echo characteristics of "targets" in the water.

#### **4.3.1.7 Fish finder**

A fish finder is an instrument used to locate fish underwater by detecting reflected pulses of sound energy, as in sonar. A modern fish finder displays measurements of reflected sound on a graphical display, allowing an operator to interpret information to locate schools of fish, underwater debris, and the bottom of body of water. Fish finder instruments are used both by sport and commercial fishermen. Modern electronics allows a high degree of integration between the fish finder system, marine radar, compass and GPS navigation systems.

#### **4.3.1.8 Magnetic compass**

The magnetic compass is the most familiar compass type. It functions as a pointer to "magnetic north", the local magnetic meridian, because the magnetized needle at its heart aligns itself with the horizontal component of the Earth's magnetic field. The



Fig 4.13

magnetic field exerts a torque on the needle, pulling one end or pole of the needle approximately toward the Earth's North magnetic pole, and pulling the other toward the South magnetic pole. The needle is mounted on a low-friction pivot point, in better compasses a jewel bearing, so it can turn easily. When the compass is held level, the needle turns until, after a few seconds to allow oscillations to die out, it settles into its equilibrium orientation.

In navigation, directions on maps are usually expressed with reference to geographical or true north, the direction toward the Geographical North Pole, the rotation axis of the Earth. Depending on where the compass is located on the surface of the Earth the angle between true north and magnetic north, called magnetic declination can vary widely with geographic location. The local magnetic declination is given on most maps, to allow the map to be oriented with a compass parallel to true north. The Earth's magnetic fields are constantly changing which is referred to as geomagnetic secular variation. The effect of this means a map with the latest declination information should be used. Some magnetic compasses include means to manually compensate for the magnetic declination, so that the compass shows true directions.



#### 4.3.1.9 Gyro compass

A gyrocompass is a type of non-magnetic compass which is based on a fast-spinning disc and rotation of the Earth (or another planetary body if used elsewhere in the universe) to automatically find geographical direction. Although one important component of a gyrocompass is a gyroscope, these are not the same devices; a gyrocompass is built to use the effect of gyroscopic precession, which is a distinctive aspect of the general gyroscopic effect. Gyrocompasses are widely used for navigation on ships, because they have two significant advantages over magnetic compasses:

- they find true north as determined by Earth's rotation, which is different from, and navigationally more useful than, magnetic north, and
- they are unaffected by ferromagnetic materials, such as ship's steel hull, which change the magnetic field

#### Detailing of Practicals

- Identification of navigation aids commonly used in vessels GPS, Gyroscope, AIS, VHF Radio, RADAR, Ultra sonic devices ( Fathometer, SONAR, Fish finder), Magnetic compass and Gyro compass.

During the OJT or field visit in a marine vessel or ships students can identify the navigation aids commonly used in vessels GPS, Gyroscope, AIS, VHF Radio, RADAR, Ultra sonic devices ( Fathometer, SONAR, Fish finder), Magnetic compass and Gyro compass.

#### Assessment Activities

- Class room test
- Assignment
- Flow chart
- Seminar
- Group discussion

#### Portfolio

- Seminar report on AIS
- charts and seminar report on navigation aids
- seminar on different types of compasses

#### TE Questions

- Explain echo sounder and fish finder used onboard ship
- What is the full-form of AIS, explain briefly the use of AIS.
- Write short notes on RADAR and SONAR

## UNIT - 4

### LIFE SAVING EQUIPMENTS

Onboard ship, the most importance is given for the safety of the crew. Lifesaving appliances are aids or appliances required in an emergency. Lifesaving appliances such as life boat, life raft, life buoy, life jacket are discussed in detail.

#### Detailing Of The Concepts

##### 4.4.1 LIFE SAVING EQUIPMENTS

###### 4.4.1.1 Life raft

A life raft is a small inflatable boat carried for emergency evacuation in the event of a disaster aboard a ship. Inflatable life rafts may be equipped with auto-inflation (carbon dioxide or nitrogen) canisters or mechanical pumps. A quick release and pressure release mechanism is fitted on ships so that the canister or pump automatically inflates the life raft, and the life raft breaks free of the sinking vessel. Commercial aircraft are also required to carry auto-inflating life rafts in case of an emergency water landing; offshore oil platforms also have life rafts.

###### 4.4.1.2 Lifebuoy

A lifebuoy is a life - saving buoy designed to be thrown to a person in the water, to provide buoyancy and prevent drowning. Some modern lifebuoys are fitted with one or more seawater-activated lights, to aid rescue at night.

The lifebuoy is usually ring-or horseshoe-shaped and has a connecting line allowing the casualty to be pulled to the rescuer in a boat. They are carried by ships and are also located beside bodies of water that have the depth or potential to drown someone.

###### 4.4.1.3 Life jacket

A life jacket is a piece of equipment designed to assist a wearer to keep afloat in water. The wearer may be either conscious or unconscious. Life jackets are available in different sizes to accommodate variations in body weight. Designs differ depending on wearing convenience and level of protection..

###### 4.4.1.4 Lifeboat

Generally each merchant ship has one lifeboat fitted on the port side and one on the starboard side, so that a lifeboat is always available even if the ship is listing to one side. Ship-launched lifeboats are lowered from davits on a ship's deck, and are hard to sink in normal circumstances. The cover serves as protection from sun, wind and rain, can be used to collect rainwater, and is normally made of a reflective or

fluorescent material that is highly visible. Lifeboats have oars, flares and mirrors for signaling, first aid supplies, and food and water for several days. Some lifeboats are more capably equipped to permit self-rescue, with supplies such as a radio, an engine and sail, heater, navigational equipment, solar water stills, rainwater catchments and fishing equipment.

**Life Raft****Lifebuoy****Life Jacket****Lifeboat****Fig 4.14**

### **Detailing Of Practicals**

- Identification of Life raft, Life bouy, Life Jacket and Life Boat.

Life raft, Life bouy, Life Jacket and Life Boat are identified during the OJT or Field visit in a marine vessel.

