# MECHANIC MOTOR VEHICLE

## NSQF LEVEL - 4

## 1st Year

## TRADE THEORY

**SECTOR:** AUTOMOTIVE

**(As per revised syllabus July 2022 - 1200 Hrs)**



Directorate General of Training

**DIRECTORATE GENERAL OF TRAINING**
**MINISTRY OF SKILL DEVELOPMENT & ENTREPRENEURSHIP**
**GOVERNMENT OF INDIA**

**NATIONAL INSTRUCTIONAL MEDIA INSTITUTE, CHENNAI**

**Post Box No. 3142, CTI Campus, Guindy, Chennai - 600 032**

**Sector : Automotive**

**Duration : 2 Years**

**Trade : Mechanic Motor Vehicle - 1st Year - Trade Theory - NSQF Level 4 - (Revised - 2022)**

**Developed & Published by**

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# FOREWORD

The Government of India has set an ambitious target of imparting skills to 30 crores people, one out of every four Indians, by 2020 to help them secure jobs as part of the National Skills Development Policy. Industrial Training Institutes (ITIs) play a vital role in this process especially in terms of providing skilled manpower. Keeping this in mind, and for providing the current industry relevant skill training to Trainees, ITI syllabus has been recently updated with the help of comprising various stakeholder's viz. Industries, Entrepreneurs, Academicians and representatives from ITIs.

The National Instructional Media Institute (NIMI), Chennai has now come up with instructional material to suit the revised curriculum for **Mechanic Motor Vehicle - 1st Year - Trade Theory - NSQF Level - 4 (Revised 2022)** in **Automotive Sector under Annual Pattern.** The NSQF Level - 4 (Revised 2022). Trade Practical will help the trainees to get an international equivalency standard where their skill proficiency and competency will be duly recognized across the globe and this will also increase the scope of recognition of prior learning. NSQF Level - 4 (Revised 2022) trainees will also get the opportunities to promote life long learning and skill development. I have no doubt that with NSQF Level - 4 (Revised 2022) the trainers and trainees of ITIs, and all stakeholders will derive maximum benefits from these IMPs and that NIMI's effort will go a long way in improving the quality of Vocational training in the country.

The Executive Director & Staff of NIMI and members of Media Development Committee deserve appreciation for their contribution in bringing out this publication.

Jai Hind

Addl.Secretary/Director General (Training)
Ministry of Skill Development & Entrepreneurship,
Government of India.

New Delhi - 110 001

# PREFACE

The National Instructional Media Institute (NIMI) was established in 1986 at Chennai by the then Directorate General of Employment and Training (D.G.E & T), Ministry of Labour and Employment, (now under Directorate General of Training, Ministry of Skill Development and Entrepreneurship) Government of India, with technical assistance from the Govt. of the Federal Republic of Germany. The prime objective of this institute is to develop and provide instructional materials for various trades as per the prescribed syllabi (NSQF Level 5) under the Craftsmen and Apprenticeship Training Schemes.

The instructional materials are created keeping in mind, the main objective of Vocational Training under NCVT/NAC in India, which is to help an individual to master skills to do a job. The instructional materials are generated in the form of Instructional Media Packages (IMPs). An IMP consists of Theory book, Practical book, Test and Assignment book, Instructor Guide, Audio Visual Aid (Wall charts and Transparencies) and other support materials.

The trade practical book consists of a series of exercises to be completed by the trainees in the workshop. These exercises are designed to ensure that all the skills in the prescribed syllabus are covered. The trade theory book provides related theoretical knowledge required to enable the trainee to do a job. The test and assignments will enable the instructor to give assignments for the evaluation of the performance of a trainee. The wall charts and transparencies are unique, as they not only help the instructor to effectively present a topic but also help him to assess the trainee's understanding. The instructor guide enables the instructor to plan his schedule of instruction, plan the raw material requirements, day to day lessons and demonstrations.

In order to perform the skills in a productive manner instructional videos are embedded in QR code of the exercise in this instructional material so as to integrate the skill learning with the procedural practical steps given in the exercise. The instructional videos will improve the quality of standard of practical training and will motivate the trainees to focus and perform the skill seamlessly.

IMPs also deal with the complex skills required to be developed for effective team work. Necessary care has also been taken to include important skill areas of allied trades as prescribed in the syllabus.

The availability of a complete Instructional Media Package in an institute helps both the trainer and management to impart effective training.

The IMPs are the outcome of collective efforts of the staff members of NIMI and the members of the Media Development Committees specially drawn from Public and Private sector industries, various training institutes under the Directorate General of Training (DGT), Government and Private ITIs.

NIMI would like to take this opportunity to convey sincere thanks to the Directors of Employment & Training of various State Governments, Training Departments of Industries both in the Public and Private sectors, Officers of DGT and DGT field institutes, proof readers, individual media developers and coordinators, but for whose active support NIMI would not have been able to bring out this material.

**Chennai - 600 032** **EXECUTIVE DIRECTOR**

# ACKNOWLEDGEMENT

National Instructional Media Institute (NIMI) sincerely acknowledges with thanks for the co-operation and contribution extended by the following Media Developers and their sponsoring organisations to bring out this Instructional Material **(Trade Theory)** for the trade of **Mechanic Motor Vehicle 1st Year - NSQF Level - 4 (Revised 2022)** under **Automotive** Sector for ITIs.

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NIMI records its appreciation for the Data Entry, CAD, DTP operators for their excellent and devoted services in the process of development of this Instructional Material.

NIMI also acknowledges with thanks the invaluable efforts rendered by all other NIMI staff who have contributed towards the development of this Instructional Material.

NIMI is also grateful to everyone who has directly or indirectly helped in developing this Instructional Material.

# INTRODUCTION

**TRADE PRACTICAL**

The trade practical manual is intended to be used in practical workshop. It consists of a series of practical exercises to be completed by the trainees during the 1st Year Course of **Mechanic Motor Vehicle under Automotive Sector.** Trade supplemented and supported by instructions / informations to assist in performing the exercises. These exercises are designed to ensure that all the skills in compliance with NSQF LEVEL - 4 (Revised 2022) syllabus are covered. The manual is divided into Fourteen modules.

| | |
|---|---|
| Module 1 | Workshop Safety Practice |
| Module 2 | Engineering Measurement |
| Module 3 | Basic Workshop Practice |
| Module 4 | Basic Electrical and Electronics |
| Module 5 | Hydraulic and Pneumatic |
| Module 6 | Classification of Vehicles and Engine |
| Module 7 | Engine Components |
| Module 8 | Cooling and Lubrication System |
| Module 9 | Intake and Exhaust System |
| Module 10 | Fuel System |
| Module 11 | Engine Performance Testing |
| Module 12 | Emission Control System |
| Module 13 | Charging and Starting System |
| Module 14 | Trouble shooting |

The skill training in the shop floor is planned through a series of practical exercises centered around some practical project. However, there are few instances where the individual exercise does not form a part of project.

While developing the practical manual, a sincere effort was made to prepare each exercise which will be easy to understand and carry out even by below average trainee. However the development team accept that there is a scope for further improvement. NIMI looks forward to the suggestions from the experienced training faculty for improving the manual.

**TRADE THEORY**

The manual of trade theory consists of theoretical information for the Course of the **Mechanic Motor Vehicle** Trade. The contents are sequenced according to the practical exercise contained in NSQF LEVEL - 4 (Revised 2022) syllabus on Trade Practical. Attempt has been made to relate the theoretical aspects with the skill covered in each exercise to the extent possible. This correlation is maintained to help the trainees to develop the perceptional capabilities for performing the skills.

The trade theory has to be taught and learnt along with the corresponding exercise contained in the manual on trade practical. The indications about the corresponding practical exercises are given in every sheet of this manual.

It will be preferable to teach/learn trade theory connected to each exercise at least one class before performing the related skills in the shop floor. The trade theory is to be treated as an integrated part of each exercise.

The material is not for the purpose of self-learning and should be considered as supplementary to class room instruction.

## CONTENTS

# LEARNING / ASSESSABLE OUTCOME

On completion of this book you shall be able to

| S.No | Learning Outcome | Ref. Ex.No |
|---|---|---|
| 1 | Check & perform Measuring & marking by using various Measuring & Marking tools (Vernier Calipers, Micrometer, Telescope gauges, Dial bore gauges, Dial indicators, straightedge, feeler gauge, thread pitch gauge, vacuum gauge, tyre pressure gauge.) following safety precautions | 1.1.01-04 to 1.2.05-11 1.2.12-16 |
| 2 | Plan & perform basic fastening & fitting operation by using correct hand tools, Machine tools & equipments. | 1.3.17-19 |
| 3 | Test various electrical/ electronic components using proper measuring instruments and compare the data using standard parameters. | 1.4.20-24 1.5.25-27 |
| 4 | Check & Interpret Vehicle Specification data & VIN and Select & operate various Service Station Equipments. | 1.6.28-36 |
| 5 | Dismantle & assemble of Engine from vehicle (LMV/HMV) along with other accessories. | 1.6.28-36 |
| 6 | Overhaul Engine and check functionality. | 1.7.37-55 |
| 7 | Trace, Test & Repair Cooling and Lubrication System of engine. | 1.8.56-62 |
| 8 | Trace & Test Intake and Exhaust system of engine. | 1.9.63-66 |
| 9 | Service Fuel System and check proper functionality. | 1.10.67-70 |
| 10 | Test Engine Performance and set idling speed. | 1.11.71-76 |
| 11 | Monitor emission of vehicle and execute different operation to obtain optimum pollution as per emission norms. | 1.12.77-80 |
| 12 | Carryout overhauling of Alternator and Starter Motor. | 1.13.81 to 1.13.82 |
| 13 | Diagnose & rectify the defects in LMV/HMV to ensure functionality of vehicle. | 1.14.83 |

## SYLLABUS

| Duration | Reference Learning Outcome | Professional Skills (Trade Practical) With Indicative Hours | Professional Knowledge (Trade Theory) |
|---|---|---|---|
| Professional Skill 115 Hrs;<br>Professional Knowledge 30 Hrs | Check & perform Measuring & marking by using various Measuring & Marking tools (Vernier Calipers, Micrometer, Telescope gauges, Dial bore gauges, Dial indicators, straightedge, feeler gauge, thread pitch gauge, vacuum gauge, tire pressure gauge.) following safety precautions | 1 Familiarisation with institute, Job opportunities in the automobile sector, Machinery used in Trade. Types of work done by the students in the shop floor. (10 Hrs)<br>2 Importance of maintenance and cleanliness of Workshop. (10 Hrs)<br>3 Practice operation of different workshop equipment. (05 Hrs)<br>4 Demonstrate Energy saving Tips of ITI electricity Usage. (05 Hrs) | **Admission & introduction to the trade**<br>Introduction to the Course duration, course content, study of the syllabus. General rule pertaining to the Institute, facilities available- Hostel, Recreation, Medical and Library working hours and time table<br>**Occupational Safety & Health**<br>Importance of Safety and general Precautions to be observed in the shop. Basic first aid, safety signs - for Danger, Warning, caution & personal safety message. Safe handling of Fuel Spillage, Fire extinguishers used for different types of fire. Safe disposal of toxic dust, safe handling and Periodic testing of lifting equipment, Authorization of Moving &road testing vehicles. Electrical safety tips.<br>**Introduction to road safety and Automotive emissions**.(08 hrs) |
| | | 5 Practice using all marking aids, like steel rule with spring callipers, dividers, scriber, punches, Chisel etc.(15 Hrs)<br>6 Layout a work piece- for line, circle, arcs and circles. (5 Hrs)<br>7 Practice to remove wheel lug nuts with use of an air impact wrench.(15 Hrs)<br>8 Practice on General workshop tools & power tools. (10 Hrs) | **Hand & Power Tools:**<br>Marking scheme, Marking material-chalk, Prussian blue. Cleaning tools- Scraper, wire brush, Emery paper, Description, care and use of Surface plates, steel rule, measuring tape, try square. Callipers-inside and outside. Dividers, surface gauges, scriber, punches-prick punch, centre punch, pin punch, hollow punch, number and letter punch. Chisel-flat, cross-cut. Hammer- ball pein, lump, mallet. Screw drivers-blade screwdriver, Phillips screw driver, Ratchet screwdriver. Allen key, bench vice & C-clamps, Spanners- ring spanner, open end spanner & the combination spanner, universal adjustable open end spanner. Sockets & accessories, Pliers - Combination pliers, multi grip, long nose, flat-nose, Nippers or pincer pliers, Side cutters, Tin snips, Circlips pliers, external circlips pliers. Air impact wrench, air ratchet, wrenches- Torque wrenches, pipe wrenches, car jet washers Pipe flaring & cutting tool, pullers-Gear and bearing. (10 hrs) |
| | | 9 Carryout Measuring practice on Cam height, Camshaft Journal dia, crankshaft journal dia, Valve stem dia, piston diameter, and piston pin dia with outside Micrometers. (5 Hrs)<br>10 Carryout Measuring practice on the height of the rotor of an oil pump from the surface | Systems of measurement, Description, care & use of - Micrometers- Outside and depth micrometer, Micrometer adjustments, Vernier callipers, Telescope gauges, Dial bore gauges, Dial indicators, straightedge, feeler gauge, thread pitch gauge, vacuum gauge, tire pressure gauge. (12 hrs) |

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| | | of the housing or any other auto component measurement with depth micrometer. (5 Hrs)<br>11 Carryout Measuring practice on valve spring free length. (5 Hrs)<br>12 Carryout Measuring practice on cylinder bore for taper and out-of-round with Dial bore gauges.(5 Hrs)<br>13 Perform Measuring practice to measure wear on crankshaft end play, crankshaft run out, and valve guide with dial indicator. (5 Hrs)<br>14 Perform Measuring practice to check the flatness of the cylinder head is warped or twisted with straightedge is used with a feeler gauge. (5 Hrs)<br>15 Perform Measuring practice to check the end gap of a piston ring, piston-to-cylinder wall clearance with feeler gauge. (5 Hrs)<br>16 Practice to check engine manifold vacuum with vacuum gauge. (5 Hrs) | |
| Professional Skill 50 Hrs;<br>Professional Knowledge 08 Hrs | Plan & perform basic fastening & fitting operation by using correct hand tools, Machine tools & equipments. | 17 Practice on Marking and Drilling clear and Blind Holes, Sharpening of Twist Drills Safety precautions to be observed while using a drilling machine. (20 Hrs)<br>18 Practice on Tapping a Clear and Blind Hole, Selection of tape drill Size, use of Lubrication, Use of stud extractor. (20 Hrs)<br>19 Practice Cutting Threads on a Bolt/ Stud. Adjustment of two piece Die, Reaming a hole/ Bush to suit the given pin/ shaft, scraping a given machined surface. (10 Hrs) | Drilling machine - Description and study of Bench type Drilling machine, Portable electrical Drilling machine, drill holding devices, Work Holding devices, Drill bits.<br>Taps and Dies: Hand Taps and wrenches, Calculation of Tap drill sizes for metric and inch taps. Different type of Die and Die stock. Screw extractors. Hand Reamers - Different Type of hand reamers, Drill size for reaming, Lapping, Lapping abrasives, type of Laps. (08 hrs) |
| Professional Skill 140 Hrs;<br>Professional Knowledge 30 Hrs | Test various electrical/ electronic components using proper measuring instruments and compare the data using standard parameters. | 20 Practice in joining wires using soldering Iron, Construction of simple electrical circuits, measuring of current, voltage and resistance using digital multimeter, practice continuity test for fuses, jumper wires, fusible links, and circuit breakers. (40 Hrs) | Basic electricity, Electricity principles, Ground connections, Ohm's law, Voltage, Current, Resistance, Power, Energy. Voltmeter, ammeter, Ohmmeter Mulitmeter, Conductors & insulators, Wires, Shielding, Length vs. resistance, Resistor ratings (07 hrs) |
| | | 21 Diagnose series, parallel, series-parallel circuits using Ohm's law, Check electrical circuit with a test lamp, perform voltage drop test in circuits using multimeter, measure current flow using multimeter / ammeter, use of service manual wiring diagram for troubleshooting. (20 Hrs) | Fuses & circuit breakers, Ballast resistor, Stripping wire insulation, cable colour codes and sizes, Resistors in Series circuits , Parallel circuits and Series-parallel circuits, Electrostatic effects, Capacitors and its applications, Capacitors in series and parallel. (07 hrs) |

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| | | 22 Carryout Cleaning and topping up of a lead acidbattery, testing battery with hydrometer. (15 Hrs)<br>23 Connect battery to a charger for battery charging, Inspecting & testing a battery after charging, Measure and Diagnose the cause(s) of excessive Key-off battery drain (parasitic draw) and do corrective action. Testing of relay and solenoids and its circuit. (20 Hrs).<br>24 Test diode for functionality. (05 Hrs) | Description of Chemical effects, Batteries & cells, Lead acid batteries & Sealed Maintenance Free (SMF) batteries, Magnetic effects, Heating effects, Thermo-electric energy, Thermisters, Thermo couples, Electrochemical energy, Photo-voltaic energy, Piezo-electric energy, Electromagnetic induction, Relays, Solenoids, Primary & Secondary windings, Transformers, stator and rotor coils.<br>Basic electronics: Description of Semi conductors, Solid state devices- Diodes, Transistors, (08 hrs) |
| | | 25 Identify Hydraulic and pneumatic components used in vehicle. (20 Hrs)<br>26 Trace hydraulic circuit on hydraulic jack, hydraulic power steering, and Brake circuit. (15 Hrs)<br>27 Identify components in Air brake systems. (05 Hrs) | Introduction to Hydraulics & Pneumatics: - Definition of Pascal law, pressure, Force, viscosity. Description, symbols and application in automobile of Gear pump-Internal & External,<br>single acting, double acting & Double ended cylinder; Pressure relief valve, Non return valve, Flow control valve used in automobile.<br>Pneumatic Symbols, Description and function of air Reciprocating Compressor. Function of Air service unit (FRL-Filter, Regulator & Lubricator). (08 hrs) |
| Professional Skill 25 Hrs;<br>Professional Knowledge 06 Hrs | Check & Interpret Vehicle Specification data & VIN and Select & operate various Service Station Equipments. | 28 Carryout Identification of different type of Vehicle. (10 Hrs)<br>29 Perform Demonstration of vehicle specification data (10 Hrs)<br>30 Perform Identification of vehicle information Number (VIN). Demonstration of Garage, Service station equipments.- Vehicle hoists - Two post and four post hoist, Engine hoists, Jacks, Stands. (05 Hrs) | Definition: - Classification of vehicles on the basis of load as per central motor vehicle rule, wheels, final drive, and fuel used, axles, position of engine and steering transmission, body and load. Brief description and uses of Vehicle hoists - Two post and four post hoist, Engine hoists, Jacks, Stands.(06 hrs) |
| Professional Skill 50 Hrs;<br>Professional Knowledge 10 Hrs | Dismantle & assemble of Engine from vehicle (LMV/ HMV) along with other accessories. | 31 Identify parts in a Diesel engine of LMV/ HMV. (07 Hrs)<br>32 Identify parts in a Petrol engine of LMV/ HMV. (07Hrs)<br>33 Practice on starting and stopping of engines. (07 Hrs)<br>34 Observe and report the reading of Tachometer, Odometer, temp and Fuel gauge under ideal and on load condition. (07 Hrs)<br>35 Practice identification of | Introduction to Engine:<br>Description of internal & external combustion engines, Classification of IC engines, Principle & working of 2&4-stroke diesel engine (Compression ignition Engine (C.I)), Principle of Spark Ignition Engine(SI), differentiate between 2-stroke and 4 stroke, C.I engine and S.I Engine, Direct injection and Indirect injection, Technical terms used in engine, Engine specification. Study of various gauges/instrument on a dash board of a vehicle- Speedometer, Tachometer, Odometer and Fuel gauge, and Indicators such as gearshift position, Seat belt warning |