### **Assessment Activities**

- Class room test
- Assignment
- Flow chart
- Seminar
- Group discussion

### **Portfolio**

- charts and seminar report on life saving appliances

### **TE Questions**

- Differentiate between life raft and life boat
- List all life saving appliances onboard ship and explain any two

## UNIT - 5

### WELDING AND WELDING DEFECTS

Riveting of metal plates was widely used in construction of ships. The introduction of welding brought drastic change in construction of ship. New welding technologies ensured highly water tight joints and more strength. The different types of welding methods are plastic welding (Resistance, Gas, Thermit and Forging) and Fusion welding (Arc, Gas and Thermit). The topics Under water welding and its two types such as Wet (Metal Arc) and Dry (Flux cored arc), different types of arc Welding Methods- Metal Arc, MIG, TIG and Submerged arc welding, Gas Welding (Oxy-Acetylene) etc. are discussed in detail. The welding defects such as undercut, porosity, slag inclusion, spatter and arc strike which may occur while doing welding are covered.

#### Detailing of the Concepts

##### 4.5.1 WELDING

#### Importance and Basic Concept of Welding

Welding is a fabrication process that joins materials, usually metals or thermoplastics, by causing coalescence. This is often done by melting the work pieces and adding a filler material to form a pool of molten material (the weld pool) that cools to become a strong joint, with pressure sometimes used in conjunction with heat, or by itself, to produce the weld.

Welding is used in every industry large or small, as a principle means of fabrication and repairing metal product. The process is efficient, economical and dependable. This is the only process which has been tried in the space and finds applications for fabricating products in air, underwater and in space

Welding is the least expensive process and widely used now a days in fabrication. Welding joints different metals with the help of a number of processes in which heat is supplied either electrically or by mean of a gas torch. Different welding processes are used in the manufacturing of Auto mobiles bodies, structural work, tanks, and general machine repair work. In the industries, welding is used in refineries and pipe line fabrication. It may be called a secondary manufacturing process

#### Classification of welding processes:

There are about 35 different welding and brazing process and several soldering methods, in use by the industry today. A simple and logical way is to satisfy the welding processes according to the sources of energy used for achieving coalescence. The welding processes can thus be broadly classified as;

- (a) Fusion welding
- (b) Pressure welding
- (c) Thermo chemical welding
- (a) Fusion welding

**1. Gas flame welding**

- Oxy-acetylene welding
- hydrogen welding

**2. Electric arc welding**

- Shielded Metal Arc Welding (SMAW)
- Gas Metal Arc Welding (GMAW)/Metal Inert Gas Welding (MIG)
- Gas Tungsten Arc Welding (GTAW)/Tungsten Inert Gas (TIG) Welding
- Submerged Arc Welding
- Plasma Arc Welding

**3. Radiant energy welding**

- Electron Beam Welding
- Laser Beam Welding

The following processes fall under solid state (cold) welding

**(b) Pressure welding**

**Electric resistance welding**

- Spot Welding
- Seam Welding
- Projection Welding
- Resistance Butt Welding
- Flash Welding
- Percussion Welding
- Electro-slag Welding

**Friction Welding**

**Ultrasonic Welding**

**Explosive Welding**

## Forge and Diffusive Welding

### (c) Thermo chemical welding

- Thermit Welding
- Atomic Hydrogen Welding

Out of the above welding processes carbon arc and atomic hydrogen welding are not commonly used in industries these days.

#### 4.5.1.1 Gas Welding

It is fusion welding process that joins the metal by using heat of combustion of a strong gas flame. The intense heat raises the temperature of ends, melts and fuses together the edges of the plate to be welded. Filler metal may be added the plate to flowing molten to fill the cavity between the plates. Different oxy-acetylene combinations are used to produce different types heating flames. Oxy-acetylene welding is the most commonly used gas welding process. This process is explained in detail in the following paragraphs.

### Oxy-Acetylene Welding

Oxy-Acetylene, commonly known as Oxy-fuel, is one of the oldest welding processes, though in recent years, it has become less popular in industrial applications

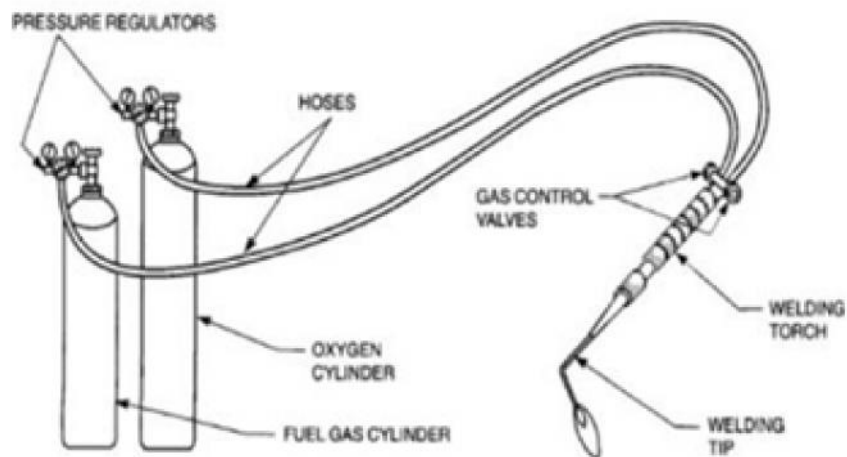


Fig 4.15

However, it is still widely used for a variety of applications. Oxy-fuel equipment is versatile, lending itself to welding, brazing, braze-welding, silver soldering, metal heating (for bending and forming) and oxy-fuel cutting.

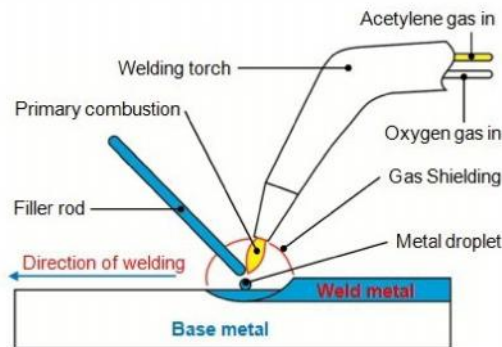


Fig 4.16

#### 4.5.1.2 Shielded Metal Arc Welding (SMAW)

Shielded metal arc welding is one of the world's most popular welding processes, accounting for over half of all welding in some countries. Because of its versatility and simplicity, it is particularly dominant in the maintenance and repair industry, and is heavily used in the construction of steel structures and in industrial fabrication.