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| | | difference in components of Petrol and Diesel Engines. (07 Hrs)<br>36 Practice on dismantling engine of LMV/HMV as per procedure. (15 Hrs) | light, Parking-brake-engagement warning light and an Engine-malfunction light.<br>Different type of starting and stopping method of Diesel Engine<br>Procedure for dismantling of diesel engine from a vehicle.<br>**Petrol Engine Basics:**<br>4-stroke spark-ignition engines- Basic 4-stroke principles. Spark-ignition engine components- Basic engine components, Engine cams & camshaft, Engine power transfer, Scavenging, Counter weights, Piston components.<br>Intake & exhaust systems -Electronic fuel injection systems, Exhaust systems.<br>Intake system components, Air cleaners, Carburettor air cleaners, EFI air cleaners, Intake manifolds, Intake air heating.<br>Gasoline Fuel Systems: Description of Gasoline fuel, Gasoline fuel characteristics, Controlling fuel burn, Stoichiometric ratio, Air density, Fuel supply system, Pressure & vacuum.(10 hrs) |
| Professional Skill 175 Hrs;<br>Professional Knowledge 32 Hrs | Overhaul Engine and check functionality. | 37 Overhauling of cylinder head assembly, use of service manual for clearance and other parameters, Practice on removing rocker arm assembly manifolds. (10 Hrs)<br>38 Perform Checking valve seats & valve guide - Replacing the valve if necessary check valve overlap. Testing leaks of valve seats for leakage - Dismantle rocker shaft assembly -clean & check rocker shaft-and levers, for wear and cracks and reassemble. (10 Hrs)<br>39 Check valve springs, tappets, push rods, tappet screws and valve stem cap. (10 Hrs)<br>40 Reassemble valve parts in sequence, refit cylinder head and manifold & rocker arm assembly, adjustable valve clearances, starting engine after adjustments. (10 Hrs) | Engine Components: Description and Constructional feature of Cylinder head, Importance of Cylinder head design, Type of Petrol and Diesel combustion chambers, Effect on size of Intake & exhaust passages, Head gaskets. Importance of Turbulence<br>Valves & Valve Trains- Description and Function of Engine Valves, different types, materials, Type of valve operating mechanism, Importance of Valve seats, and Valve seats inserts in cylinder heads, Valve stem oil seals, size of Intake valves, Valve trains, Valve- timing diagram, concept of Variable valve timing. Description of Camshafts &drives ,Description of Overhead camshaft, importance of Cam lobes, Timing belts & chains, Timing belts & tensioners. (08 hrs) |
| | | 41 Practice Overhauling piston and connecting rod Assembly. Use of service manual for clearance and other parameters(5 Hrs)<br>42 Practice on removing oil sump and oil pump - clean the sump. Practice on removing the big | Description & functions of different types of pistons, piston rings and piston pins and materials. Used recommended clearances for the rings and its necessity precautions while fitting rings, common troubles and remedy. Compression ratio. |

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| | | end bearing, connecting rod with the piston. (5 Hrs)<br>43 Practice on removing the piston rings; Dismantle the piston and connecting rod. Check the side clearance of piston rings in the piston groove & lands for wear. Check piston skirt and crown for damage and scuffing, clean oil holes. (5 Hrs)<br>44 Measure -the piston ring close gap in the cylinder, clearance between the piston and the liner, clearance between crank pin and the connecting rod big end bearing. (5 Hrs)<br>45 Check connecting rod for bend and twist. Assemble the piston and connecting rod assembly. (5 Hrs)<br>46. Carryout Overhauling of crankshaft by referring service manual for clearance and other parameters. (15 Hrs)<br>47 Practice on removing damper pulley, timing gear/timing chain, flywheel, main bearing caps, bearing shells and crankshaft from engine checking oil retainer and thrust surfaces for wear.(15 Hrs)<br>48 Measure crank shaft journal for wear, taper and ovality, Checking crankshaft for fillet radii, bend & twist. (10 Hrs)<br>49 Perform Checking of flywheel and mounting flanges, spigot, bearing. (10 Hrs) | Description & function of connecting rod, importance of big- end split obliquely, Materials used for connecting rods big end & main bearings. Shells piston pins and locking methods of piston pins. (04 hrs)<br>Description and function of Crank shaft, camshaft, Engine bearings- classification and location - materials used & composition of bearing materials- Shell bearing and their advantages- special bearings material for diesel engine application bearing failure & its causes-care & maintenance. Crank-shaft balancing, Firing order of the engine. (08 hrs) |
| | | 50 Check vibration damper for defects, Practice on removing cam shaft from engine block, Check for bend & twist of camshaft. (10 Hrs)<br>51 Perform Inspection of cam lobe, camshaft journals and bearings and measure cam lobe lift. (10 Hrs)<br>52 Practice Fixing bearing inserts in cylinder block & cap check nip and spread clearance & oil holes & locating lugs fix crank shaft on block-torque bolts - check end play remove shaft - check seating, repeat similarly for connecting rod and Check seating and refit. (15 Hrs) | Description and function of the fly wheel and vibration damper. Crank case & oil pump, gears timing mark, Chain sprockets, chain tensioner etc. Function of clutch & coupling units attached to flywheel. (08 hrs) |
| | | 53 Practice Cleaning and Checking of cylinder blocks. (10 Hrs)<br>54 Check cylinder blocks Surface flatness visually. (05 Hrs)<br>55 Measure cylinder bore for taper & ovality, clean oil gallery passage and oil pipe line, Bore - descale water passages. (10 Hrs) | Description of Cylinder block, Cylinder block construction, and Different type of Cylinder sleeves (liner). (04 hrs) |

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| Professional Skill 50 Hrs;<br>Professional Knowledge 08 Hrs | Trace, Test & Repair Cooling and Lubrication System of engine. | 56 Practice on Checking &Top up coolant, (5 Hrs)<br>57 Drain & refill coolant, Checking / replacing a coolant hose, testing cooling system pressure, Practice on Removing & replacing radiator/ thermostat. (5 Hrs)<br>58 Inspect the radiator pressure cap, testing of thermostat. (5 Hrs)<br>59 Perform Cleaning & reverse flushing. (5 Hrs)<br>60 Carryout overhauling water pump and refitting. (10 Hrs)<br>61 Practice on Checking engine oil, Drainingengine oil, Replacing oil filter, Refilling engine oil. (10 Hrs)<br>62 Carryout Overhauling of oil pump, oil coolers, air cleaners and air filters and adjust oil pressure relief valves, repairs to oil flow pipe lines and unions if necessary. (10 Hrs) | Need for Cooling systems, Heat transfer method, Boiling point & pressure, Centrifugal force, Vehicle coolant properties and recommended change of interval, Different type of cooling systems, Basic cooling system components- Radiator, Coolant hoses, Water pump, Cooling system thermostat, Cooling fans, Temperature indicators, Radiator pressure cap, Recovery system, Thermo-switch.<br>Need for lubrication system, Functions of oil, Viscosity and its grade as per SAE , Oil additives, Synthetic oils, The lubrication system, Splash system, Pressure system, Corrosion/noise reduction in the lubrication system. Lubrication system components - Description and function of Sump, Oil collection pan, Oil tank, Pickup tube, different type of Oil pump & Oil filters Oil pressure relief valve, Spurt holes & galleries, Oil indicators, Oil cooler. (08 hrs) |
| Professional Skill 40 Hrs;<br>Professional Knowledge 08 Hrs | Trace & Test Intake and Exhaust system of engine. | 63 Carryout Dismantling & assembling of turbocharger check for axial clearance as per service manual. (10 Hrs)<br>64 Check Exhaust system for rubber mounting for damage, deterioration and out of position; for leakage, loose connection, dent and damage. (10 Hrs)<br>65 Practice on Exhaust manifold removal and installation. (10 Hrs)<br>66 Practice on Catalytic converter removal and installation. (10 Hrs) | Intake system components- Description and function of Air cleaners, Different type air cleaner, Description of Intake manifolds and material,<br>Exhaust system components- Description and function of Exhaust manifold, Exhaust pipe, Extractors, Mufflers- Reactive, absorptive, Combination., Catalytic converters, Flexible connections, Ceramic coatings, Back-pressure, Electronic mufflers.(08 hrs) |
| Professional Skill 50 Hrs;<br>Professional Knowledge 08 Hrs | Service Fuel System and check proper functionality. | 67 Practice Testing of MPFI components and replacement if necessary. (10 Hrs)<br>68 Check delivery from fuel Pump. Replacing a fuel filter. (10 Hrs)<br>69 Bleed air from the fuel lines, Servicingprimary & secondary filters. (15 Hrs)<br>70 Remove a fuel injection pump from an engine-refit the pump to the engine re- set timing - fill lubricating-oil start and adjust slow speed of the engine. (15 Hrs) | Diesel Fuel Systems- Description and function of Diesel fuel injection, fuel characteristics, concept of Quiet diesel technology & Clean diesel technology.<br>Diesel fuel system components - Description and function of Diesel tanks & lines, Diesel fuel filters, water separator, Lift pump, Plunger pump, Priming pump,<br>Electronic Diesel control- Electronic Diesel control systems, Common Rail Diesel Injection (CRDI) system, Sensors, actuators and ECU (Electronic Control Unit) used in Diesel Engines.(08 hrs) |

| | | | |
|---|---|---|---|
| Professional Skill 50 Hrs;<br>Professional Knowledge 08 Hrs | Test Engine Performance and set idling speed. | 71 Reassemble all parts of engine in correct Sequence and torque all bolts and nuts as per workshop manual of the engine. (10 Hrs)<br>72 Perform Engine component assembly procedures- Testing cylinder compression, checking idle speed, Removing & replacing a cam belt, Inspecting & adjusting an engine drive belt, Replacing an engine drive belt. (15 Hrs)<br>73 Practice on Start engine adjust idling speed and damping device in pneumatic governor and venture control unit checking (5 Hrs)<br>74 Test Performance of engine with off load adjusting timings. (5 Hrs)<br>75 Start engine- adjusting idle speed of the engine fitted with mechanical governor checking- high speed operation of the engine. (5 Hrs)<br>76 Check performance for missing cylinder by isolating defective injectors and test-dismantle and replace defective parts and reassemble and refit back to the engine (10 Hrs) | Engine assembly procedure with aid of special tools and gauges used for engine assembling.(08 hrs)<br>Emission Control:- Vehicle emissions<br>Standards- Euro and Bharat II, III, IV, V Sources of emission, Combustion, Combustion chamber design. Types of emissions: Characteristics and Effect of Hydrocarbons, Hydrocarbons in exhaust gases, Oxides of nitrogen, Particulates, Carbon monoxide, Carbon dioxide, Sulphur content in fuels Description of Evaporation emission control, Catalytic conversion, Closed loop, Crankcase emission control, Exhaust gas recirculation (EGR) valve, , Controlling air-fuel ratios, Charcoal storage devices, Diesel particulate filter (DPF). Selective Catalytic Reduction (SCR), EGR VS SCR (04 hrs) |
| Professional Skill 35 Hrs;<br>Professional Knowledge 04 Hrs | Monitor emission of vehicle and execute different operation to obtain optimum pollution as per emission norms. | 77 Practice Monitoring emissions procedures by use of Engine gas analyser or Diesel smoke meter. (10 Hrs)<br>78 Checking & cleaning a Positive crank case ventilation (PCV) valve. Obtaining & interpreting scan tool data. (10 Hrs)<br>79 Perform Inspection of EVAP canister purge system by use of scan Tool. (5 Hrs)<br>80 Perform EGR /SCR Valve Removal and installation for inspection. (10Hrs) | Description .of charging circuit operation of alternators, regulator unit, ignition warning lamp- troubles and remedy in charging system. |
| Professional Skill 30 Hrs;<br>Professional Knowledge 04 Hrs | Carryout overhauling of Alternator and Starter Motor. | 81 Practice on removing alternator from vehicle dismantling, cleaning checking for defects, assembling and testing for motoring action of alternator & fitting to vehicles. (15 Hrs)<br>82 Practice on removing starter motor Vehicle and overhauling the starter motor, testing of starter motor (15 Hrs) | Description of starter motor circuit,<br>Constructional details of starter motor solenoid switches, common troubles and remedy in starter circuit. (04 hrs) |
| Professional Skill 30 Hrs;<br>Professional Knowledge 04 Hrs | Diagnose & rectify the defects in LMV/HMV to ensure functionality of vehicle. | 83 Practice on troubleshooting in LMV/ HMV for Engine Not starting - Mechanical & Electrical causes, High fuel consumption, Engine overheating, Low Power Generation, Excessive oil consumption, Low/High Engine Oil Pressure, Engine Noise. (30 Hrs) | Troubleshooting: Causes and remedy for<br>Engine Not starting - Mechanical &<br>Electrical causes, High fuel consumption, Engine overheating, Low Power Generation, Excessive oil consumption, Low/High Engine Oil Pressure, Engine Noise. (04 hrs) |

# Organization of ITIs and scope of the Mechanic Motor Vehicle

**Objective:** At the end of this lesson you shall be able to
- **state brief introduction about Industrial Training Institutes (ITI).**

**Brief Introduction of Industrial Training Institute (ITIs)**

Industrial Training Institute plays a vital role in economy of the country, especially in terms of providing skilled manpower.

The Directorate General of Training (DGT) comes under **Ministry of Skill Development and Entrepreneurship (MSDE)** offers a range of vocational training trades in different sectors based on economy /labour market. The vocational training programmes are delivered under the aegis of **National Council of Vocational Training (NCVT).** Craftsmen Training scheme (CTS) and Apprenticeship Training Scheme (ATS) are two pioneer programmes of NCVT for Propagator Vocational Training.

They are giving training about 132 trades including Engineering and Non-engineering trades with the duration of 1 or 2 years. The minimum eligibility for admission in ITIs 8th, 10th and 12th pass with respect to the trades and admission process will be held in every year in July.

From 2018 annual pattern was introduced with implemented revised syllabus.

At the end of each year, All India Trade Test (AITT) will be conducted in every July with OMR answer sheet pattern and multiple choice type questions. After passing, National trade certificates (NTC), will be issued by DGT which is authorized and recognized internationally.

After completion of instructional training with 'NTC' certificate, they have to undergo Apprenticeship training (ATS) for one or two year with respect to trades under the Apprentice ACT 1961, in various government and private establishments with stipend. At the end of the Apprenticeship training, All India Apprentice Test will be conducted and apprentice certificate will be issued. They can get job opportunities in private or government establishment in India/Abroad or they can start small scale industries in manufacturing or in service sector with subsidiary government loan.

# Scope of the Mechanic Motor Vehicle

**Objective:** At the end of this lesson you shall be able to
- **importance and scope of the mechanic motor vehicle trade training.**

**Scope of the Mechanic Motor Vehicle training:** Mechanic Motor vehicle trade under craftsmen training scheme (CTS) is one of the most popular trade delivered nation wide through the network of ITI. This trade two year duration.

**Carrier Progress Pathways:** Can join the apprenticeship training in different types of industries and issue National Apprenticeship Certificate (NAC)

Can join Craftsman Instructor Training Scheme (CITS) to become an instructor in ITIs

**Job Opportunities**

- mechanic Motor vehicle can join in central and state government establishments, like railway, airport, marine, military and Automotive industry.
- employment opportunities in overseas.

**Self-employment opportunities**

- Service centre in rural and urban areas.
- Maintenance contractor
- Manufacturer of sub-assembly
- Dealership/agency for Automotive spare parts
- Own repair shop or garage.

**General discipline in the institute:** Always be polite, courteous while in institute

Do not arguments with others, on matters of related to your training or with the office while seeking clarifications

Do not bring bad name to your institute by your improper habitude.

Do not waste your precious time in gossips with your friends and on activities other than training.

Do not be late to the theory practical and other classes.

Do not interfere in other's activities.

Attentive and listen to the lecture carefully during the theory class and practical demonstration given by the instructor.

Give respect to your trainer and all other staffs and co-trainees in your institute.

Be interested in all the training activities.

Do not make noise and play while undergoing training.

Keep the institute premises neat and clean avoid polluting the environment.

Do not take away any material from the institute which does not belong to you.

Always attend the institute well dressed and good physical appearance.

Be regular to attend the training without fail and avoid absent from the theory or practical classes for simple reasons.

Prepare well before writing a test/examination.

Avoid any malpractice during the test/examination.

Write your theory and practical records regularly and submit them on time for correction

Take care of your safety as well as other's safety while doing the practicals.

**Time-table**

Practical and theory class hours are scheduled in advance and working hours as generally 8 hrs included lunch hours

**Course Content in the syllabus**

Engine, cooling, lubrication intake & exhaust, fuel emission, charging and starting systems.

- Identify the various types of tools equipment, raw materials, spares used in mechanic Motor vehicle trade,
- Practice to measuring, fitting, welding, sheet metal works, mechanical and electrical and hydraulic system fault diagnosis and rectification
- Practice to indent and repairing various type of diesel engines,

**Facilities in I.T.I**

Hostel facilities, first aid kid, visiting doctor's and also libraries are available in mandatory of the I.T.I'S

## Occupational health and safety

**Objectives:** At the end of this lesson you shall be able to
- **define safety**
- **state the goal of occupational health and safety**
- **explain need of occupational health and safety**
- **state the occupational hygiene**
- **list types of occupational hazards.**

**Safety:** Safety means freedom or protection from harm, danger, hazard, risk, accident, injury or damage.

**Occupational health and safety**

- Occupational health and safety is concerned with protecting the safety, health and welfare of people engaged in work or employment.
- The goal is to provide a safe work environment and to prevent hazards.
- It may also protect co-workers, family members, employers, customers, suppliers, nearby communities, and other members of the public who are impacted by the workplace environment.
- It involves interactions among many related areas, including occupational medicine, occupational (or industrial) hygiene, public health, and safety engineering, chemistry, and health physics.

**Need of occupational health and safety**

- Health and safety of the employees is an important aspect of a company's smooth and successful functioning.
- It is a decisive factor in organizational effectiveness. It ensures an accident-free industrial environment.
- Proper attention to the safety and welfare of the employees can yield valuable returns.
- Improving employees morale
- Reducing absenteeism
- Enhancing productivity
- Minimizing potential of work-related injuries and illnesses
- Increasing the quality of manufactured products and/or rendered services.

**Occupational (Industrial) Hygiene**

- Occupational hygiene is anticipation, recognition, evaluation and control of work place hazards (or) environmental factors (or) stresses
- This is arising in (or) from the workplace.
- Which may cause sickness, impaired health and well being (or) significant discomfort and inefficiency among workers.