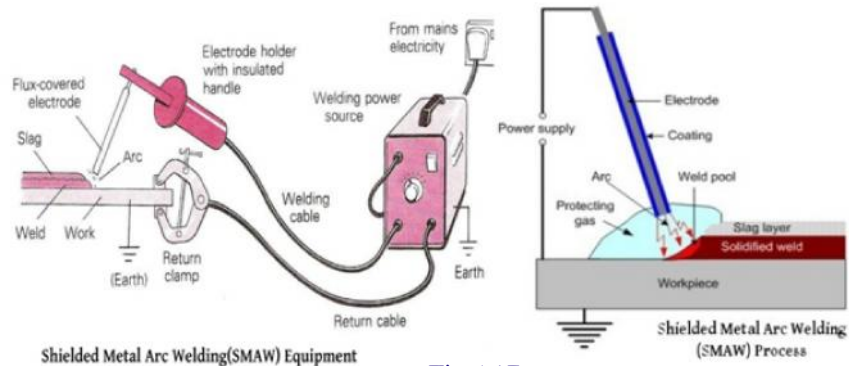


Fig 4.17

Shielded metal arc welding (SMAW), also known as Manual Metal Arc Welding (MMA or MMAW), flux shielded arc welding or informally as stick welding, is a manual arc welding process that uses a consumable electrode covered with a flux to lay the weld. An electric current, in the form of either alternating current or direct current from a welding power supply, is used to form an electric arc between the electrode and the metals to be joined. The work piece and the electrode melts forming the weld pool that cools to form a joint. As the weld is laid, the flux coating of the electrode disintegrates, giving off vapours that serve as a shielding gas and providing a layer of slag, both of which protect the weld area from atmospheric contamination



The choice of electrode for SMAW depends on a number of factors, including the weld material, welding position and the desired weld properties. The electrode is coated in a metal mixture called flux, which gives off gases as it decomposes to prevent weld contamination, introduces de-oxidisers to purify the weld, causes weld protecting slag to form, improves the arc stability, and provides alloying elements to improve the weld quality. The composition of the electrode core is generally similar and sometimes identical to that of the base material.

### **Principles of SMAW**

Shielded Metal Arc Welding (SMAW) is a process which melts and joins metals by heating them with an arc between a coated metal electrode and the work piece. The electrode outer coating, called flux, assists in creating the arc and provides the shielding gas and slag covering to protect the weld from contamination. The electrode core provides most of the weld filler metal.

When the electrode is moved along the work piece at the correct speed the metal deposits in a uniform layer called a bead. power sources.

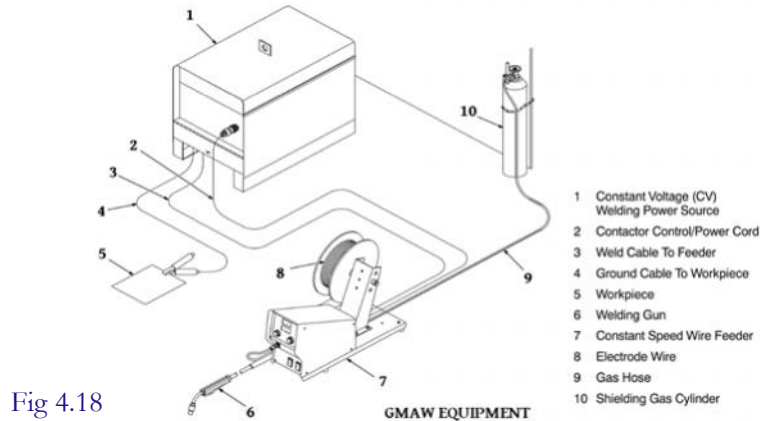
The power in a welding circuit is measured in voltage and current. The voltage (Volts) is governed by the arc length between the electrode and the work piece and is influenced by electrode diameter. Current is a more practical measure of the power in a weld circuit and is measured in amperes (Amps). The amperage needed to weld depends on electrode diameter, the size and thickness of the pieces to be welded, and the position of the welding. Generally, a smaller electrode and lower amperage is needed to weld a small piece than a large piece of the same thickness. Thin metals require less current than thick metals, and a small electrode requires less amperage than a large one.

It is preferable to weld on work in the flat or horizontal position. However, when forced to weld in vertical or overhead positions it is helpful to reduce the amperage from that used when welding horizontally. Best welding results are achieved by maintaining a short arc, moving the electrode at a uniform speed, and feeding the electrode downward at a constant speed as it melts.

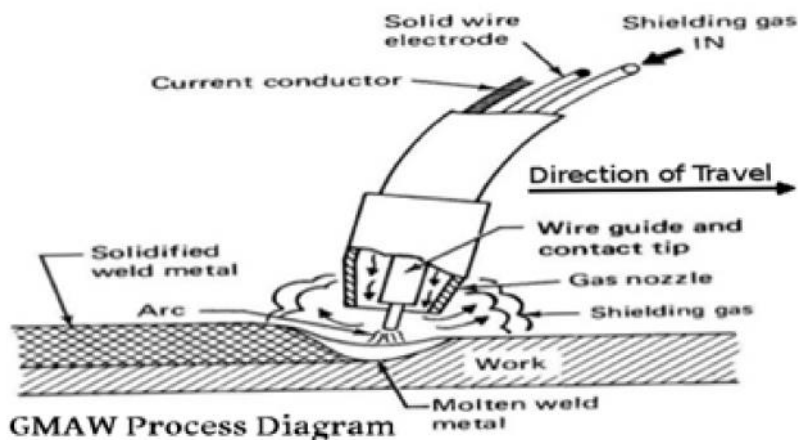
#### **4.5.1.3 Gas Metal Arc Welding (GMAW)/Metal Inert Gas Welding (MIG)**

Gas metal arc welding (GMAW), sometimes referred to by its subtypes metal inert gas (MIG) welding or metal active gas (MAG) welding, is a welding process in which an electric arc forms between a consumable wire electrode and the work piece metal(s), which heats the work piece metal(s), causing them to melt and join. Along with the wire electrode, a shielding gas feeds through the welding gun, which

shields the process from contaminants in the air. The process can be semi-automatic or automatic. A constant voltage, direct current power source is most commonly used with GMAW, but constant current systems, as well as alternating current, can be used. There are four primary methods of metal transfer in GMAW, called globular, short-circuiting, spray, and pulsed-spray, each of which has distinct properties and corresponding advantages and limitations



To perform gas metal arc welding, the basic necessary equipment is a welding gun, a wire feed unit, a welding power supply, a welding electrode wire, and a shielding gas supply. The GMAW welding gun has a number of key parts—a control switch, a contact tip, a power cable, a gas nozzle, an electrode conduit and liner, and a gas hose. The control switch, or trigger, when pressed by the operator, initiates the wire feed, electric power, and the shielding gas flow, causing an electric arc to be struck.



**Fig 4.19**

The contact tip, normally made of copper and sometimes chemically treated to reduce spatter, is connected to the welding power source through the power cable and transmits the electrical energy to the electrode while directing it to the weld area. It must be firmly secured and properly sized, since it must allow the electrode to pass while maintaining electrical contact. On the way to the contact tip, the wire is protected and guided by the electrode conduit and liner, which help prevent buckling and maintain an uninterrupted wire feed. The gas nozzle directs the shielding gas evenly into the welding zone.

Gas Metal Arc Welding (GMAW) is a welding process which joins metals by heating the metals to their melting point with an electric arc. The arc is between a continuous, consumable electrode wire and the metal being welded. The arc is shielded from contaminants in the atmosphere by a shielding gas.

**GMAW can be done in three different ways:**

- a) Semi-automatic Welding - equipment controls only the electrode wire feeding. Movement of welding gun is controlled by hand. This may be called hand-held welding.
- b) Machine Welding - uses a gun that is connected to a manipulator of some kind (not hand-held). An operator has to constantly set and adjust controls that move the manipulator.
- c) Automatic Welding - uses equipment which welds without the constant adjusting of controls by a welder or operator. On some equipment, automatic sensing devices control the correct gun alignment in a weld joint.

Basic equipment for a typical GMAW semi-automatic set up:

- a) Welding Power Source - provides welding power.
- b) Wire Feeders (Constant Speed And Voltage-Sensing) - controls supply of wire to welding gun.

Constant Speed Feeder - Used only with a constant voltage (CV) power source. This type of feeder has a control cable that will connect to the power source. The control cable supplies power to the feeder and allows the capability of remote voltage control with certain power source/feeder combinations. The wire feed speed (WFS) is set on the feeder and will always be constant for a given preset value.

Voltage-Sensing Feeder - Can be used with either a constant voltage (CV) or constant current (CC) - direct current (DC) power source. This type of feeder is powered off of the arc voltage and does not have a control cord. When set to (CV), the

feeder is similar to a constant speed feeder. When set to (CC), the wire feed speed depends on

the voltage present. The feeder changes the wire feed speed as the voltage changes. A voltage sensing feeder does not have the capability of remote voltage control.

- c) Supply of Electrode Wire.
- d) Welding Gun - delivers electrode wire and shielding gas to the weld puddle
- e) Shielding Gas Cylinder - provides a supply of shielding gas to the arc.

#### 4.5.1.4 Gas Tungsten Arc Welding(GTAW)/ Tungsten Inert Gas(TIG) Welding

Gas tungsten arc welding (GTAW), also known as tungsten inert gas (TIG) welding, is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from atmospheric contamination by an inert shielding gas (argon or helium), and a filler metal is normally used, though some welds, known as auto genous welds, do not require it. A constant-current welding power supply produces electrical energy, which is conducted across the arc through a column of highly ionized gas and metal vapours known as a plasma.

GTAW is most commonly used to weld thin sections of stainless steel and non-ferrous metals such as aluminum, magnesium, and copper alloys. The process grants the operator greater control over the weld than competing processes such as shielded metal arc welding and gas metal arc welding, allowing for stronger, higher quality welds. However, GTAW is comparatively more complex and difficult to master, and furthermore, it is significantly slower than most other welding techniques.

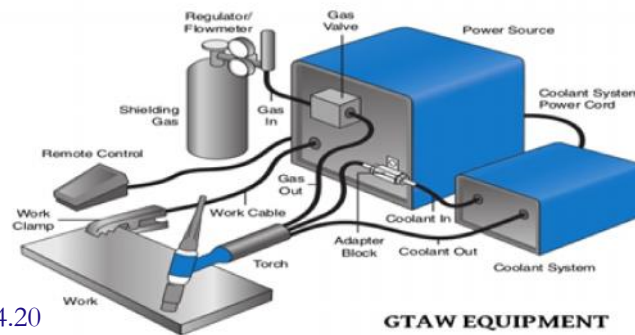


Fig 4.20

The equipment required for the gas tungsten arc welding operation includes a welding torch utilizing a non-consumable tungsten electrode, a constant-current welding power supply, and a shielding gas source.

#### 4.5.1.5 Submerged Arc Welding (SAW)

Submerged arc welding (SAW) is a common arc welding process. SAW is normally operated in the automatic or mechanized mode, however, semi-automatic (hand-held) SAW guns with pressurized or gravity flux feed delivery are available. The process is normally limited to the flat or horizontal-fillet welding positions (although horizontal groove position welds have been done with a special arrangement to support the flux).

It feeds flux and filler metal to the welding joint. The granulated flux shields and thus protects molten weld from atmospheric contamination. The flux cleans weld metal and can modify its chemical composition also. The flux is granulated to a definite size. It may be of fused, bonded or mechanically mixed type. The flux may consist of fluorides of calcium and oxides of calcium, magnesium, silicon, aluminum and manganese. Alloying elements may be added as per requirements. Substances evolving large amount of gases during welding are never mixed with the flux. Flux with fine and coarse particle sizes are recommended for welding heavier and smaller thickness respectively.

The flux starts depositing on the joint to be welded. Since the flux when cold is non-conductor of electricity, the arc may be struck either by touching the electrode with the job or by placing steel wool between electrode and job before switching on the welding current or by using a high frequency unit. In all cases the arc is struck under a cover of flux. Flux otherwise is an insulator but once it melts due to heat of the arc, it becomes highly conductive and hence the current flow is maintained between the electrode and the work piece through the molten flux. The upper portion of the flux, in contact with atmosphere, which is visible remains granular (unchanged) and can be reused. The lower, melted flux becomes slag, which is waste material and must be removed after welding.

#### Advantages

- High deposition rates (over 45kg/h (100lb/h) have been reported).
- High operating factors in mechanized applications.
- Deep weld penetration.
- Sound welds are readily made (with good process design and control).
- High speed welding of thin sheet steels up to 5 m/min (16ft/min) is possible.
- Minimal welding fume or arc light is emitted.

- Practically no edge preparation is necessary depending on joint configuration and required penetration.
- The process is suitable for both indoor and outdoor works.
- Welds produced are sound, uniform, ductile, corrosion resistant and have good impact value.
- Single pass welds can be made in thick plates with normal equipment.