**Anticipation (Identification):** Methods of identification of possible hazards and their effects on health

**Recognition (Acceptance):** Acceptance of ill-effects of the identified hazards

**Evaluation (Measurement & Assessment):** Measuring or calculating the hazard by Instruments, Air sampling and Analysis, comparison with standards and taking judgment whether measured or calculated hazard is more or less than the permissible standard

**Control of Workplace Hazards:** Measures like Engineering and Administrative controls, medical examination, use of Personal Protective Equipment (PPE), education, training and supervision

**Occupational Hazards**

"Source or situation with a potential for harm in terms of injury or ill health, damage to property, damage to the workplace environment, or a combination of these"

**Types of occupational health hazards**

- Physical Hazards
- Chemical Hazards
- Biological Hazards
- Physiological Hazards
- Psychological Hazards
- Mechanical Hazards
- Electrical Hazards
- Ergonomic Hazards.

**1 Physical Hazards**

- Noise
- Heat and cold stress
- Vibration
- Radiation (ionising & Nonionising)
- Illumination etc.,

**2 Chemical Hazards**

- Inflammable
- Explosive
- Toxic
- Corrosive
- Radioactive

**3 Biological Hazards**

- Bacteria
- Virus
- Fungi
- Plant pest
- Infection.

**4 Physiological**

- Old age
- Sex
- Ill health
- Sickness
- Fatigue.

**5 Psychological**

- Wrong attitude
- Smoking
- Alcoholism
- Unskilled
- Poor discipline
  - absenteeism
  - disobedience
  - aggressive behaviours
- Accident proneness etc,
- Emotional disturbances
  - violence
  - bullying
  - sexual harassment

**6 Mechanical**

- Unguarded machinery
- No fencing
- No safety device
- No control device etc.,

**7 Electrical**

- No earthing
- Short circuit
- Current leakage
- Open wire
- No fuse or cut off device etc,

**8 Ergonomic**

- Poor manual handling technique
- Wrong layout of machinery
- Wrong design
- Poor housekeeping
- Awkward position
- Wrong tools etc,

**Safety Slogan**

**A Safety rule breaker, is an accident maker**

# Safety practice

**Objectives:** At the end of this lesson you shall be able to
- **state the causes for accidents in general terms**
- **state the safe attitudes**
- **list out the four basic categories of safety signs.**

**Causes for accidents:** Normally accidents do not just happen. They are caused.

Causes for accidents are many. Some of the important causes are listed below.

- Unawareness of danger
- Disregard for safety
- Negligence
- Lack of understanding of proper safety procedures
- Untidy condition of workplace
- Inadequate light and ventilation
- Improper use of tools
- Unsafe conditions

**Safe attitudes:** People's attitudes govern what they do or fail to do. In most cases where someone is working with unsafe equipment or in an unsafe situation, somebody has allowed that state of affairs to come about by something they have done or failed to do.

Most accidents don't just happen; they are caused by people who (for example) damage equipment or see it is faulty but don't report it, or leave tools and equipment lying about for other people to trip over.

**Responsibilities:** Safety doesn't just happen - it has to be organised and achieved like the work-process of which it forms a part. The law states that both an employer and his employees have a responsibility in this behalf.

**Employer's responsibilities:** The effort a firm puts into planning and organising work, into training people, into engaging skilled and competent workers, maintaining plant and equipment, and checking, inspecting and keeping records- all of this contributes to the safety in the workplace.

The employer will be responsible for the equipment provided, the working conditions, what employees are asked to do, and the training given.

**Employee's responsibilities:** You will be responsible for the way you use the equipment, how you do your job, the use you make of your training, and your general attitude to safety.

A great deal is done by employers and other people to make your working life safer; but always remember you are responsible for your own actions and the effect they have on others. You must not take that responsibility lightly.

**Rules and procedures at work:** What you must do, by law, is often included in the various rules and procedures laid down by your employer. They may be written down, but more often than not, are just the way a firm does things - you will learn these from other workers as you do your job. They may govern the issue and use of tools, protective clothing and equipment, reporting procedures, emergency drills, access to restricted areas, and many other matters. Such rules are essential; they contribute to the efficiency and safety of the job.

**Safety signs:** As you go about your work on a construction site you will see a variety of signs and notices. Some of these will be familiar to you - a 'no smoking' sign for example; others you may not have seen before. It is up to you to learn what they mean - and to take notice of them. They warn of the possible danger, and must not be ignored.

Safety signs fall into four separate categories. These can be recognised by their shape and colour. Sometimes they may be just a symbol; other signs may include letters or figures and provide extra information such as the clearance height of an obstacle or the safe working load of a crane.

The four basic categories of signs are as follows. (Fig 1)

1 Prohibition signs
2 Mandatory signs
3 Warning signs
4 Information signs

**Prohibition signs**

| | |
|---|---|
| **Shape** | Circular. |
| **Colour** | Red border and cross bar. Black symbol on white background. |
| **Meaning** | Shows it must not be done. |
| **Example** | No smoking. |

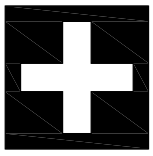
**Mandatory signs**

| | |
|---|---|
| **Shape** | Circular. |
| **Colour** | White symbol on blue background. |
| **Meaning** | Shows what must be done. |
| **Example** | Wear hand protection. |

**Warning signs**


| | |
|---|---|
| **Shape** | Triangular. |
| **Colour** | Yellow background with black border and symbol. |
| **Meaning** | Warns of hazard or danger. |
| **Example** | Caution, risk of electric shock. |

**Information signs**



| | |
|---|---|
| **Shape** | Square or oblong. |
| **Colour** | White symbols on green background. |
| **Meaning** | Indicates or gives information of safety provision. |
| **Example** | First aid point. |

**Prohibition signs (Fig 2)**

Fig 2


**Mandatory signs (Fig 3)**

Fig 3


**Warning signs (Fig 4)**

Fig 4


**Questions about your safety**

Do you know the general safety rules that cover your place of work?

Are you familiar with the safety laws that cover your particular job?

Do you know how to do your work without causing danger to yourself, your workmates and the general public?

Are the plant, machinery and tools that you use really safe? Do you know how to use them safely and keep them in a safe condition?

Do you wear all the right protective clothing, and have you been issued with all the necessary safety equipment?

Have you been given all the necessary safety information about the materials used?

Have you been given training and instruction to enable you to do your job safely?

Do you know who is responsible for safety at your place of work?

Do you know who are the appointed `Safety Representatives'?

- Stop the machine before changing the speed.
- Disengage the automatic feeds before switching off.
- Check the oil level before starting the machine.
- Before starting the machine, move the ram by hand to ensure that the ram or tool-handler does not strike the workpiece or table.
- Never start a machine unless all the safety guards are in position.
- Take measurements only after stopping the machine.
- Use wooden planks over the bed while loading and unloading heavy jobs.
- Do not stop the machine before the finish of the cutting stroke.

**Safety is a concept, understand it.**

**Safety is a habit, cultivate it.**

# Knowledge of personal safety and general precautions observed in the shop

**Objectives:** At the end of this lesson you shall be able to
- **state the is personal protective equipment and its purpose**
- **name the two categories of personal protective equipment**
- **list the most common type of personal protective equipment**
- **list the conditions for selection of personal protective equipment**
- **state the safety precaution in handling diesel machines.**

Scan the QR Code to view the video for the exercise

### Personal Protective Equipment (PPE)

Devices, equipment, clothing are used by the employees, as a last resort, to protect against hazards in the workplace. The primary approach in any safety effort is that the hazard to the workmen should be eliminated or controlled by engineering methods rather than protecting the workmen through the use of personal protective equipment (PPE). Engineering methods could include design change, substitution, ventilation, mechanical handling, automation, etc.

The Factories Act, 1948 and several other labour legislations 1996 have provisions for effective use of appropriate types of PPE.

### Ways to ensure workplace safety and use personal protective equipment (PPE) effectively

- Workers to get up-to-date safety information from the regulatory agencies that workplace safety in their specific area.
- To use all available text resources that may be in work area and for applicable safety information on how to use PPE best.
- When it comes to the most common types of personal protective equipment, like goggles, gloves or bodysuits, these items are much less effective if they are not worn at all times, or whenever a specific danger exists in a work process. Using PPE consistent will help to avoid some common kinds of industrial accidents.
- Personal protective gear is not always enough to protect workers against workplace dangers. Knowing more about the overall context of your work activity can help to fully protect from anything that might threaten health and safety on the job.
- Inspection of gear thoroughly to make sure that it has the standard of quality and adequately protect the user should be continuously carried out.

**Categories of PPEs:** Depending upon the nature of hazard, the PPE is broadly divided into the following two categories:

1 **Non-respiratory:** Those used for protection against injury from outside the body, i.e. for protecting the head, eye, face, hand, arm, foot, leg and other body parts

2 **Respiratory:** Those used for protection from harm due to inhalation of contaminated air.

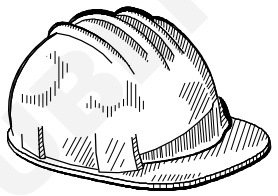
They are to meet the applicable BIS (Bureau of Indian Standards) standards for different types of PPE.

The guidelines on 'Personal Protective Equipment' is issued to facilitate the plant management in maintaining an effective programme with respect to protection of persons against hazards, which cannot be eliminated or controlled by engineering methods listed in table1.

**Table1**

| No. | Title |
|---|---|
| PPE1 | Helmet |
| PPE2 | Safety footwear |
| PPE3 | Respiratory protective equipment |
| PPE4 | Arms and hands protection |
| PPE5 | Eyes and face protection |
| PPE6 | Protective clothing and coverall |
| PPE7 | Ears protection |
| PPE8 | Safety belt and harnesses |

Fig 1



HELMET

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Fig 2

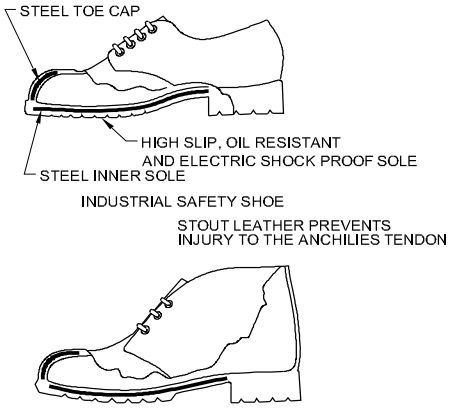


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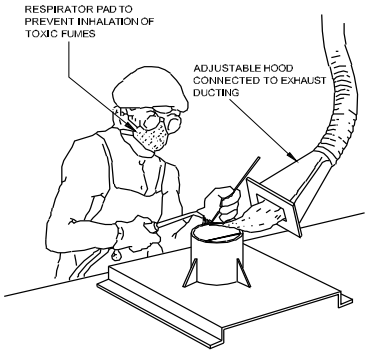
Fig 3

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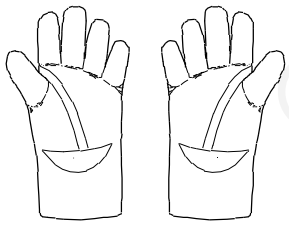
**Common type of personal protective equipments and their uses and hazards are as follows**

| Types of protection | Hazards | PPE to be used |
|---|---|---|
| Head protection (Fig 1) | 1. Falling objects<br>2. Striking against objects<br>3. Spatter | Helmets |
| Foot protection (Fig 2) | 1. Hot spatter<br>2. Falling objects<br>3. Working wet area | Leather leg guards<br>Safety shoes<br>Gum boots |
| Nose (Fig 3) | 1. Dust particles<br>2. Fumes/ gases/ vapours | Nose mask |
| Hand protection (Fig 4) | 1. Heat burn due to direct contact<br>2. Blows sparks moderate heat<br>3. Electric shock | Hand gloves |
| Eye protection (Fig 5, Fig 6) | 1. Flying dust particles<br>2. UV rays, IR rays heat and High amount of visible radiation | Goggles<br>Face shield<br>Hand shield<br>Head shield |
| Face Protection (Fig 6, Fig 7) | 1. Spark generated during Welding, grinding<br>2. Welding spatter striking<br>3. Face protection from UV rays | Face shield<br>Head shield with or without ear muff<br>Helmets with welders screen for welders |
| Ear protection (Fig 7) | 1. High noise level | Ear plug<br>Ear muff |
| Body protection (Fig 8&9) | 1. Hot particles | Leather aprons |

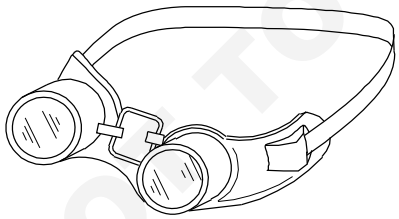
Fig 4



GLOVES

MVN110224

Fig 5



GOGGLES

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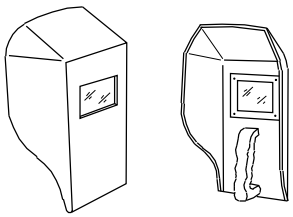
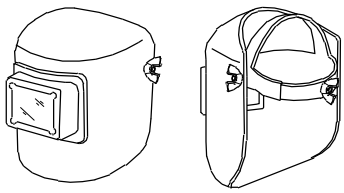
Fig 6



HAND SCREEN

MVN110226

Fig 7



WELDING HELMET

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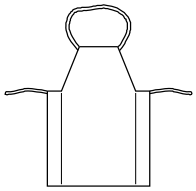
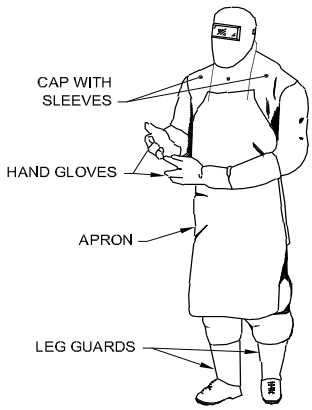
Fig 8



APRON

MVN110228

Fig 9




LEG GUARDS

MVN110229

# Safety practice - fire extinguishers

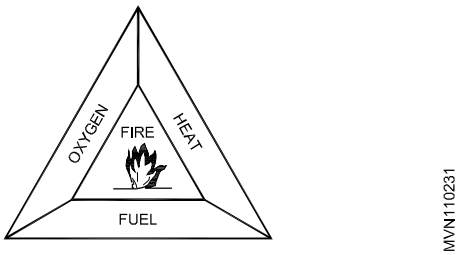
**Objectives:** At the end of this lesson you shall be able to
- **state the effects of a fire break out**
- **state the causes for fire in a workshop**
- **state the conditions required for combustion relevant to fire prevention**
- **state the general precautionary measures to be taken for prevention of fire.**

Scan the QR Code to view the video for the exercise

Fire is the burning of combustible material. It might injure people, and sometimes cause loss of life as well. Hence, every effort must be made to prevent fire.

The following are the three factors that must be present in combination for a fire to continue to burn. (Fig 1)

Fig 1




**Fuel:** Any substance, liquid, solid or gas will burn, if there is oxygen and high enough temperatures.

**Heat:** Every fuel will begin to burn at a certain temperature. It varies and depends on the fuel. Solids and liquids give off vapour when heated, and it is this vapour which ignites. Some liquids do not have to be heated as they give off vapour at normal room temperature say 15°C, *eg.* petrol.

**Oxygen:** Usually exists in sufficient quantity in air to keep a fire burning.

**Extinguishing of fire:** Isolating or removing any of these factors from the combination will extinguish the fire. There are three basic ways of achieving this.

– **Starving** the fire of fuel removes this element.

– **Smothering** - ie. isolate the fire from the supply of oxygen by blanketing it with foam, sand etc.

– **Cooling** - use water to lower the temperature.

**Removing any one of these factors will extinguish the fire.**

**Preventing fires:** The majority of fires begin with small outbreaks which burn unnoticed until they have a secure hold. Most fires could be prevented with more care and by following some simple common sense rules.

Accumulation of combustible refuse (cotton waste soaked with oil, scrap wood, paper, etc.) in odd corners are a fire risk. Refuse should be removed to collection points.

The cause of fire in electrical equipment is misuse or neglect. Loose connections, wrongly rated fuses, over loaded circuits cause overheating which may in turn lead to a fire. Damage to insulation between conductors in cables causes fire.

Clothing and anything else which might catch fire should be kept well away from heaters. Make sure that the heater is shut off at the end of the working day.

Highly flammable liquids and petroleum mixtures (thinner, adhesive solutions, solvents, kerosene, spirit, LPG gas etc.) should be stored in the flammable material storage area.

Blowlamps and torches must not be left burning when they are not in use.

**Extinguishing fires:** Fires are classified into four types in terms of the nature of fuel.

Different types of fire have to be dealt with in different ways and with different extinguishing agents.

An extinguishing agent is the material or substance used to put out the fire, and is usually (but not always) contained in a fire extinguisher with a release mechanism for spraying into the fire.

It is important to know the right type of agent for extinguishing a particular type of fire; using a wrong agent can make things worse. There is no classification for 'electrical fires' as such, since these are only fires in materials where electricity is present.

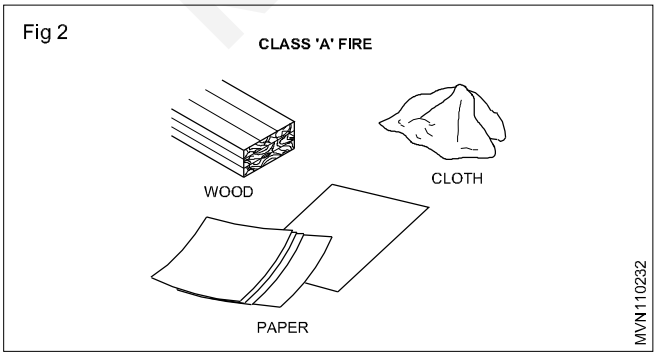
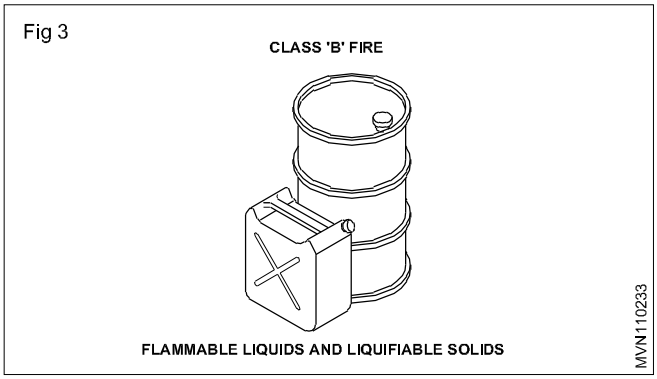
| Fuel | Extinguishing |
|---|---|
| Fig 2   | Most effective ie. cooling with water. Jets of water should be sprayed on the base of the fire and then gradually upwards. |

Fig 3

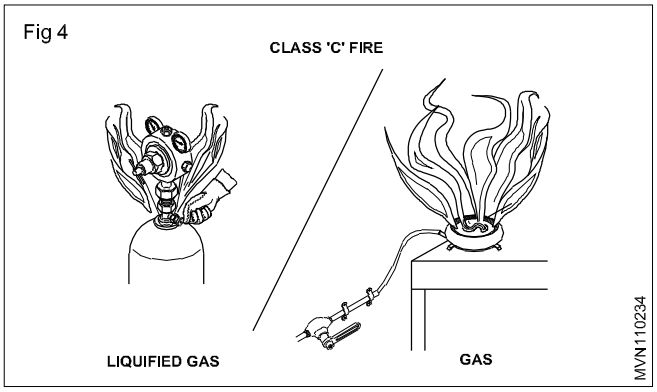



Should be smothered. The aim is to cover the entire surface of the burning liquid. This has the effect of cutting off the supply of oxygen to the fire.