### **Limitations**

- Limited to ferrous (steel or stainless steels) and some nickel-based alloys.
- Normally limited to the 1F, 1G, and 2F positions.
- Normally limited to long straight seams or rotated pipes or vessels.
- Requires relatively troublesome flux handling systems.
- Flux and slag residue can present a health and safety concern.
- Requires inter-pass and post weld slag removal.

### **4.5.2 Underwater welding (Hyperbaric welding)**

Hyperbaric welding is the process of welding at elevated pressures, normally underwater. Hyperbaric welding can either take place wet in the water itself or dry inside a specially constructed positive pressure enclosure and hence a dry environment. It is predominantly referred to as "hyperbaric welding" when used in a dry environment, and "underwater welding" when in a wet environment. The applications of hyperbaric welding are diverse-it is often used to repair ships, offshore oil platforms, and pipelines. Steel is the most common material welded.

The advantages of underwater welding are largely of an economic nature, because underwater-welding for marine maintenance and repair jobs bypasses the need to pull the structure out of the sea and saves valuable time and dry docking costs.

#### **4.5.2 .1 Dry welding**

Dry hyperbaric welding involves the weld being performed at raised pressure in a chamber filled with a gas mixture sealed around the structure being welded. Most arc welding processes such as Shielded Metal Arc Welding (SMAW), Flux-cored arc welding (FCAW), Gas tungsten arc welding (GTAW), Gas metal arc welding (GMAW), Plasma Arc Welding (PAW) could be operated at hyperbaric pressures, but all suffer as the pressure increases. Gas tungsten arc welding is most commonly used.

### 4.5.2 .2 Wet welding

Wet underwater welding directly exposes the diver and electrode to the water and surrounding elements. Divers usually use around 300-400 amps of direct current to power their electrode, and they weld using varied forms of arc welding. This practice commonly uses a variation of shielded metal arc welding, employing a waterproof electrode. Other processes that are used include flux-cored arc welding and friction welding. In each of these cases, the welding power supply is connected to the welding equipment through cables and hoses. The process is generally limited to low carbon equivalent steels, especially at greater depths, because of hydrogen-caused cracking.

### 4.5.3 Welding Positions

There are 4 main welding positions for the deposition of material as shown in the illustration below.

- a) Flat,    b) Horizontal,    c) Vertical and,    d) Overhead

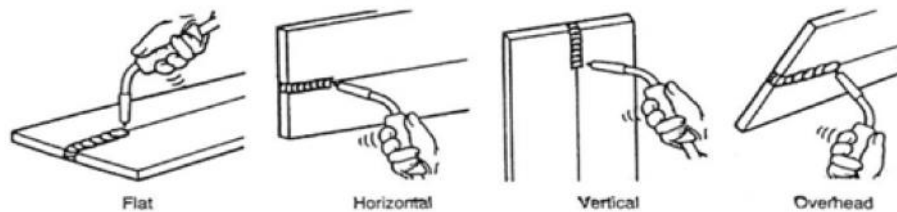


Fig 4.21

*Welding Positions*

### 4.5.4 Weld Defects and Their Causes

#### Lack of Penetration

Lack of penetration is the failure of the filler metal to penetrate into the joint. It is caused by:

- a) Incorrect edge penetration.
- b) Incorrect welding technique.
- c) Inadequate de-slagging.

#### Lack of Fusion

Lack of fusion is the failure of the filler metal to fuse with the parent metal. It is caused by:

- a) Insufficient heat.

- b) Too fast a travel.
- c) Incorrect welding technique.

### **Porosity**

Porosity is a group of small holes throughout the weld metal. It is caused by the trapping of gas during the welding process, due to chemicals in the metal, dampness, or too rapid cooling of the weld.

### **Slag Inclusion**

Slag inclusion is the entrapment of slag or other impurities in the weld. It is caused by the slag from previous runs not being cleaned away, or insufficient cleaning and preparation of the base metal before welding commences.

### **Undercut**

Undercuts are grooves or slots along the edges of the weld caused by:

- a) Too fast a travel.
- b) Too great a heat build-up.
- c) Bad welding technique

### **Overlays**

Overlays consist of metal that has flowed on to the parent metal without fusing with it. The defect is caused by:

- a) Insufficient heat.
- b) Contamination of the surface of the parent metal.
- c) Bad welding technique.

### **Cracking**

Cracking is the formation of cracks either in the weld metal or the parent metal. It is caused by:

- a) Bad welding technique.
- b) Unsuitable parent metals used in the weld.

### **Blowholes**

Blowholes are large holes in the weld caused by:

- a) Gas being trapped, due to moisture
- b) Contamination of either the filler or parent metals.

### **Burn Through**

Burn through is the collapse of the weld pool due to:

- a) Poor edge preparation.
- b) Too great a heat concentration.



### Excessive Penetration

Excessive penetration is where the weld metal protrudes through the root of the weld. It is caused by:

- a) Too big a heat concentration.
- a) Too slow a travel.

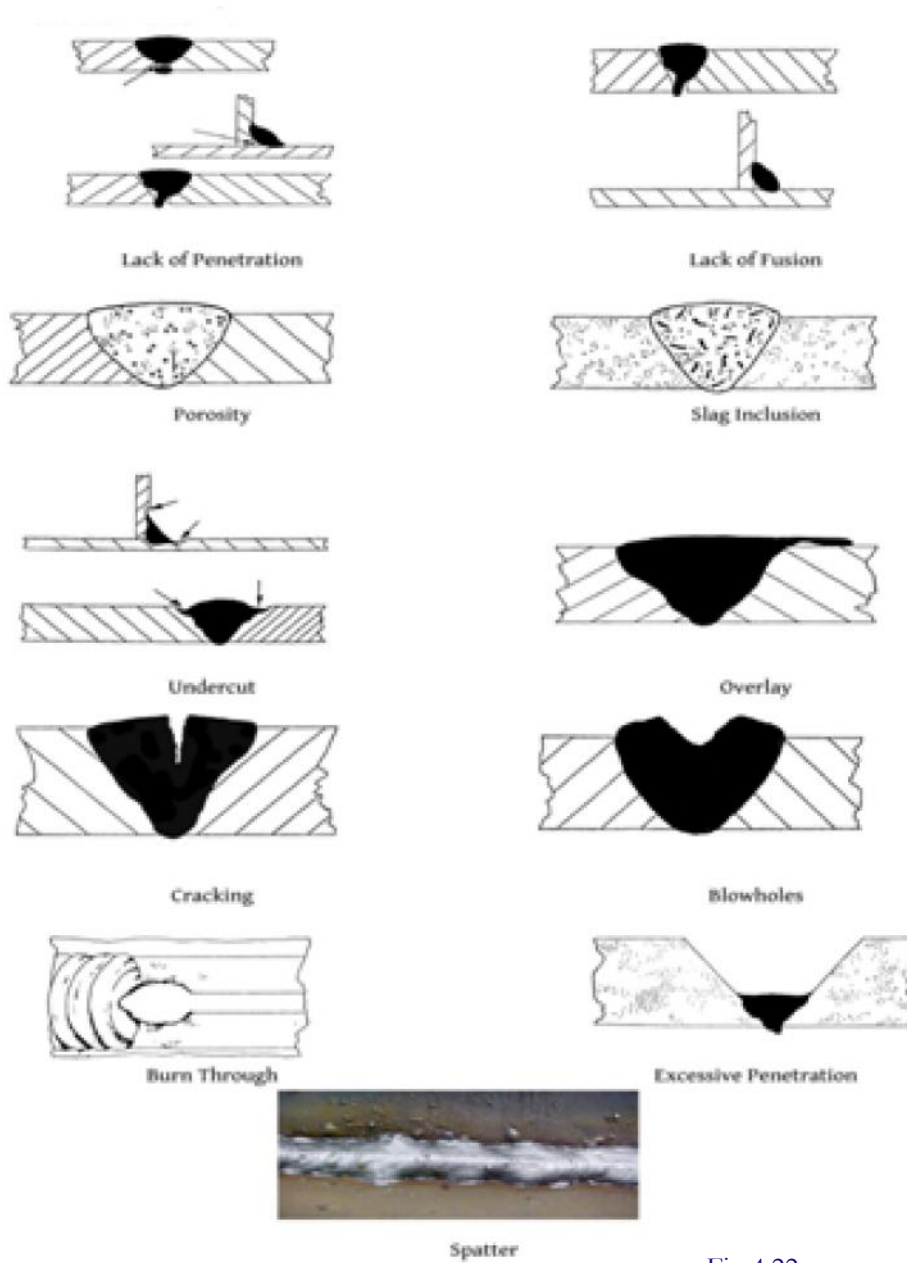


Fig 4.22

## WELDING SYMBOLS

Designation	Illustration	Symbol
(a) Single-V butt/groove weld		
(b) Square butt/groove weld		
(c) Single bevel butt/groove weld		
(d) Single-UJ butt/groove weld		
(e) Single-J butt/groove weld		
(f) Butt weld between plates with raised edges (ISO) Edge weld on a flanged groove joint (AWS)		
(g) Single-V butt weld with broad root face		
(h) Single bevel butt weld with broad root face		

Fig 4.23

WELDING SYMBOLS

## DETAILING OF PRACTICALS

### Hands on experience on Shielded Metal Arc Welding (SMAW).

Preparation of the base plate

- Prepare 2 pieces of 100 mm X 50mm X6 mm metal flat.
- Bevel the each pieces as shown in figure.
- For accurate welding tack a piece of metal at both end of the work.
- Place the work on a flat surface.
- Clamp the earth cable on the work piece.
- Fill the V groove through welding.
- Remove the tack welded pieces from both sides and filed.
- Remove the slag spatters by using chipping hammer.

- Clean the weld area by wire brush.

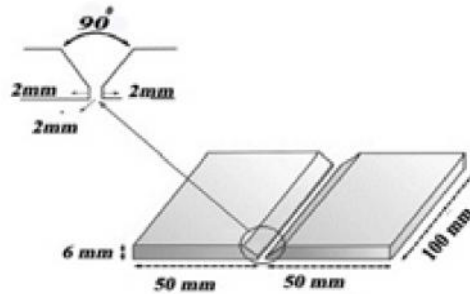


Fig 4.24

- **Identification of welding defects such as undercut, porosity, spatter, arc strike, excessive penetration, cracking, blow holes.**

Facilitator supply the defect numbered welded joint and asked students to identify the defects.

### Assessment Activities

- Assignment
- Flow chart
- Seminar
- Group discussion

### PORTFOLIO

- Chart preparation and seminar on different types of arc welding processes
- Practical Activity log on vertical welding in butt joint
- Practical Activity log on preparation of 'v' groove in work piece
- Chart preparation and seminar on different weld defects

### TE Questions

- 1 explain Tungsten inert gas welding process with a neat sketch
- 2 briefly explain any three weld defects
- 3 list the advantages and disadvantages of submerged arc welding

## UNIT - 6

### NON - DESTRUCTIVE TESTING

As a part of inspection and certification a lot of tests are done on weld joints. These tests include destructive and non-destructive tests. The different types of non-destructive testing such as visual inspection, liquid penetration test, magnetic particle test, radiographic test and ultrasonic test are explained in detail in this unit.

#### Detailing of the Concepts

##### 4.6.1 Weld Testing

Methods of weld testing and analysis are used to assure the quality and correctness of the weld after it is completed. This term generally refers to testing and analysis focused on the quality and strength of the weld, but may refer to technological actions to check for the presence, position and extent of welds. These are divided into destructive and non-destructive methods.

##### 4.6.2 Types of Non Destructive Testing

Common Non Destructive Tests are Visual Testing (VT), Penetrant Testing (PT), Magnetic-particle Testing (MT), Ultrasonic Testing (UT) and Radiographic Testing (RT)

##### 4.6.2.1 Visual Testing (VT)

Visual inspection is one of the most common and most powerful means of non-destructive testing. Visual testing requires adequate illumination of the test surface and proper eye-sight of the tester. To be most effective visual inspection does however, merit special attention because it requires training (knowledge of product and process, anticipated service conditions, acceptance criteria, record keeping, for example) and it has its own range of equipment and instrumentation. It is also a fact that all defects found by other NDT methods ultimately must be substantiated by visual inspection. VT can be classified as Direct visual testing, Remote visual testing and Translucent visual testing. The most common NDT methods MT and PT are indeed simply scientific ways of enhancing the indication to make it more visible. Often the equipment needed is simple for internal inspection, light lens systems such as bore scopes allow remote surfaces to be examined.

##### 4.6.2.2 Penetrant Testing (PT)

Liquid penetrant (PT) also referred as dye penetrant is an inexpensive Non-destructive testing technique which can be performed by qualified certified inspectors.

(PT) is used to detect casting, forging and welding surface defects such as hairline cracks, surface porosity, leaks in new products, and fatigue crack on in-service components.