Water should never be used on burning liquids.

Foam, dry powder or $CO_2$ may be used on this type of fire.

Fig 4

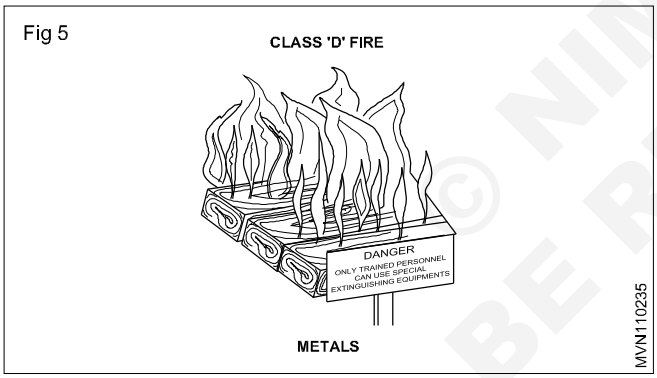



Extreme caution is necessary in dealing with liquefied gases. There is a risk of explosion and sudden outbreak of fire in the entire vicinity. If an appliance fed from a cylinder catches fire - shut off the supply of gas. The safest course is to raise an alarm and leave the fire to be dealt with by trained personnel.

Dry powder extinguishers are used on this type of fire.

Special powders have now been developed which are capable of controlling and/or extinguishing this type of fire.

Fig 5




The standard range of fire extinguishing agents is inadequate or dangerous when dealing with metal fires.

Fire on electrical equipment.

Halon, Carbon dioxide, dry powder and vapourising liquid (CTC) extinguishers can be used to deal with fires in electrical equipment. Foam or liquid (eg. water) extinguishers must not be used on electrical equipment under any circumstances.

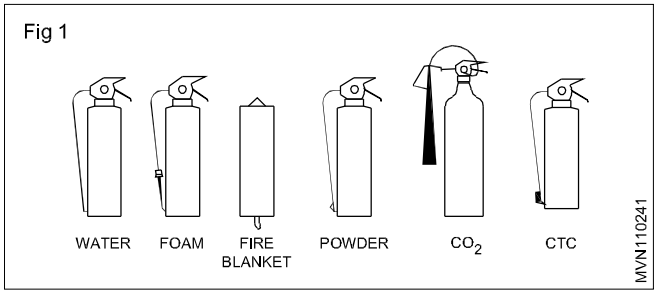
## Types of fire extinguishers

**Objectives:** At the end of this lesson you shall be able to

- **distinguish different types of fire extinguishers**
- **determine the correct type of fire extinguisher to be used based on the class of fire**
- **describe the general procedure to be adopted in the event of a fire.**

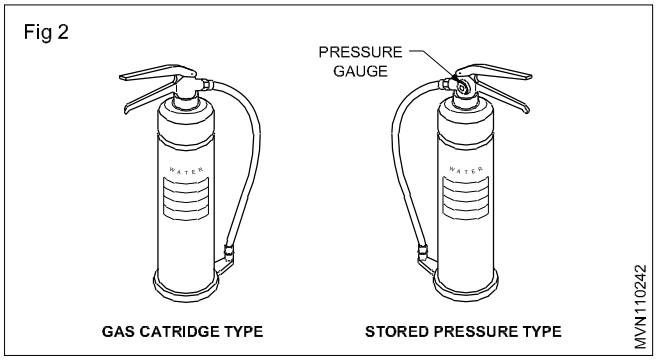
Many types of fire extinguishers are available with different extinguishing 'agents' to deal with different classes of fires. (Fig 1)

Fig 1




**Water-filled extinguishers:** There are two methods of operation. (Fig 2)

Fig 2

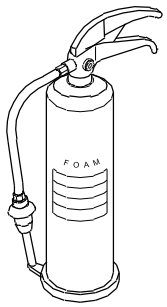


– Gas cartridge type
– Stored pressure type

With both methods of operation the discharge can be interrupted as required, conserving the contents and preventing unnecessary water damage.

**Foam extinguishers (Fig 3):** These may be of stored pressure or gas cartridge types. Always check the operating instructions on the extinguisher before use.

Fig 3




MVN110243

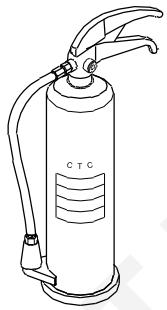
**Most suitable for**

– Flammable liquid fires
– Running liquid fires.

Must not be used on fires where electrical equipment is involved.

**Dry powder extinguishers (Fig 4):** Extinguishers fitted with dry powder may be of the gas cartridge or stored pressure type. Appearance and method of operation is the same as that of the water-filled one. The main distinguishing feature is the fork shaped nozzle. Powders have been developed to deal with class D fires.

Fig 4



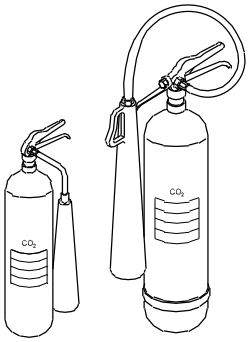

MVN110244

**Carbon dioxide ($CO_2$):** This type is easily distinguished by the distinctively shaped discharge horn. (Fig 5).

Suitable for Class B fires. Best suited where contamination by deposits must be avoided. Not generally effective in open air.

Always check the operating instructions on the container before use. Available with different gadgets of operation such as - plunger, lever, trigger etc.

Fig 5

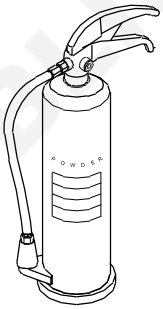



MVN110245

**Halon extinguishers (Fig 6):** These extinguishers may be filled with carbon-tetrachloride and Bromochlorodifluoro methene (BCF). They may be either gas cartridge or stored pressure type.

They are more effective in extinguishing small fires involving pouring liquids. These extinguishers are particularly suitable and safe to use on electrical equipment as the chemicals are electrically non-conductive.

Fig 6




MVN110246

**The fumes given off by these extinguishers are dangerous, especially in confined space.**

**The general procedure in the event of a fire**

– Raise an alarm.
– Turn off all machinery and power (gas and electricity).
– Close the doors and windows, but do not lock or bolt them. This will limit the oxygen fed to the fire and prevent its spreading.
– Try to deal with the fire if you can do so safely. Do not risk getting trapped.
– Anybody not involved in fighting the fire should leave calmly using the emergency exits and go to the designated assembly point. Failure to do this may mean that some person being unaccounted for and others may have to put themselves to the trouble of searching for him or her at risk to themselves.

# Elementary first-aid

**Objectives:** At the end of this lesson you shall be able to
- **define first aid**
- **list out the first aid key points**
- **describe the responsiveness.**

First aid is defined as the immediate care and support given to an acutely injured or ill person, primarily to save life,

First aid procedure often consists of simple and basic life saving techniques that an individual performs with proper training and knowledge.

**The key aims of first aid can be summarized in three key points**

- **Preserve life:** If the patient was breathing, a first aider would normally place them in the recovery position, with the patient learnt over on their side, which also has the effect of clearing the tongue from the pharynx. The first aider will be taught to deal with this through a combination of 'back slaps' and 'abdominal thrusts'. Once the airway has been opened, the first aider would assess to see if the patient is breathing.
- **Prevent further harm:** Also sometimes called prevent the condition from worsening, or danger of further injury, this covers both external factors, such as moving a patient away from any cause of harm, and applying first aid techniques to prevent worsening of the condition, such as applying pressure to stop a bleed becoming dangerous.
- **Promote recovery:** First aid also involves trying to start the recovery process from the illness or injury, and in some cases might involve completing a treatment, such as in the case of applying a plaster to a small wound.

**ABC of first aid:** ABC stands for airway, breathing and circulation.

- **Airway:** Attention must first be brought to the airway to ensure it is clear. Obstruction (choking) is a life-threatening emergency.
- **Breathing:** Breathing if stops, the victim may die soon. Hence means of providing support for breathing is an important next steps. There are several methods practiced in first aid.
- **Circulation:** Blood circulation is vital to keep person alive. The first aiders now trained to go straight to chest compressions through CPR methods.

When providing first aid one needs to follow some rule. There are certain basic norms in teaching and training students in the approach and administration of first aid to sick and injured.

**Important guideline for first aiders**

**Evaluate the situation:** Are there things that might put the first aider at risk. When faced with accidents like fire, toxic smoke, gasses, an unstable building, live electrical wires or other dangerous scenario, the first aider should be very careful not to rush into a situation, which may prove to be fatal.

**Avoid moving the victim:** Avoid moving the victim unless they are immediate danger. Moving a victim will often make injuries worse, especially in the case of spinal cord injuries.

**Call emergency services:** Call for help or tell someone else to call for help as soon as possible. If alone at the accident scene, try to establish breathing before calling for help, and do not leave the victim alone unattended.

**Determine responsiveness:** If a person is unconscious, try to rouse them by gently shaking and speaking to them.

**If the person remains unresponsive, carefully roll them on the side (recovery position) and open his airway.**

- Keep head and neck aligned.
- Carefully roll them onto their back while holding his head.

**First aid**

- Call “EMERGENCY” number.
- Check the person's airway, breathing, and pulse frequently. If necessary, begin rescue breathing and CPR.
- If the person is breathing and lying on the back and after ruling out spinal injury, carefully roll the person onto the side, preferably left side. Bend the top leg so both hip and knee are at right angles. Gently tilt the head back to keep the airway open. If breathing or pulse stops at any time, roll the person on to his back and begin CPR.
- If there is a spinal injury, the victims position may have to be carefully assessed. If the person vomits, roll the entire body at one time to the side. Support the neck and back to keep the head and body in the same position while you roll.
- Keep the person warm until medical help arrives.

## Safe disposal of toxic dust

**Objectives:** At the end of this lesson you shall be able to
- **list the waste material in a work shop**
- **explain the methods of disposal of waste material.**

**Introduction:** The Automotives produces fumes containing unburnt gases such as carbon-monoxide, nitrogen oxide and other gases which are harmful to human health. Hence a systematic and scientifically designed methods are adopted for safe disposal of such toxic waste.

Dust from vehicle components to be blown into the air, since such dust floating in air for many hours, may cause harm to people who breath unknowingly.

Brake and clutch components produces dust, when used compressed air jet to clean them. While cleaning conforming the PPE to safety regulation & policies. This includes overall coat, Face mask, safety goggles for eyes earmuffs & earplug for ear protection, rubber gloves &barrier cream for hand and valved respirator for breathing.

Some auto parts having asbestos, is a toxic material, which cause lung cancer. Airborne dust in workshop leads to asthma and throat infections. Do not use compressed air to clean dust from various components & parts of the Vehicle. Solvent used for cleaning can also form a toxic waste. Wash work cloths separately from other cloths so that toxic dust does not get transfer to other clothes. After cleaning a vehicle, there are certain chemicals present in this vehicle diet which turns toxic. To eliminate the toxic waste, create small diet piles and dispose them spontaneous rather than waiting for big diet pile till the end of the day. Workshop diet is best cleaned using a water hose, which does not allow diet to fully. But the waste water must be caught in a sledge pit and not into the storm water drain. Vacuum cleaner is a best device control toxic waste. Providing high speed exhaust ventilation can solve toxic diet.

Use grease which can not re-used is stored in a separate container and stored with unique identification. In a similar manner waste oil is stored in separate container, labeled 'Waste oil' and stored in different location, meant for disposal used diesel oil and kerosene are also stored in separate containers and kept at disposal area.

Scan the QR Code to view the video for the exercise

## Safety disposal of used engine oil

**Objectives:** At the end of this lesson you shall be able to
- **state the purpose of disposal used oil**
- **state the method of safety disposal of used oil.**

**Waste oil:** The waste oils, derived from fuels or lubricants, originally come from petroleum oil, sometimes known as mineral oils. Many lubricants may also contain synthetic components.

Waste oil is harmful to the environment and some, for example used engine oils, may cause cancer. so it needs to be managed carefully. You may need to account for Health and Safety guidance as well as the environment.

**Purpose:** Oils are defined as greasy, viscous substances from plant, animal, mineral sources (petroleum), and synthetics that are not soluble in water, and are usually flammable. These oils which have been used could be contaminated by physical or chemical impurities such as dirt, metal scrapings, and water. Oils that enter storm drains or waterways are a serious environmental hazard. used oil can pollute fresh water. The purpose of this procedure is to describe the proper means for handling and disposing of used oil from equipment maintenance operations, process procedures, and any other activities where used oils are generated.

## Safe handling of fuel spillage

**Objectives:** At the end of this lesson you shall be able to
- **state the safe handling of fuel spillage**
- **state the effect of fuel spillage in workplace.**

Diesel fuel is a flammable liquid and fuel spillage or leaks in work place may be cause for slippage or fire hazard.

**Safe handling of fuel**

1 Improper handling of fuel may cause for fuel spillage and explosion, so fuel handling should be use appropriate method.

2 Fuel should not be stored near the working hot engine.

3 Don't refueling, when it is hot, fuel tank vapor may cause for fire.

4 No smoking is allowed when refueling to the engine.

5 Don't spill the fuel during refilling the fuel tank or fuel container.

6 Use funnel during filling the fuel in fuel tank to avoid fule spillage.

7 Use tray during air bleeding from the fuel system to avoid fuel spillage.

8 Fuel leaks and spills near the engine may cause for accident so it should be clean and mopped up quickly as soon as the spillage.

9 Stationary engine fuel tank should be position away from any source of direct heat to the fuel tank.

## Safe handling and periodic testing of lifting equipments

Scan the QR Code to view the video for the exercise

**Objective:** At the end of this lesson you shall be able to
- **state the periodic testing of lifting equipments.**

Safe and successful lifting operations depends on periodical testing of lifting equipment, maintenance and handling of operation, failure of this equipment may result in significant loss and fatal accident.

**Lifts and cranes**

**Safety precautions for handling of lifts and cranes.**

- Never exceed the safe working load (SWL) of the equipment you are using.
- Always support vehicles with axle stands before working underneath them.
- There is always a danger when loads are lifted or suspended. Never work under an unsupported, Suspended or raised load such as a suspended engine.
- Always ensure that lifting equipment such as jacks, hoists, axle stands, slings, etc, are adequate and suitable for the job, In good condition and regularly maintained.
- Never improvise lifting tackle.

**Periodic testing of lifting equipment**

- Visually inspect the component of the lifting equipment such as lifting chain, slings chain hoist before operating the equipment.
- In Hydraulic function of lift (or) cranes cheek the oil level and top up the oil level periodically.
- The Hydraulic oil used in the lifts or cranes should be replaced periodically.
- The lifting equipment should be over hauled once (or) twice a year.
- Cheek the electrical connections of the lifting equipment periodically.
- The calibration of the lifting equipment should be done once in a year and calibration certificate must to obtained from the authorized testing center.

## Authorization moving of road testing vehicles

**Objectives:** At the end of this lesson you shall be able to
- **state the function of regional transport office**
- **state road safety**
- **Issue of fitness certificate and vehicle permits.**

**Ministry of road transport & highways:** Regional transport office is responsible, for registration monitoring controlling authoring of any Automotives our country.

**Responsibility of regional transport office**

**Issue of license**

- Testing and insurance of learning license
- Issue of renewal of driving license
- Issue of international driving license
- Addition of a new class of vehicle to driving license
- Issue of renewal of license for the establishment of a motor driving school
- Issue of renewal of driving instruction license
- Issue of conductor's license

**Revenue collection for the government**

- Tax on motor vehicle
- Collection of IMV fees
- Departmental action cases
- Inspection of vehicles at check posts

**Environmental upgradation**

- CNG/LPG conversion
- PUC testing
- Road safety measures

**Registration of vehicle**

- Issue of renewal of registration certificate for motor vehicles
- Transfer of ownership in registration certificate of motor vehicle
- Entirely termination of hire-purchase /lease/ hypothecation in R.C to book
- Recording of changes in registration certificate
- Issue of certificate of temporary registration
- Issue of no objection certificate(NOC)

- Issue and renewal of trade certificate
- Issue of fitness certificate and vehicle permits.

**Road safety precautions:** The biggest responsibility lies on the driver while using the road. The vehicle being a fast moving object it can do a lot of damage, if carelessly driven. In order to promote safety, the following general precautions should be observed by every road user.

Always keep to your left; while overtaking it should be done on the right side.

When passing stationary vehicles, keep a watch on pedestrians who may come out suddenly from the front of the stationary vehicle.

Drive slowly on narrow winding road.

When the traffic is held up, never try to force your way by encroaching on the off-side of the road.

Do not overtake on bends

Overtake only when a driver in front of you gives the signal to do so, and always overtake on the right side.

Always keep a good distance between your vehicle and the others. Too close a driving is dangerous.

Always park the vehicle at specified places.

Always give the signal when turning.

Drive slowly and carefully on a road where a school or hospital is situated.

**Reversing the vehicle:** In driving the vehicle backwards, reverse it into a limited opening either to the left or right under control and with reasonable accuracy. Reverse lights can be used at nights to indicate to the other road users who are coming at the back of the vehicle being reversed.

**Problem with automotive emissions:** The emissions given off by the burning of gasoline hake shown to be toxic to people and animals when breathes. But they also contribute to the ugly hare called smog, which hangs around the atmosphere causing problems long after the car has moved on. Here are the major pollutants.

Hydrocarbon (HC), Carbon Monoxide (CO) Nitrogen Oxide ($NO_2$), Volatile organic compounds (VOCs) particulate matter (diesel vehicle), Sulphur Oxide (SOx).

**Electrical safety tips**

Many injuries occur as the result of contact with electrical equipment or appliances. If the part of the body comes in contact with the electrical circuit, a shock will occur. The current will enter the body at one point and leave at another and this passage of electricity can cause severe pain, burning of skin at the point of contact, and even death. So it is need safe and free from electrical hazards.

**Safety tips**

1 Use only properly grounded or double insulated items/ equipments.

2 Do not overload outlets.

3 Do not plug multi-outlet bars to other multi outlet bars.

4 Only use equipment that has been approved by national testing laboratory.

5 Minimize the use of extension cards.

6 Do not cover power cords with rugs or mats.

7 Do not run electrical cord through pedestrian aisles.

8 Disconnect the power before servicing the equipment.

9 Do not ignore warning signs.

10 Replace the defective cords immediately.

11 Cover or guard any exposed electrical components or wire.

12 Don't use electrical equipment when your hands or equipments are we and don't use it near wet surface/ water.

13 Don't pull cord from a distance.

## Marking material

**Objectives:** At the end of this lesson you shall be able to
- **name the common types of marking material**
- **select the correct marking material for different applications.**

**Common types of Marking Materials:** The common marking materials are Whitewash, Cellulose Lacquer, Prussian Blue and Copper Sulphate.

**Whitewash**

Whitewash is prepared in many ways.

Chalk powder mixed with water

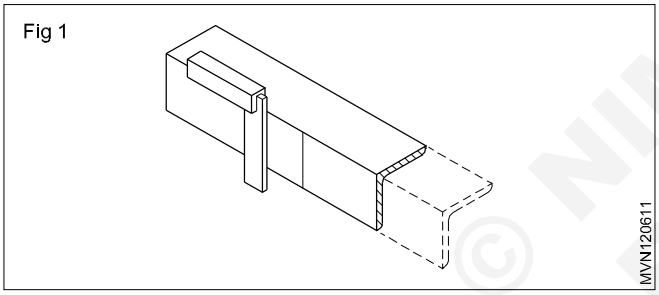
Chalk mixed with methylated spirit

White lead powder mixed with turpentine

Whitewash is applied to rough forgings and castings with oxidised surfaces. (Fig 1)

Whitewash is not recommended for work pieces of high accuracy.