DPT is based upon capillary action, where surface tension fluid low penetrates into clean and dry surface-breaking discontinuities. Penetrant may be applied to the test component by dipping, spraying, or brushing. After adequate penetration time has been allowed, the excess penetrant is removed and a developer is applied. The developer helps to draw penetrant out of the flaw so that an invisible indication becomes visible to the inspector

#### 4.6.2.2.1 Inspection steps

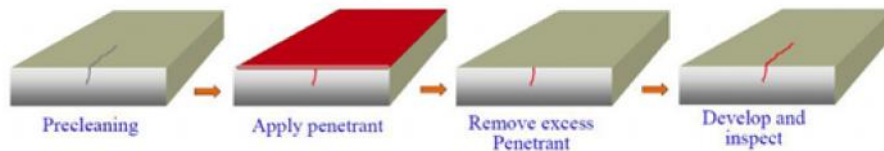


Fig 4.25

The test surface is cleaned to remove any dirt, paint, oil, grease or any loose scale that could either keep penetrant out of a defect, or cause irrelevant or false indications. Cleaning methods may include solvents, alkaline cleaning steps, vapor degreasing, or media blasting. The end goal of this step is a clean surface where any defects present are open to the surface, dry, and free of contamination.

#### **b. Application of Penetrant:**

The penetrant is then applied to the surface of the item being tested. The penetrant is allowed "dwell time" to soak into any flaws (generally 5 to 30 minutes). The dwell time mainly depends upon the penetrant being used, material being tested and the size of flaws sought. As expected, smaller flaws require a longer penetration time.

#### **c. Excess Penetrant Removal:**

The excess penetrant is then removed from the surface. The removal method is controlled by the type of penetrant used. If excess penetrant is not properly removed, once the developer is applied, it may leave a background in the developed area that can mask indications or defects. In addition, this may also produce false indications severely hindering your ability to do a proper inspection. Also, the removal of excessive penetrant is done towards one direction either vertically or horizontally as the case may be.

#### **d. Application of Developer:**

After excess penetrant has been removed, a white developer is applied to the sample. Several developer types are available, including: dry powder, water-suspendable,

and water-soluble. Choice of developer is governed by penetrant compatibility (one can't use water-soluble or -suspendable developer with water-washable penetrant), and by inspection conditions. When using dry powder, the sample must be dried prior to application, while soluble and suspendable developers are applied with the part still wet from the previous step.. Developer should form a semi-transparent, even coating on the surface.

The developer draws penetrant from defects out onto the surface to form a visible indication, commonly known as bleed-out. Any areas that bleed out can indicate the location, orientation and possible types of defects on the surface. Interpreting the results and characterizing defects from the indications found may require some training and/or experience.

#### **e. Inspection:**

The inspector will use visible light with adequate intensity (100 foot-candles or 1100 lux is typical) for visible dye penetrant. Inspection of the test surface should take place after 10- to 30-minute development time, depends of product kind. This time delay allows the blotting action to occur. The inspector may observe the sample for indication formation when using visible dye. It is also good practice to observe indications as they form because the characteristics of the bleed out are a significant part of interpretation characterization of flaws.

#### **f. Post Cleaning:**

The test surface is often cleaned after inspection and recording of defects, especially if post-inspection coating processes are scheduled.

### **4.6.2.3 Magnetic Particle Testing (MT)**

Magnetic Particle Testing is a non-destructive testing (NDT) process for detecting surface and slightly subsurface discontinuities in ferromagnetic materials, and some of their alloys. The process puts a magnetic field into the part. The piece can be magnetized by direct or indirect magnetization. Direct magnetization occurs when the electric current is passed through the test object and a magnetic field is formed in the material. Indirect magnetization occurs when no electric current is passed through the test object, but a magnetic field is applied from an outside source. The magnetic lines of force are perpendicular to the direction of the electric current, which may be either alternating current (AC) or some form of direct current (DC) (rectified AC).

The presence of a surface or subsurface discontinuity in the material allows the magnetic flux to leak, since air cannot support as much magnetic field per unit volume

as metals. Ferrous particles are then applied to the part. The particles may be dry or in a wet suspension. If an area of flux leakage is present, the particles will be attracted to this area. The particles will build up at the area of leakage and form what is known as an indication. The indication can then be evaluated to determine what it is, what may have caused it, and what action should be taken, if any

The first step in a magnetic particle inspection is to magnetize the component that is to be inspected. If any defects on or near the surface are present, the defects will create a leakage field. After the component has been magnetized, iron particles, either in a dry or wet suspended form, are applied to the surface of the magnetized part. The particles will be attracted and cluster at the flux leakage fields, thus forming a visible indication that the inspector can detect.

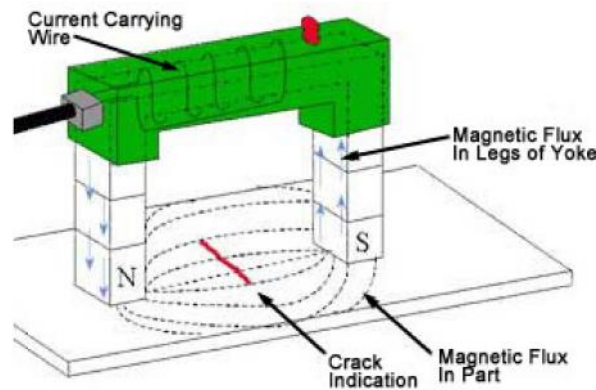


Fig 4.26

Today, most of the equipment used to create the magnetic field used in MPI is based on electromagnetism. That is, using an electrical current to produce the magnetic field. An electromagnetic yoke is a very common piece of equipment that is used to establish a magnetic field. It is basically made by wrapping an electrical coil around a piece of soft ferromagnetic steel. A switch is included in the electrical circuit so that the current and, therefore, the magnetic field can be turned on and off. They can be powered with alternating current from a wall socket or by direct current from a battery pack. This type of magnet generates a very strong magnetic field in a local area where the poles of the magnet touch the part being inspected.

#### 4.6.2.4 Ultrasonic Testing (UT)

The Ultrasonic Test inspection system consists of several functional units, such as the pulser/receiver, transducer, and display devices. A pulser/receiver is an electronic device that can produce high voltage electrical pulses. Driven by the pulser, the transducer generates high frequency ultrasonic energy. The sound energy is introduced

and propagates through the materials in the form of waves. When there is a discontinuity (such as a crack) in the wave path, part of the energy will be reflected back from the flaw surface. The reflected wave signal is transformed into an electrical signal by the transducer and is displayed on a screen. In the applet below, the reflected signal strength is displayed versus the time from signal generation to when an echo was received. Signal travel time can be directly related to the distance that the signal traveled. From the signal, information about the reflector location, size, orientation and other features can sometimes be gained.