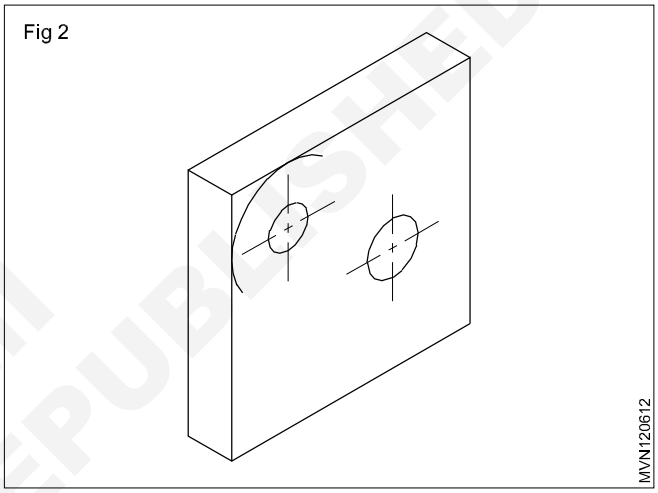
Fig 1




**Cellulose Lacquer:** This is a commercially available marking medium. It is made in different colours, and dries very quickly.

**Prussian Blue:** This is used on filed or machine-finished surfaces. This will give very clear lines but takes more time for drying than the other marking media. (Fig 2)

Fig 2




## Cleaning tools

**Objectives:** At the end of this lesson you shall be able to
- **state the different types of Cleaning Tools and their use**
- **state the precautions to be observed in the use of cleaning tools.**

Mechanical Cleaning Involves, brushing and abrasive Cleaning. It should be used very carefully on soft metals. Heavy deposits that exists even after chemical Cleaning can be removed by mechanical cleaning.

**The General Cleaning Tools are**

1 Wire brushes

2 Emery sheets.

**Wire brushes:** Wire brushes are generally used for cleaning the work surfaces.

It is made of steel wires (or) Nylon bristles fitted on a wooden piece.

The steel wires are hardened and tempered for long life to ensure good cleaning action. Different types of wire brushes is shown in Fig 1.

**Applications**

1 Wire brushes can be used for cleaning uneven Surfaces

2 A hand wire brush can be used on exterior of the block and on the head.

3 A round wire brush fixed with a hand drill motor spindle can be used for cleaning of combustion chamber and parts of the head.

4 A wire wheel can be used to clean the valves.

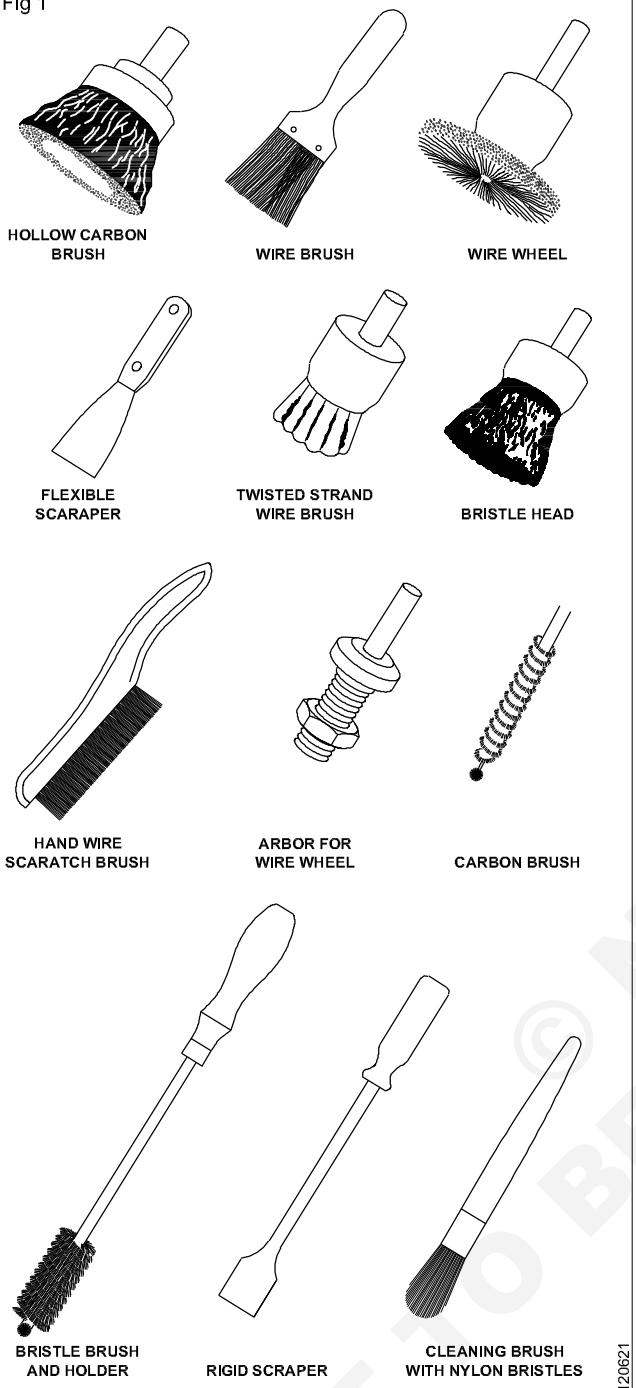
5 Nylon bristles with impregnated abrasive brush can be used for Engine boring

6 A washing brush can be used to clean the cylinders by using Soap and Water.

7 Oil passages of cylinder block can be cleaned by running a long bottle type brush through all holes in the cylinder block.

8 It is used to clean work surface before and after welding

Fig 1




CLEANING TOOLS

**Safety precautions**

Steel wire brushes should be used carefully on soft metals.

It should not make any scratches on the finished surface.

**Emery sheet (Fig 2)**

This is a type of paper used for sanding down hard and rough surfaces and also used for resistant technology purposes to give a smooth, shiny finish to manufactured products.

Emery paper is defined as a paper coated with abrasive particles in one side and used to produce smooth, shiny finish to manufactured products.

**Description**

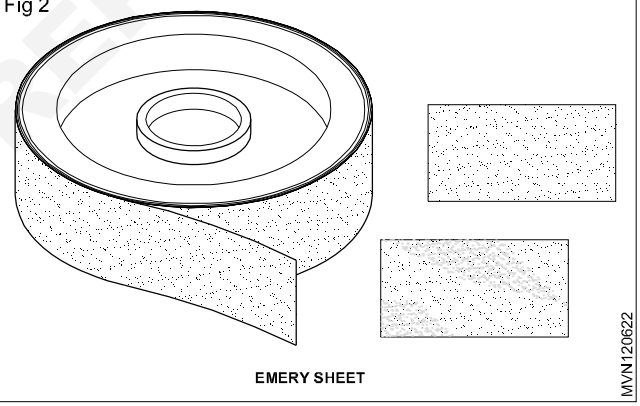
The each and every abrasive particle act as a cutting edge. The emery is considered for a suitable abrasive for workshop practices and the final adjustment of steel parts for a perfect fit. The emery paper is also used for cleaning, to remove rust from polished metal components.

The emery is graded by numbers and the Common sizes are from coarse to fine: 40, 46, 54, 60, 70, 80, 90. 100. 120, F and FF.

**Safety Precautions**

**After cleaning with emery paper, component should be rinsed properly.**

Fig 2




EMERY SHEET



## Scraper

**Objectives:** At the end of this lesson you shall be able to
- **name the different type of scrapers**
- **state the features of each type of scraper**
- **state the precaution to be observed while uses scraper.**

Scraper is a hand tool which is used to scrap the work piece surface by removing the smallest metal particles.

**Application**

It is used to obtain a smooth non scored and uniformly bearing surface which is required for sealing, sliding and guiding surface.

In Automotives it is used to remove carbon particles from cylinder head, piston head and manifold pipes

It is also used to scrap the bearings of cranks halt and sometimes the cylinder liner.

**Type of scrapers**

1 Flat scraper 2 Special scraper

**Flat scraper:** The cross section of this scraper is Flat. The cutting edge has Flat surface.

**Use**

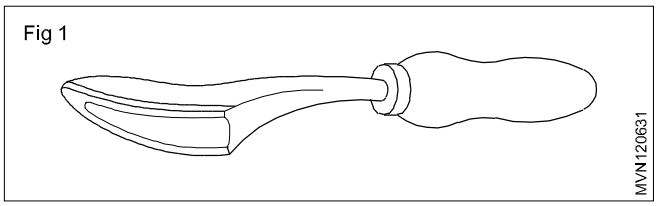
It is used to scrap the high spots of a flat Surface

**Special Scraper:** Special scraper is available for scraping and finishing curved surfaces. They are

- Half round scraper
- Three-square scraper
- Bull nose scraper

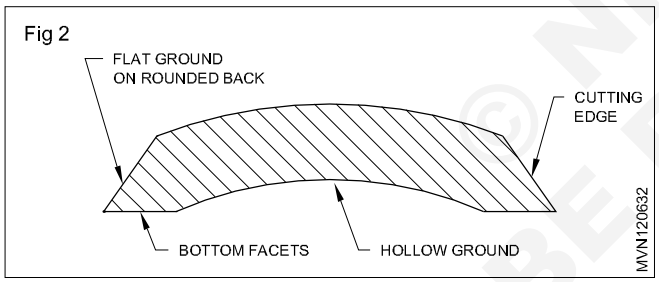
**Half round scraper:** The cross- section of this scraper is a segment and it tapers to a rounded point (Fig 1)

The round bottom face is curved and is hollow in the middle.

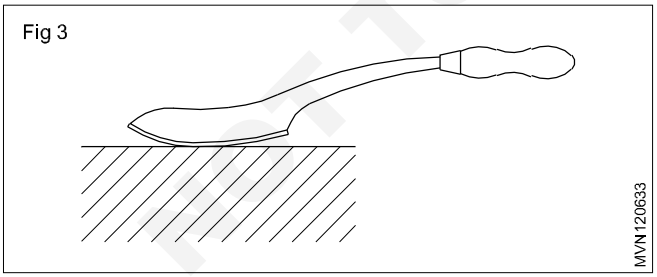



The bottom facet and the flat surfaces are ground along the edge to form the cutting edge. (Fig 2)

The cutting angle is between $45^0$ and $65^0$.

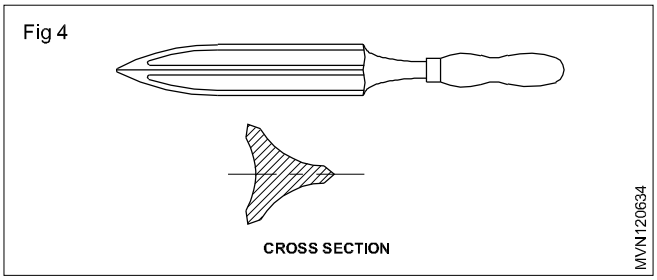



The curvature at the cutting edge helps to make point contact while scraping, and also helps to remove small spots. (Fig 3)

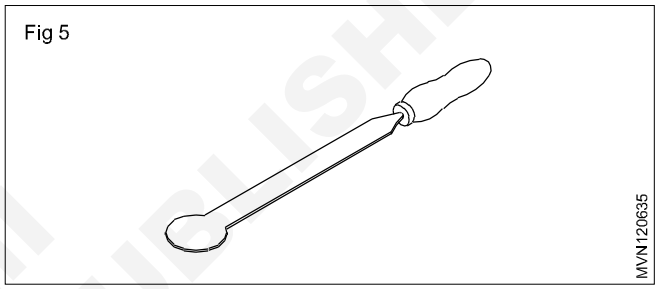



**Three- square scraper (Fig 4):** This scraper is used for scraping small diameter holes and deburring the edges of holes.

The cross-section of this is triangular. This has more number of cutting edges and the hollow portion between the cutting edges helps in re-sharpening easily.




**Bull nose scraper (Fig 5):** This scraper has the cutting edge shaped into a flat circular disc. The cutting edge forms about two thirds of the circle.

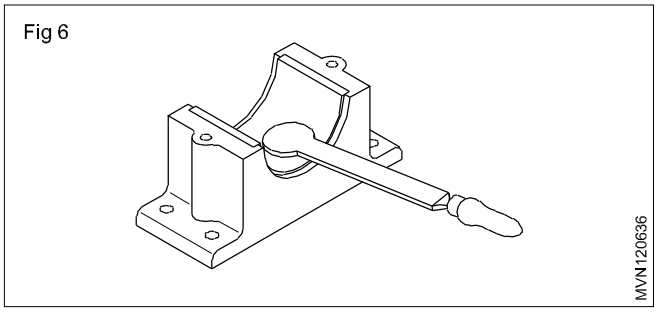



It is useful for scraping large bearings. (Fig 6) This scraper can be used in a longitudinal direction like a flat scraper or with a circumferential movement like a half round scraper. This dual action helps to prevent ridges on the scraped surfaces.

**Always use scrapers with firmly fitted handles.**

**Protect the cutting edges with a rubber cover when not in use.**

**Apply oil or grease on the cutting edges when not is use.**



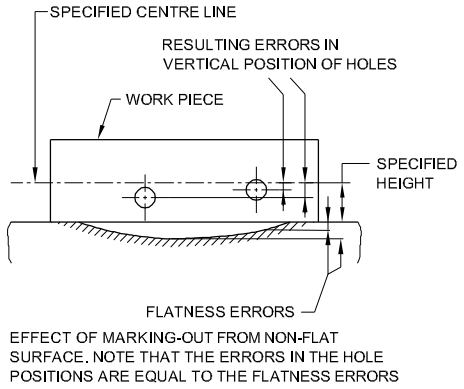
# Surface plates

**Objectives:** At the end of this lesson you shall be able to
- **state the constructional features of surface plates**
- **state the application of different grades of surface plates**
- **specify surface plates and state the uses of marking tables.**

### Surface plates - their necessity

When accurate dimensional features are to be marked or to be checked it is essential to have a datum plane with a perfectly flat surface. Marking using datum surfaces which are not perfectly flat will result in dimensional inaccuracies. (Fig 1) The most widely used datum surfaces in machine shop work are the surface plates and marking tables.

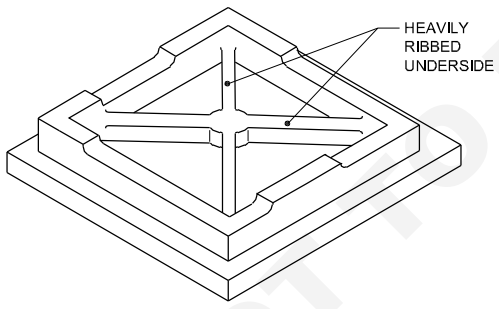
Fig 1




EFFECT OF MARKING-OUT FROM NON-FLAT SURFACE. NOTE THAT THE ERRORS IN THE HOLE POSITIONS ARE EQUAL TO THE FLATNESS ERRORS

**Materials and construction:** Surface plates are generally made of good quality cast iron which are stress-relieved to prevent distortion. The work-surface is machined and scraped. The underside is heavily ribbed to provide rigidity. (Fig 2)

Fig 2




CAST IRON SURFACE PLATE

For the purpose of steadiness and convenience in leveling. a three point suspension is given.

Smaller surface plates are placed on benches while the larger surface plates are placed on stands.

### Other materials used

Granite is also used for manufacturing surface plates. Granite is a dense and stable material. Surface plates made of granite retain their accuracy, even if the surface is scratched. Burrs are not formed on these surfaces.

### Classification and uses

Surface plates used for machine shop work are available in three grades - Grades 1, 2 and 3. The grade 1 surface plate is more acceptable than the other two grades.

### Specifications

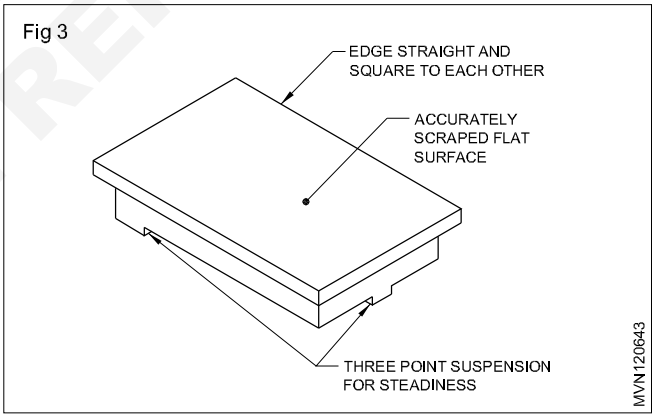
Cast iron surface plates are designated by their length, breadth, grade and the Indian Standard number.

### Example

Cast iron surface plate 2000 x 1000 Gr1. I.S.2285.

### Marking-off tables (Fig 3)

Fig 3




# Wheelbase, wheel track and measuring tape

**Objectives:** At the end of this lesson you shall be able to
- **define wheelbase**
- **define wheel track**
- **state measuring tape, its types and uses.**

The wheelbase of a vehicle equals the center distance between its front and rear wheels. (Fig 1)

**Wheel/Track:** The wheel track of a vehicle equals the center distance between its front wheels. As shown in the diagram. (Fig 4)

Measuring tape is a flexible ruler. It is made of ribbon cloth plastic fiber glass metal strip with lines for measurements. It is very common measuring tool used by many people. The available range are 3m, 5m and 10m.

**Types**

1 Plastic Tape (Fig 3)
2 Metal Tape (Fig 2)
3 Fibre glass
4 Ribbon cloth

**Application**

Dress makers

Civil Engineers

Mechanical Engineers

Surveyors

Carpenters

Medical field

**Accuracy**

Measuring tapes are marks in metric and British system. The accuracy in metric system is 1mm and in British system is 1/8".

Limitation: Accuracy is not possible, because the tape is flexible and likely to elongate while measuring long ranges and distances.