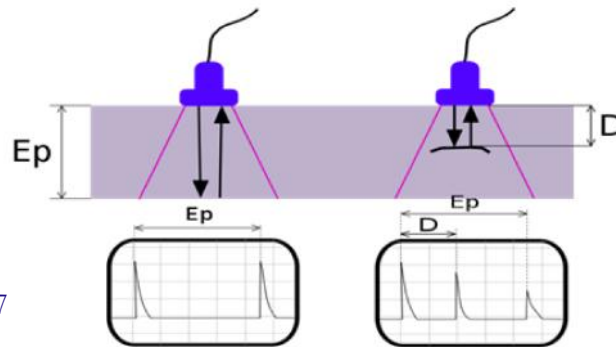


Fig 4.27

#### 4.6.2.5 Radiographic Testing(RT)

Radiographic Testing is a nondestructive testing (NDT) method of inspecting materials for hidden flaws by using the ability of short wavelength electromagnetic radiation (high energy photons) to penetrate various materials. Either an X-ray machine or a radioactive source, like Ir-192, Co-60, or in rarer cases Cs-137 are used in a X-ray computed tomography machine as a source of photons.

The beam of radiation must be directed to the middle of the section under examination and must be normal to the material surface at that point, except in special techniques where known defects are best revealed by a different alignment of the beam. The length of weld under examination for each exposure shall be such that the thickness of the material at the diagnostic extremities, measured in the direction of the incident beam, does not exceed the actual thickness at that point by more than 6%. The specimen to be inspected is placed between the source of radiation and the detecting device, usually the film in a light tight holder or cassette, and the radiation is allowed to penetrate the part for the required length of time to be adequately recorded.

The result is a two-dimensional projection of the part onto the film, producing a latent image of varying densities according to the amount of radiation reaching each area. It is known as a radio graph, as distinct from a photograph produced by light.



Because film is cumulative in its response (the exposure increasing as it absorbs more radiation), relatively weak radiation can be detected by prolonging the exposure until the film can record an image that will be visible after development. The radiograph is examined as a negative, without printing as a positive as in photography. This is because, in printing, some of the detail is always lost and no useful purpose is served.

Before commencing a radiographic examination, it is always advisable to examine the component with one's own eyes, to eliminate any possible external defects. If the surface of a weld is too irregular, it may be desirable to grind it to obtain a smooth finish, but this is likely to be limited to those cases in which the surface irregularities (which will be visible on the radio graph) may make detecting internal defects difficult.

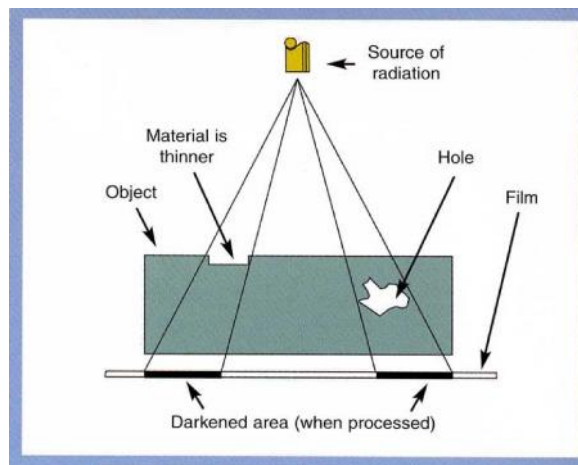


Fig 4.28

## Detailing Of Practicals

- **Hands on experience on Visual Inspection test.**

Facilitator supply the defect numbered welded joint and asked students to identify the defects.

- Hands on experience on liquid penetration test.
- Inspection steps

### a. Pre-cleaning:

The test surface is cleaned to remove any dirt, paint, oil, grease or any loose scale that could either keep penetrant out of a defect, or cause irrelevant or false indications. Cleaning methods may include solvents, alkaline cleaning steps, vapor degreasing, or media blasting. The end goal of this step is a clean surface where any defects present are open to the surface, dry, and free of contamination.

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**f. Post Cleaning:**

The test surface is often cleaned after inspection and recording of defects, especially if post-inspection coating processes are scheduled.

**■ Hands on experience on magnetic particle test.**

This method involves the magnetisation of an area to be examined and the application of ferromagnetic particles to the surface. The particles gather at areas of magnetic flux leakage and form indications characteristic of the type of discontinuity detected.

Maximum sensitivity is achieved when linear discontinuities are oriented perpendicular to the lines of flux.

The AC electromagnetic yoke technique is restricted to the detection of surface breaking discontinuities.

**Assessment Activities**

- Assignment
- Flow chart
- Seminar
- Group discussion

**PORTFOLIO**

- Chart preparation and seminar on non destructive tests
- Practical Activity log on Penetrant Testing

**TE Questions**

- 1 Advantages and disadvantages of magnetic particle testing
- 2 Write the procedure of penetrant testing
- 3 What is the principle of radiographic testing?
- 4 What is the principle of penetrant testing?
- 5 What is the principle of ultra sonic testing?

## LIST OF PRACTICALS

- Dismantling and assembling of Centrifugal pump.
- Dismantling and assembling of Reciprocating pump.
- Dismantling and assembling of Gear pump.
- Dismantling and assembling of Hand Pump.
- Dismantling and assembling of Reciprocating compressor (Single stage and Multistage).
- Dismantling and assembling of Centrifugal compressor.
- Dismantling and assembling of Mechanical Trawl winch.
- Identification of navigation aids commonly used in vessels GPS, Gyroscope, AIS, VHF Radio, RADAR, Ultra sonic devices (Fadho meter, SONAR, Fish finder), Magnetic compass and Gyro compass.
- Identification of Life raft, Life bouy, Life Jacket and Life Boat.
- Hands on experience on Shielded Metal Arc Welding (SMAW).
- Identification of welding defects such as undercut, porosity, spatter, arc strike, excessive penetration, cracking, blow holes
- Hands on experience on Visual Inspection test.
- Hands on experience on liquid penetration test.
- Hands on experience on magnetic particle test
- Hands on experience on radiographic film inspection.
- Hands on experience on ultra sonic test.

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