Fig 1

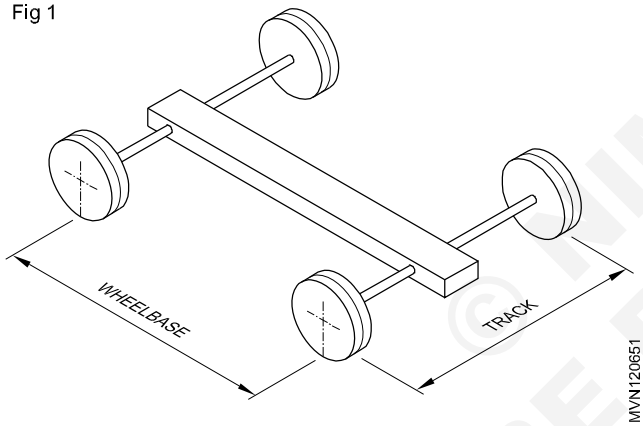



Fig 2

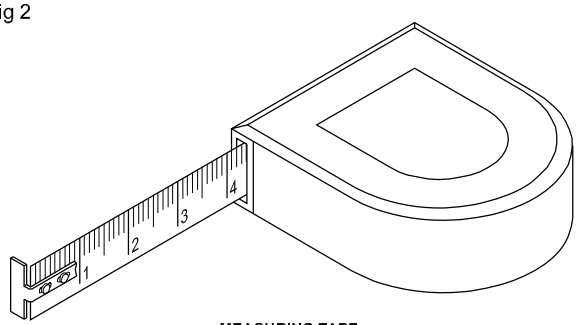



Fig 3

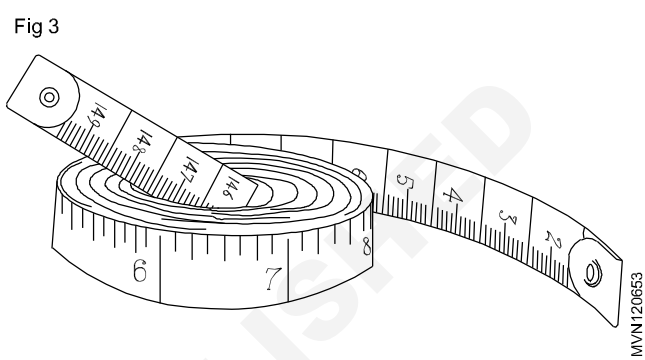
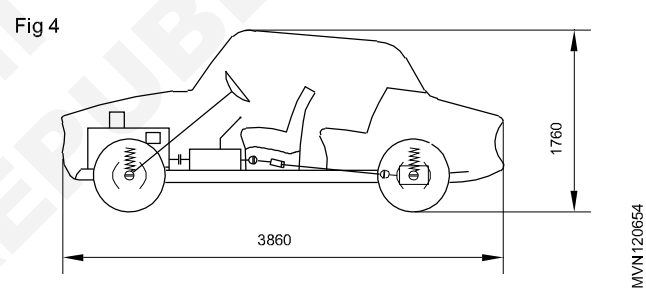



Fig 4




## Length measurement

**Objectives:** At the end of this lesson you shall be able to

- **name the base unit length measurement as per the International system of units of measurement (SI)**
- **state the multiples of a metre and their values.**

When we measure an object, we are actually comparing it with a known standard of measurement.

The base unit of length as per SI is the METRE Length SI UNIT and MULTIPLES

**Base Unit**

The base unit of length as per the System International is the metre. The table given below lists some multiples of a metre.

| | | |
|---|---|---|
| METRE (m) | = | 1000 mm |
| CENTIMETRE(cm) | = | 10 mm |
| MILLIMETRE (mm) | = | 1000 mm |
| MICROMETRE (m) | = | 0.001 mm |

**Measurement in engineering practice**

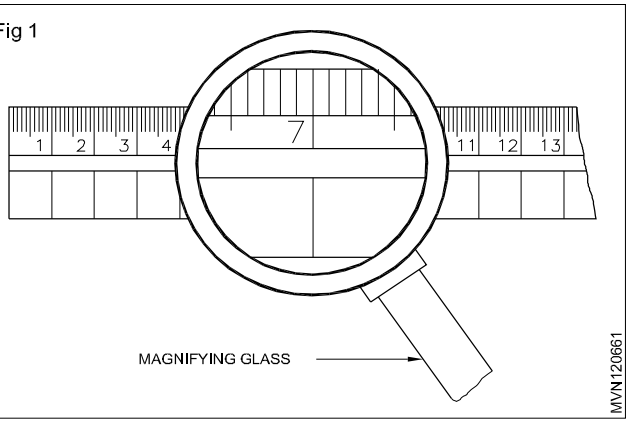
Usually, in engineering practice, the preferred unit of length measurement is the millimetre (Fig. 1). Both large and small dimensions are stated in millimetres

**The British system of length measurement**

An alternative system of length measurement is the British system. In this system, the base unit is the Imperial Standard Yard. Most countries, including Great Britain itself, have, however, in the last few years, switched over to SI units.

However in a regular Steel rule & in vernier caliper the main scale readings of metric in the bottom and imperial in inches in the top with corresponding vernier scales.

Fig 1




## Engineer's steel rule

**Objectives:** At the end of this lesson you shall be able to
- **state the constructional features of an engineer's steel rule**
- **explain the uses of a steel rule**
- **state the maintenance aspects to be considered in respect of steel rules.**

When dimensions are given in a drawing without any indication about the tolerance, it has to be assumed that measurements are to be made with a steel rule.

Steel rule are made of spring steel or stainless steel. The edges are accurately ground to form straight edges.

The surface of the steel rule is satin-chrome finished to reduce glare, and to prevent rusting.

**Sizes of steel rules (Fig 1)**

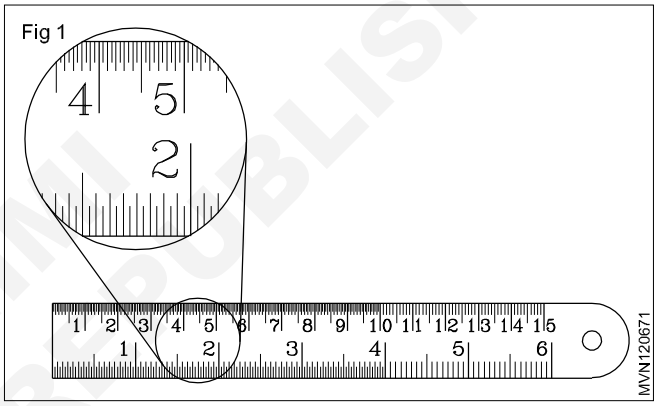
Steel rules are available in different length, the common sized being 150mm, 300 mm and 600 mm.

The engineer's steel rule is graduated in 10 mm, 5 mm, 1mm and 0.5 mm.

The reading accuracy of the steel rule is 0.5 mm.

These are heavily ribbed cast iron tables fitted with strong rigid legs. The top surface is accurately machined flat, and the sides square.

Fig 1




These are used for carrying out marking on heavy components. On certain types-parallel lines are engraved in both directions at a set distance.

These lines serve as guides for positioning components while setting and marking.

Scan the QR Code to view the video for this exercise

## Try square

**Objectives:** At the end of this lesson you shall be able to
- **name the parts of a try square**
- **state the uses of a try square.**

The try square (Fig.1) is a precision instrument which is used to check squareness (angles of $90^0$) of a surface.

The accuracy of measurement by a try square is about 0.002 mm per 10 mm length, which is accurate enough for most workshop purposes. The try square has a blade with parallel surfaces. The blade is fixed to the stock at $90^0$.

**Uses:** The try squareness is used (Fig 2 & 3)

- check flatness of surfaces (Fig 3)
- mark lines at $90^0$ to the edges of workpieces (Fig 4)
- set workpieces at right angles on work, holding devices. (Fig 5)

Try squares are made of hardened steel.

Try squares are specified according to the lengths of the blade, i.e 100 mm, 150 mm, 200 mm.

Use of a try square and steel rule.

Fig 6 shows the method of using a try square and a steel rule for accurate measurements.

**For maintaining accuracy it is important to see it, that the edges and surfaces of instruments are protected from damage and rust.**

Fig 1

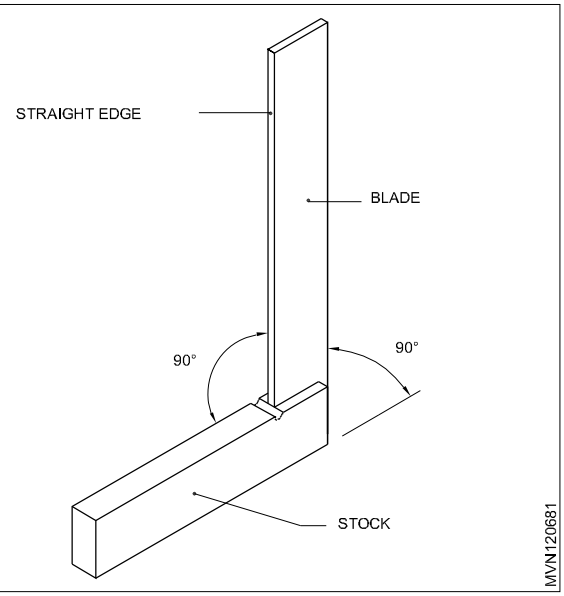



Fig 2

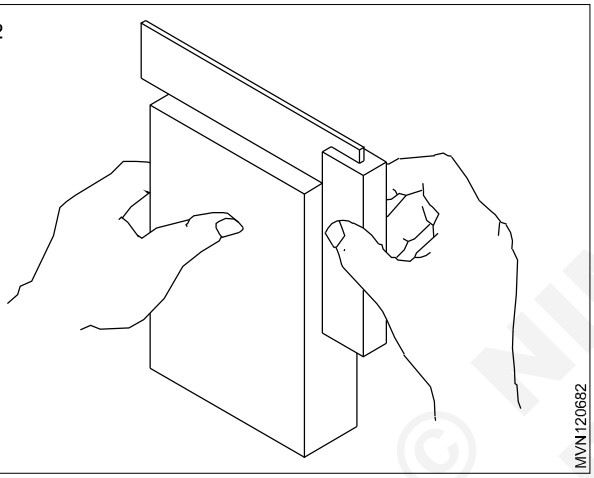



Fig 3

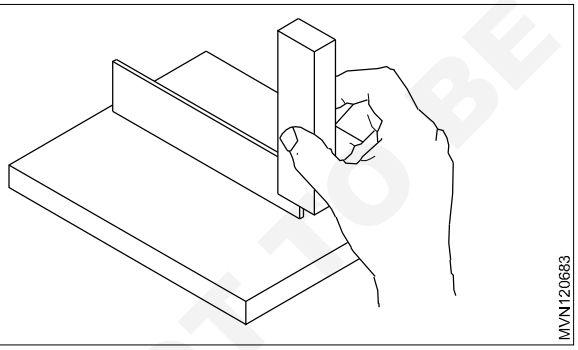



Fig 4

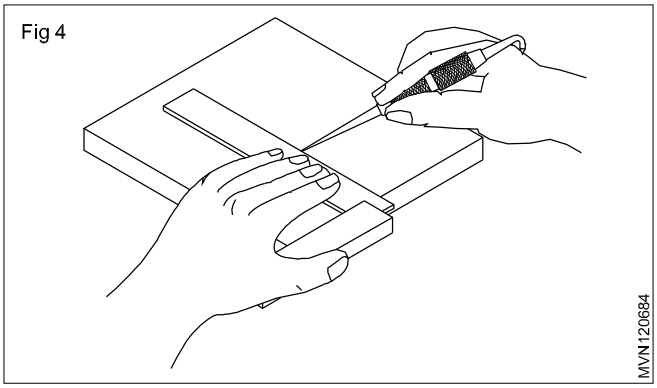



Fig 5

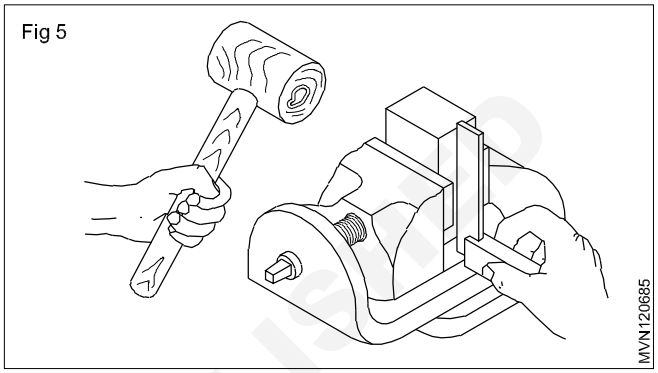
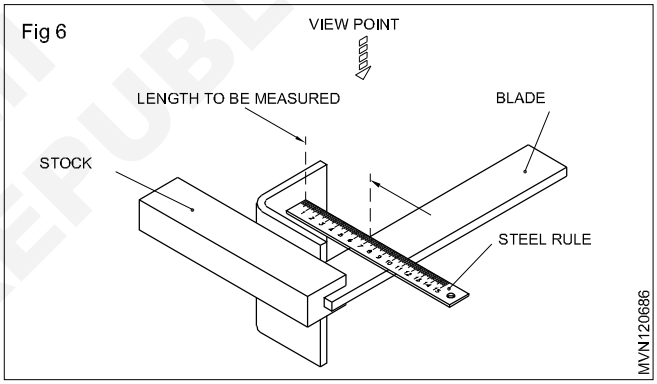



Fig 6




An experienced person can transfer measurements from a steel rule very accurately.

The steel rule graduations are accurately engraved, with the line thickness ranging from 0.12 to 0.18 mm.

Do not place a steel rule with any cutting tools. Apply a thin layer of oil when not in use.

For Accurate reading it is necessary to read vertically to avoid errors due to parallax

## Types of calipers

**Objectives:** At the end of this lesson you shall be able to

- **name the commonly used calipers**
- **compare the features of firm joint and spring joint calipers**
- **state the advantage of spring joint calipers**
- **state the uses of inside and outside calipers.**

Scan the QR Code to view the video for this exercise

Calipers are simple measuring instruments used to transfer measurements from a steel rule to objects, and vice versa.

Calipers are of different types depending on the type of joint and the shape of leg.

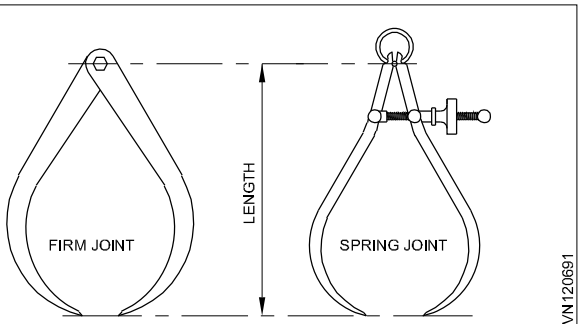
**Types of joint:** The commonly used calipers are:

- Firm joint calipers
- Spring joint calipers

**Firm Joint calipers (Fig 1)**

In the case of firm joint calipers, both legs are pivoted at one end. To take measurements of a workpiece. It is opened roughly to the required size. Fine setting is done by tapping the caliper lightly on a wooden surface.

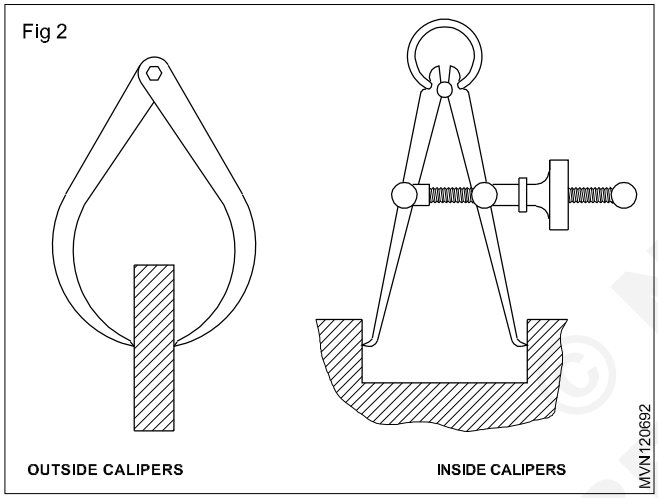
Fig 1




**Spring joint calipers (Fig 2)**

For this type of calipers, the legs are assembled by means of a pivot loaded with a spring. For opening and closing the caliper legs, a screw and nut are provided.

Fig 2




Spring joint calipers have the advantage of quick setting. The setting made will not change unless the nut is turned. The size of a caliper is specified by its length - which is the distance between the pivot centre and the tip of the leg.

The accuracy of the measurement taken depends very much on the sense of feel an touch. While measuring the job, you should get the feel when the legs are just touching the surface.

**Types of legs**

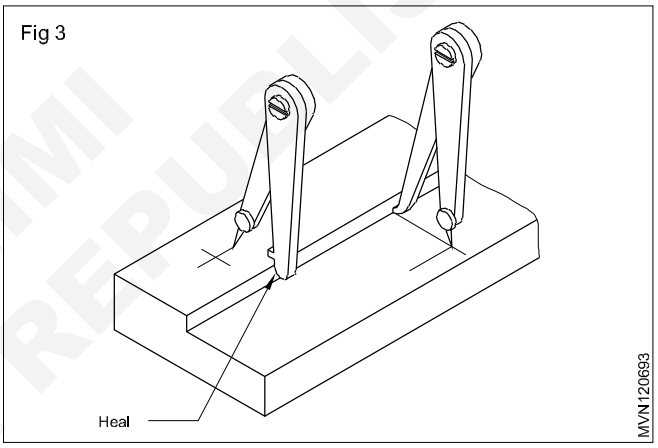
Outside and inside calipers are differentiated by the shape of the legs.

Calipers used for outside measurements are known as outside calipers. The calipers used be internal measurements are known as inside calipers.

Calipers are use along with steel rules, and the accuracy is limited to 0.5 mm; parallelism of jobs etc. can be checked with higher accuracy by using a caliper.

**Jenny calipers** are used for marking lines on inside and outside edges.

Fig 3






## Dividers

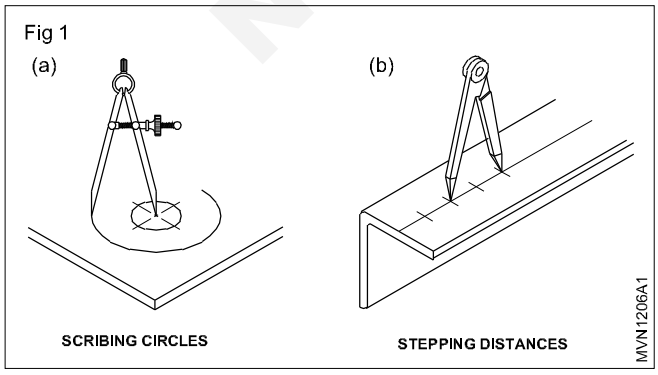
**Objectives:** At the end of this lesson you shall be able to

- **name the parts of a divider**
- **state the uses of dividers**
- **state the specifications of dividers**
- **state the important aspects of be considered in respect of divider points.**

Scan the QR Code to view the video for this exercise

Dividers are used for scribing circles, arcs and transferring and stepping of distances. (Fig 1a&1b)

Fig 1




Dividers are available with firm joints and spring joints. The measurements are set on the dividers with a steel rule. (Fig 2a&2b)

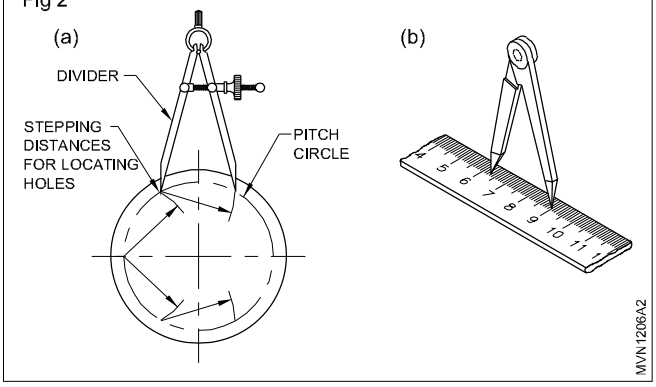
The sizes of dividers range between 50 mm to 200 mm. The distance from the point to the centre of the fulcrum roller (pivot) is the size of the divider. (Fig 3a)

For the correct location and seating of the divider legs, prick punch marks of 30° are used. (Fig 3b)

Both the legs of the divider should always be of equal length.

Dividers are specified by the type of their joints and length.

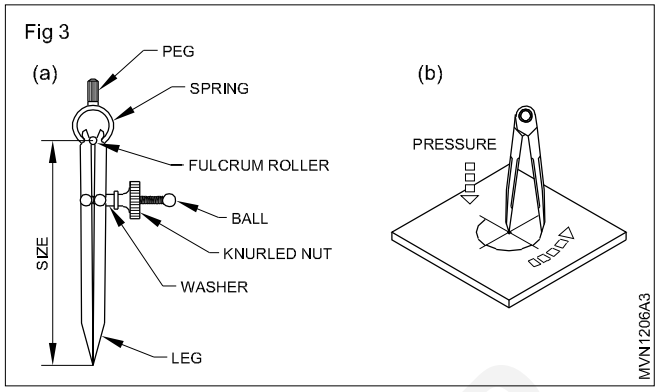
Fig 2




The divider point should be kept sharp in order to produce timelines. Frequent sharpening with an oil stone is better than sharpening by grinding. Sharpening by grinding will make the points soft.

**Do not sharpen the divider points on grinding wheels.**

Fig 3




## Surface gauges

**Objectives:** At the end of this lesson you shall be able to

- **state the constructional features of surface gauges**
- **name the types of surface gauges**
- **state the uses of surface gauges**
- **state the advantages of universal surface gauges.**

Scan the QR Code to view the video for this exercise

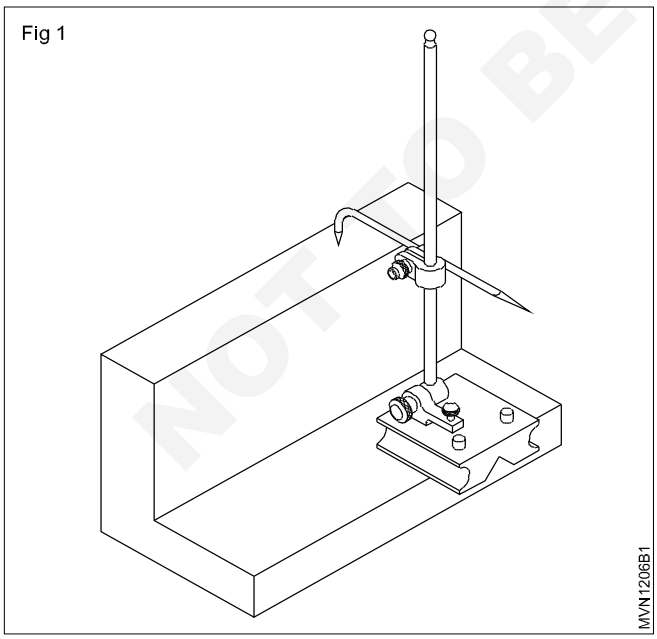
The surface gauge is one of the most common marking tools used for.

scribing lines parallel to a datum surface

**Types of surface gauges**

- Surface gauges/scribing blocks are of two types.
- Fixed
- Universal (Fig 1)

Fig 1

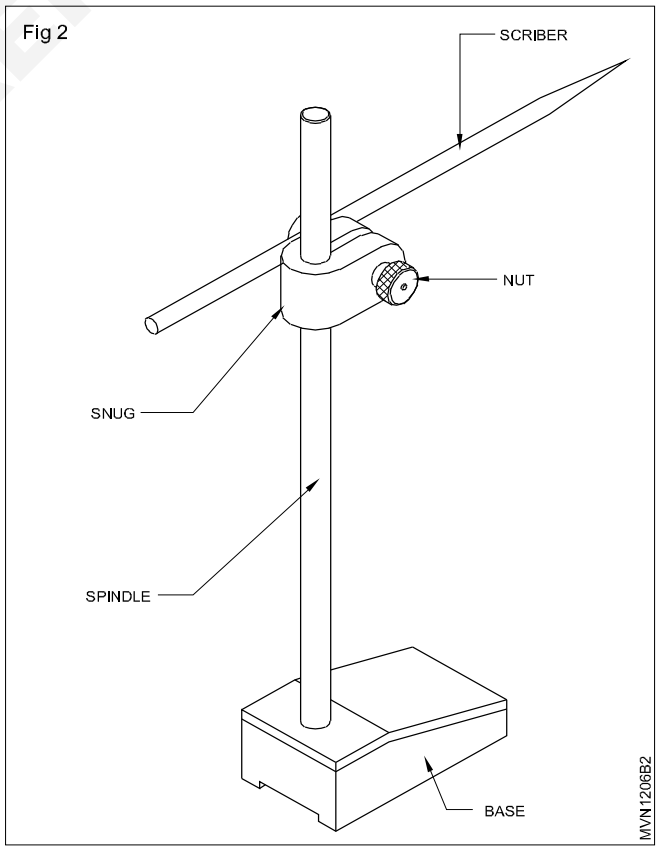



**Surface gauge-fixed type (Fig 2)**

- Setting jobs on machines parallel to a datum surface
- Checking the height and parallelism of jobs
- Setting jobs concentric to the machine spindle.

The fixed type of surface gauge consists of a heavy flat base and a spindle, fixed upright , to which a scriber is attached with a snug and a clamp-nut.

Fig 2




**Universal surface gauge (Fig 3&4):** This has the following additional features.

- The spindle can be set to any position.

- Fine adjustments can be made quickly.
- Can also be used on cylindrical surfaces.

Fig 3

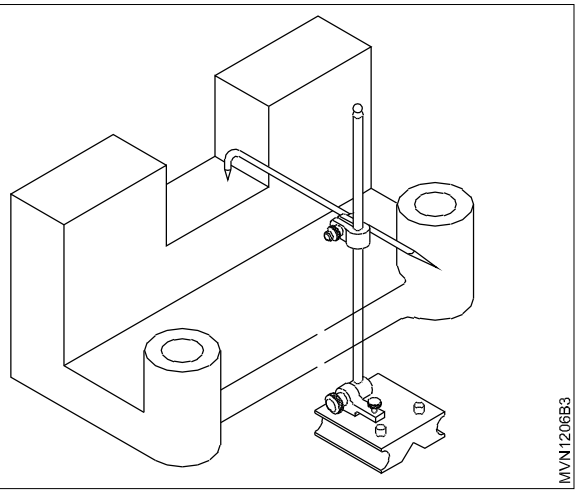
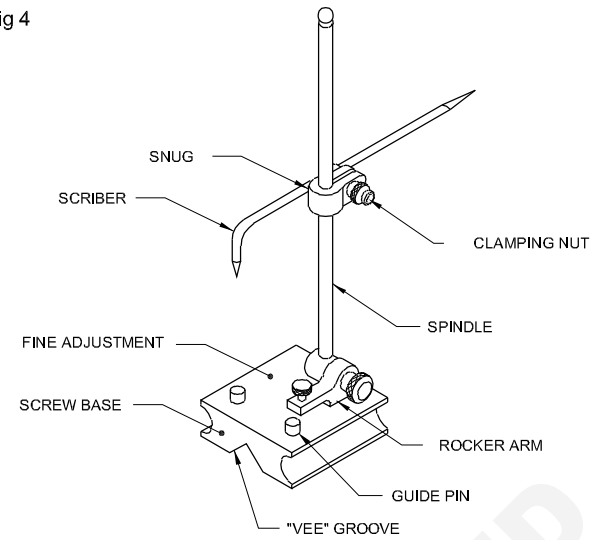



Fig 4




UNIVERSAL SURFACE GAUGE

## Scriber

**Objectives:** At the end of this lesson you shall be able to
- **state the features of scribers**
- **state the uses of scribers.**

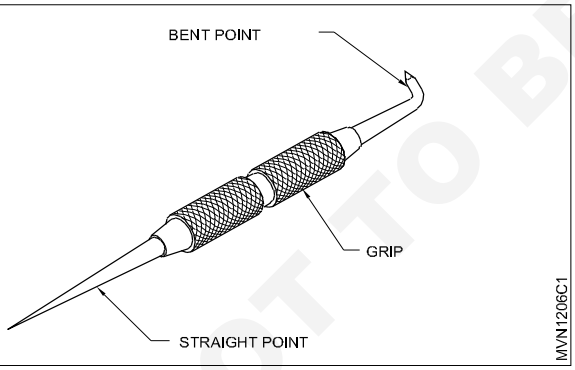
In layout work, it is necessary to scribe lines to indicate the dimensions of workpieces to be filed or machined .

The scriber is a tool used for this purpose. It is made of high carbon steel which is hardened. For drawing clear and sharp lines, a fine point is ground at one end.

Scribes are available in different shapes and sizes. The one most commonly used is the plain scriber (Fig 1).

While scribing lines, the scriber is used like a pencil so that the lines drawn are close to the straight edge (Fig 2).

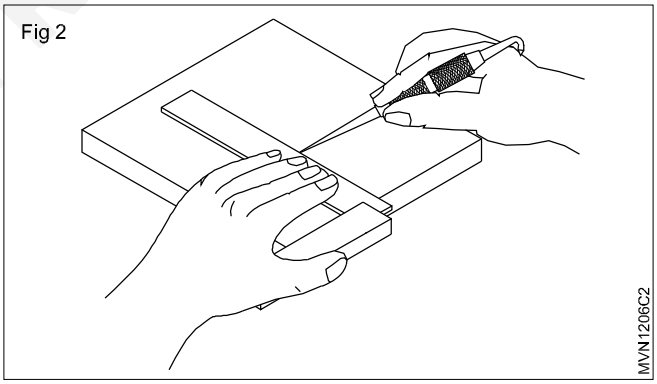
Fig 1




The point of the scriber should be ground and honed frequently for maintaining its sharpness.

**Scriber points are very sharp, and they are to be handled very carefully. Do not put the scriber in your pocket. Place a cork on the point when not in use to prevent accidents. (when it is not in use)**

Fig 2




## Hand tools

**Objective:** At the end of this lesson you shall be able to
- **state the application of punches.**

Punches are used in sheet metals and other work to mark position on work. (Fig 1)

**Prick punches**

These punches are used to make witness marks on scribed lines. (Fig 2)

This makes it easier to see accurate marking out lines.

- to check the location of the centre positions before centre punching. (Fig 3)
- to locate the pivot points of compasses for scribing circles. (Fig 4)

A 100 mm prick punch with a 7 mm diameter body could have a 2.5 mm diameter point ground to an angle of 60° or 30°

Fig 1

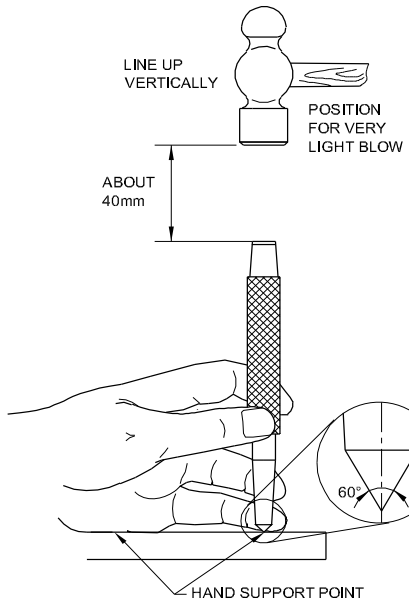



Fig 2

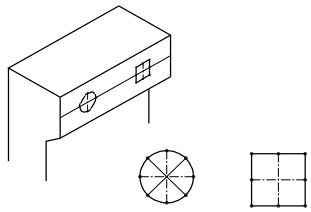



Fig 3

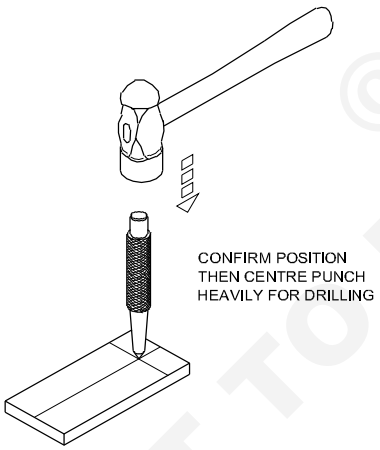
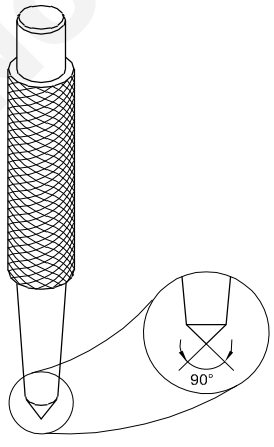



Fig 4



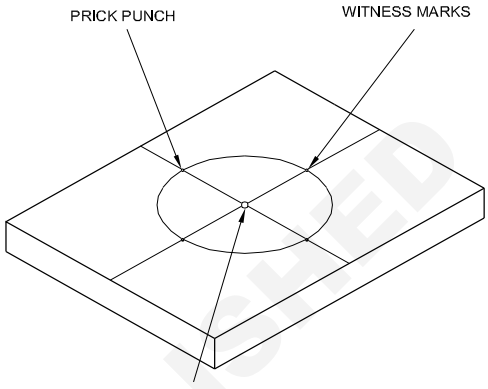

**Centre punches:** These punches are similar to prick punch, and it is generally larger then prick punch.

A 100 mm centre punch could have a 10 mm diameter body and a 6 mm diameter point ground to an angle of 90°

Centre punches are used;

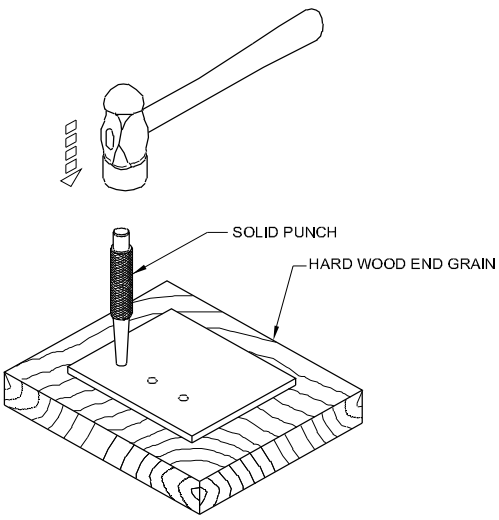
- to make deeper witness marks on scribed lines and to locate a centre position and make it easier for the drill to start correctly. (Fig 5)

Fig 5




**Solid punch (Fig 6):** In riveting sheet metal, holes must be equally spaced and lined up. The holes in the metal are usually punched with solid punches.

Fig 6

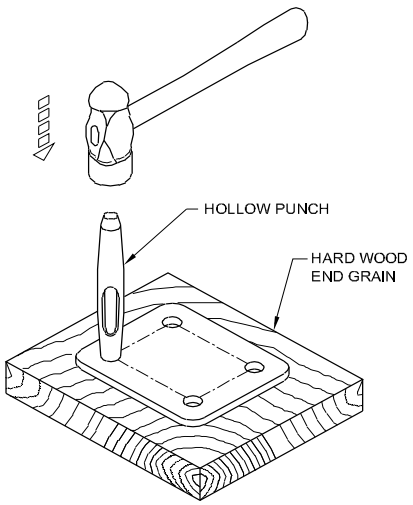



**Letter and number punches:** Also known as letter stamps or number stamps, letter punches are used to emboss the impression of a letter of number into a workpiece. They are most common in the reverse image, this allows the end result to be immediately readable, however they may be made as a positive image. This is essential in the case of die or mold making and ensure that the finished product will be readable, as a die is a negative image.

**Hollow punch (Fig 7):** These punches are also used to punch holes in thin sheet metal, leather, plastic cork etc. Gaskets, seals and spacers are made using hollow punches.

While using solid or hollow punches, the materials is rigidly supported with a block of wood (with the end of grain up) or lead. This will also avoid any damage to the tip of the punch while punching.

Fig 7

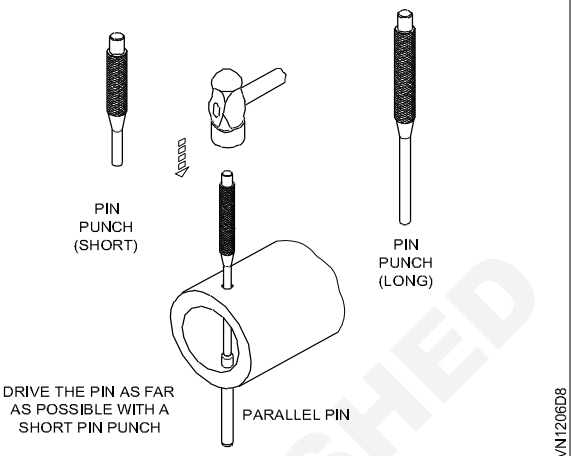



USING A HOLLOW PUNCH

**Pin punches (Fig 8):** Pin punches are used to drive locating or locking pins, dowels and rivets out of their holes.

Pin punches are available in a set of 5 pins of dia.3,4,5,6 and 8 mm with a knurled body to a length of approximately 150 mm.

Fig 8




## Chisel

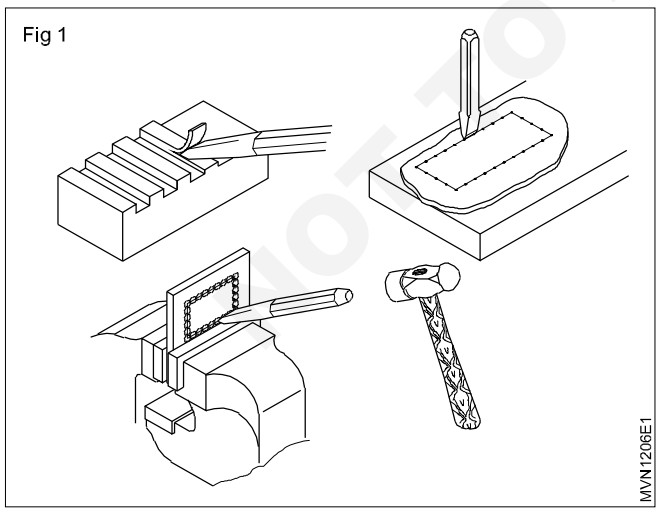
**Objectives:** At the end of this lesson you shall be able to
- **list the uses of a cold chisel**
- **name the parts of a cold chisel**
- **state the different types of chisels.**

Scan the QR Code to view the video for this exercise

The cold chisel is a hand cutting tool used by fitters for chipping and cutting off operations. (Fig 1)

Chipping is an operation of removing excess metal with the help of a chisel and hammer. Chipped surfaces being rough, they should be finished by filing.

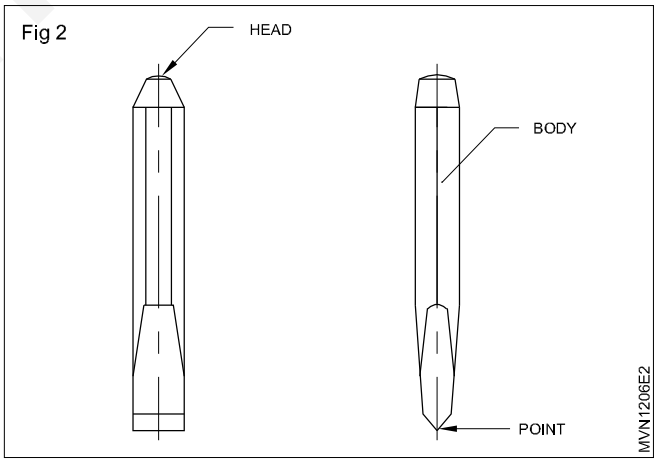
Fig 1




**Parts of a chisel (Fig 2):** A chisel has the following parts.

1 Head
2 Body
3 Point or cutting edge

Fig 2




Chisels are made from high carbon steel or chrome vanadium steel. The cross-section of chisels is usually hexagonal or octagonal. The cutting edge is hardened and tempered.

**Common types of chisels:** There are four common types of chisels;

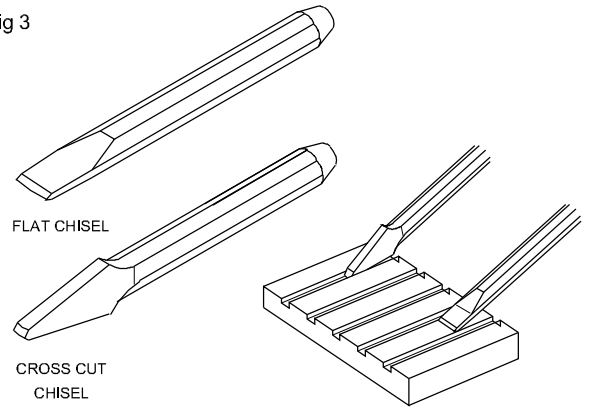
- Flat chisel (1)
- Cross-cut chisel (2)
- Hall round nose chisel

- Diamond point chisel

**Flat chisels (Fig 3):** They are used to remove metal from large flat surfaces and chip excess metal of weld joints and castings.

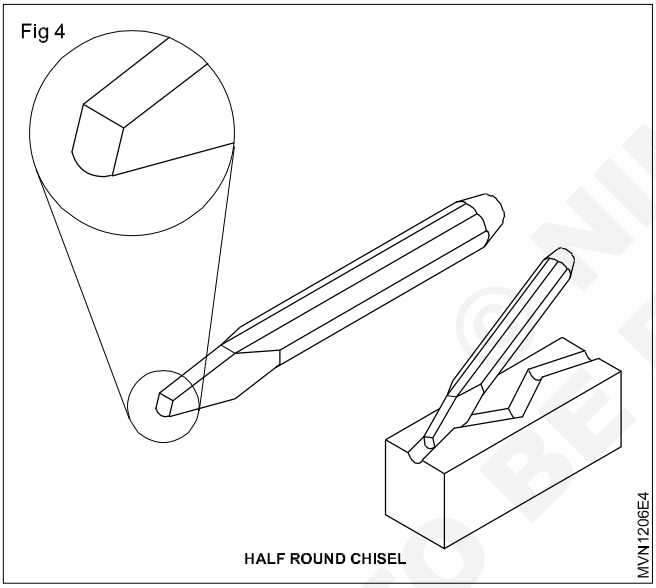
**Cross-cut or cape chisels (Fig 3):** These are used for cutting keyways, grooves and slots.

Fig 3




**Half round nose chisels (Fig 4):** They are used for cutting curved grooves (oil grooves)

Fig 4




**Diamond point chisels (Fig 5):** These are used for squaring materials at the corners.

**Web chisels/punching chisels (Fig 6):** These chisels are used for separating metals after chain drilling. Chisels are specified according to their;

- length
- width of cutting edge
- type
- cross-section of body

The length of the chisels ranges from 150mm to 400mm. The width of the cutting edge varies according to the type of chisels.

Fig 5

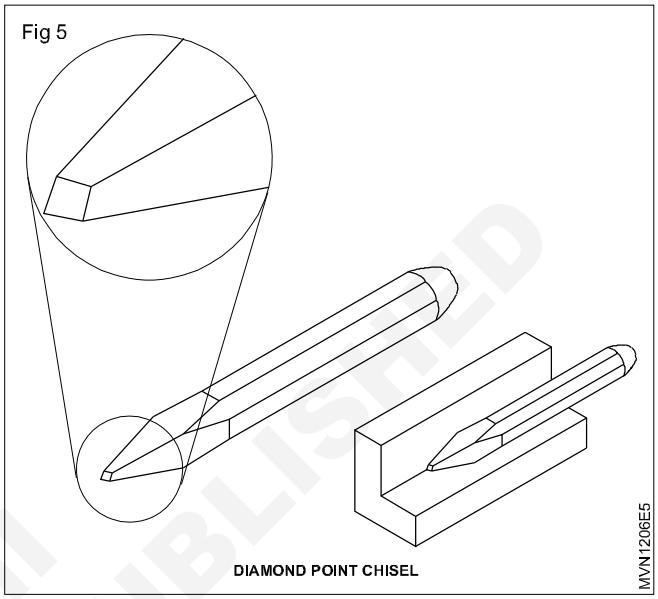
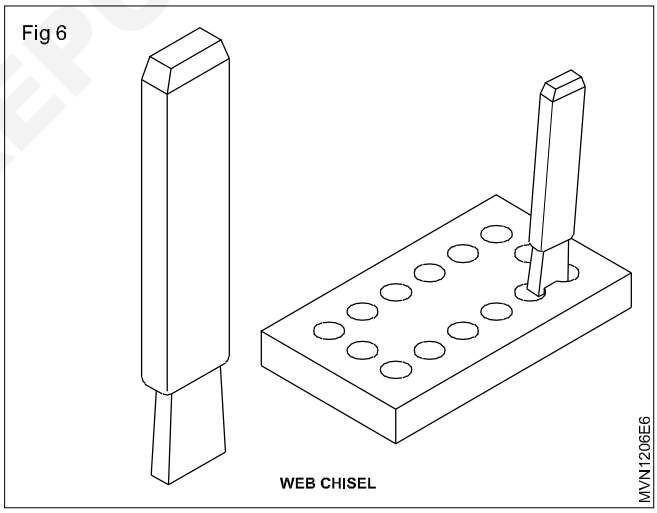



Fig 6






## Hammers

**Objectives:** At the end of this lesson you shall be able to
- **state the uses of an engineer's hammer**
- **list the parts of an engineer's hammer and state their functions**
- **name the types of engineer's hammers**
- **specify the engineer's hammer.**

An engineer's hammer (Fig 1) is a hand tool used for striking purposes while

- punching
- bending
- straightening
- chipping
- forging
- riveting

**Major parts of a hammer (Fig 2)**

The major parts of a hammer are a head and a handle.

Fig 1

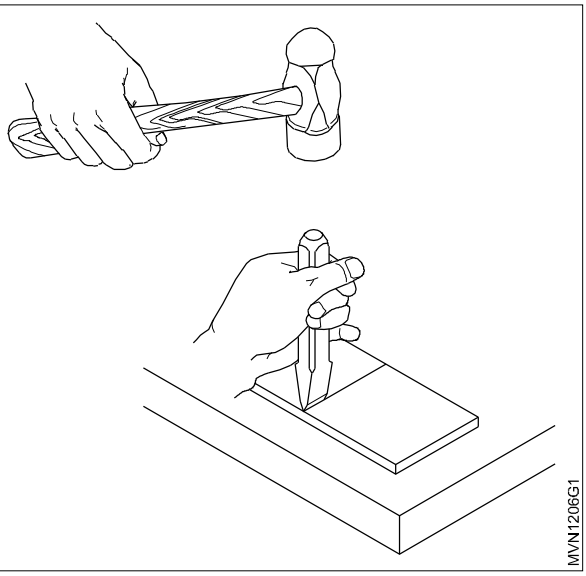
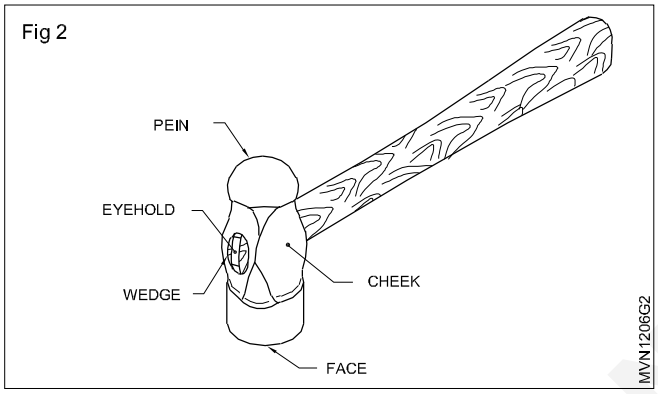



Fig 2




The head is made of drop-forged carbon steel, while the wooden handle must be capable of absorbing shock.

The parts of a hammer head are the

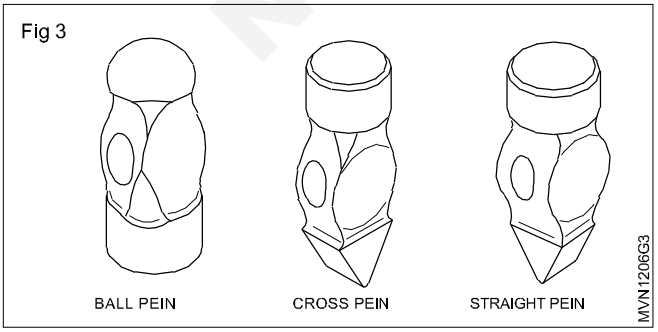
- face (1)
- pein (2)
- cheek (3)
- eyehole (4)
- wedge (5)

The face is the striking portion. Slight convexity is given to it avoid digging of the edge.

The pein is the other end of the head. It is used for shaping and forming work like riveting and bending. The pein is of different shapes like the (Fig 3)

- ball pein
- crosspein
- straight pein

Fig 3




The face and the pein are hardened.

The cheek is the middle portion of the hammer-head. The weight of the hammer is stamped here.

This portion of the hammer-head is left soft.

An eyehole is meant for fixing the handle. It is shaped to fit the handle rigidly. The wedges fix the handle in the eye hole. (Fig 4&5)

Fig 4

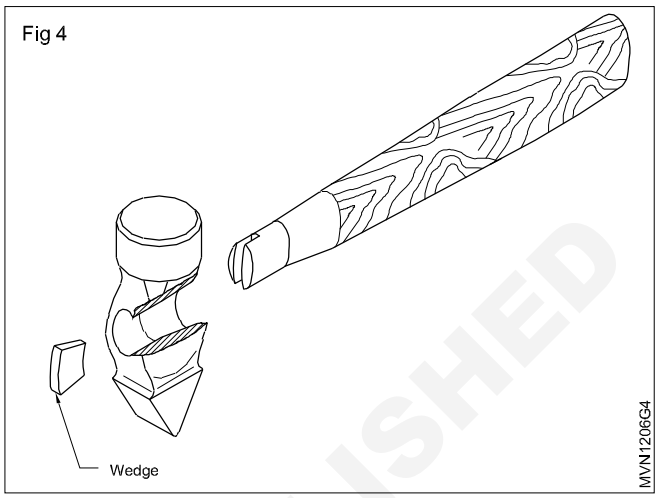
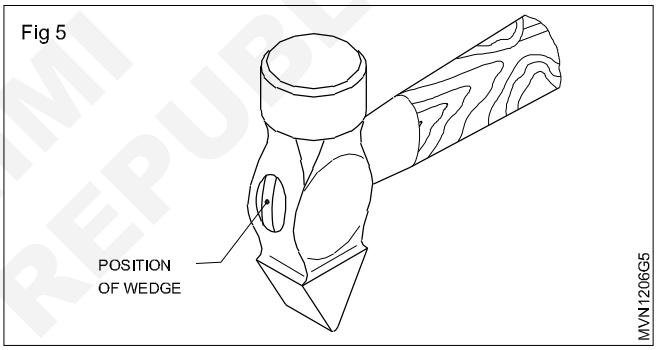



Fig 5




**Specification**

An engineer's hammers are specified by their weight and the shape of the pein. Their weight varies from 125 gms to 1.5 kg.

The ball pein hammers are used for general work in a machine/fitting shop.

**Before using a hammer**

make sure the handle is properly fitted

select a hammer with the correct weight suitable for the job

check the head and handle for any cracks

ensure the face of the hammer is free from oil or grease.

The figure shows the different parts of a hammer (Fig 6). The handle is fitted in the eye-hole of the hammer.

The face of the hammer is used for general work, such as striking chisels and punches and levelling and working over joints. (Fig 7)

**Ball pein hammer (Fig 8):** A ball pein head is used to spread metal in all directions.

Fig 6

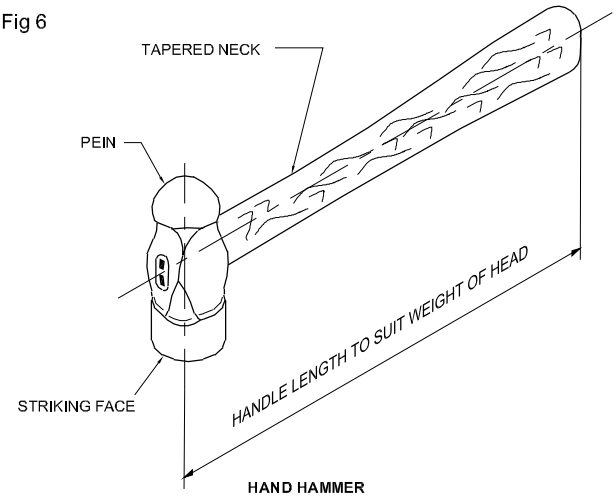



Fig 7

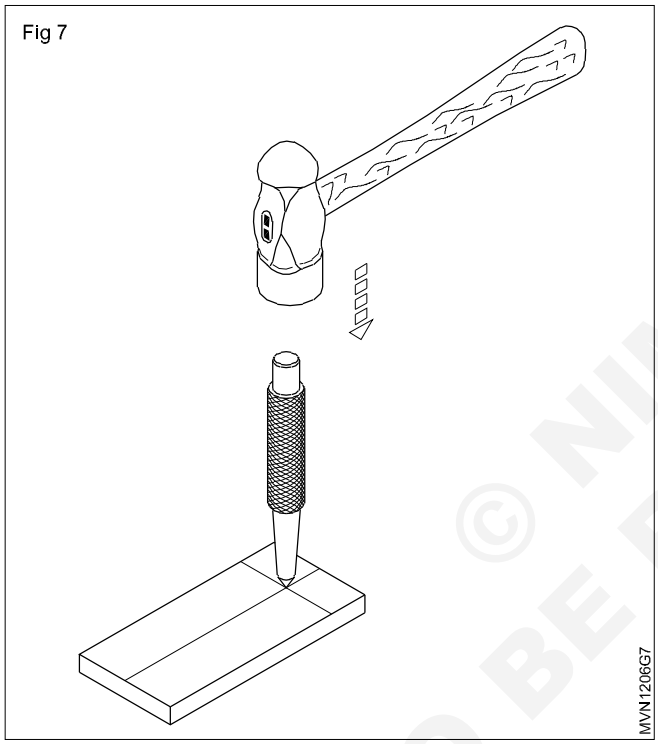
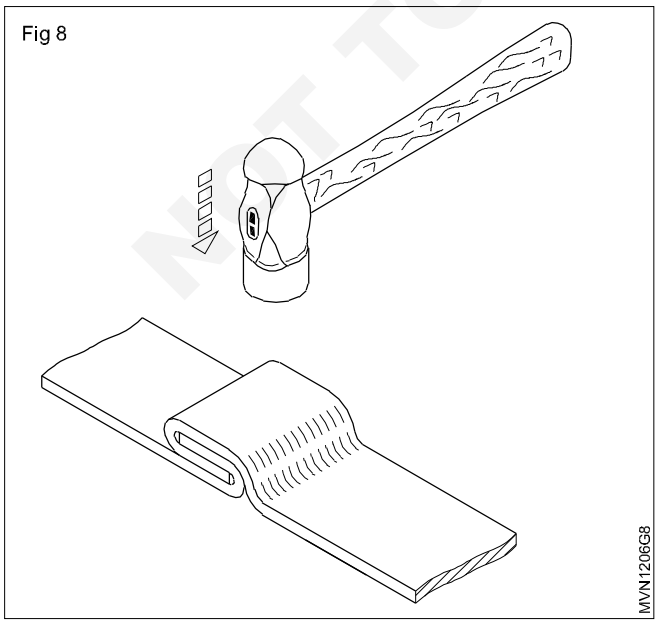


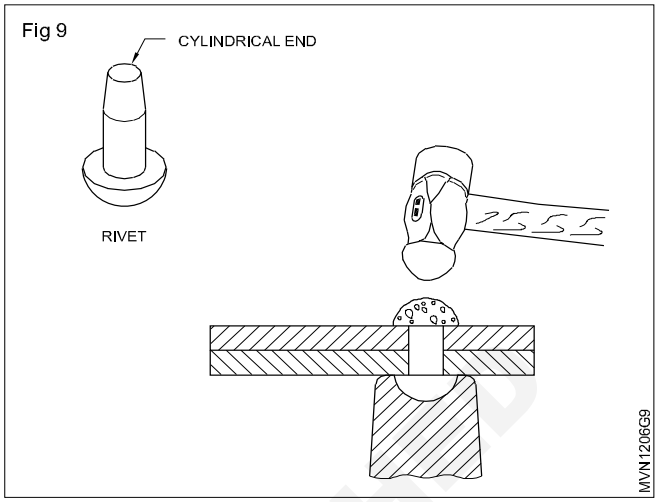

Fig 8




This hammer has a semi-spherical pein suitable for riveting. (Fig 9)

It is used for shaping the cylindrical end of a metal rivet to form a rivet head.

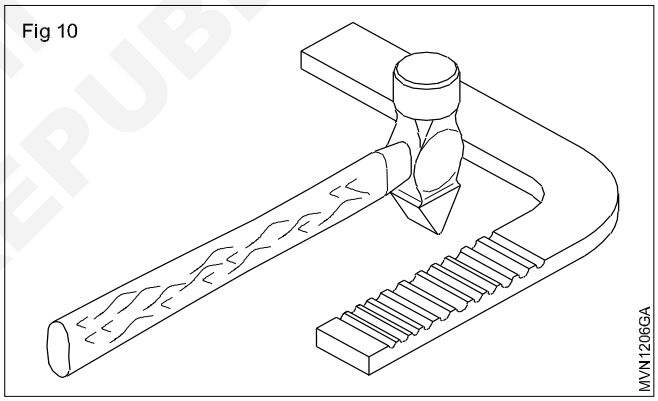
Fig 9




**Cross pein hammer (Fig 10):** A cross pein head is used to spread metal in one direction in the line of striking.

This has a blunt wedge-shaped pein at right angles to the axis of the handle.

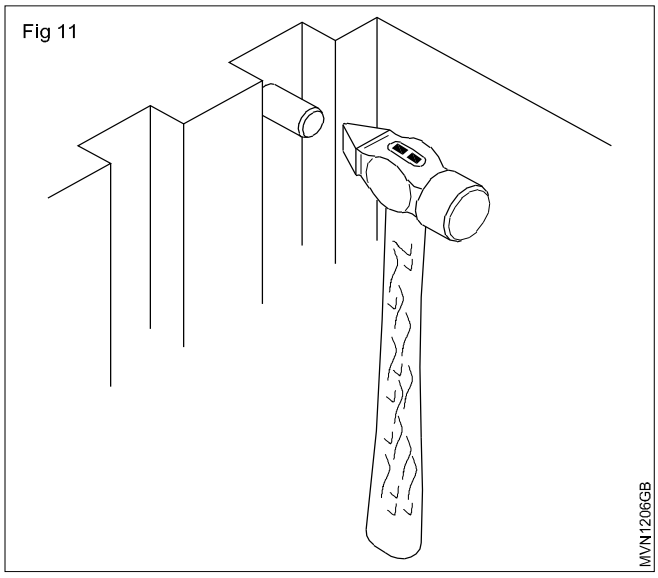
Fig 10




**Straight pein hammer**

A straight pein hammer is used to spread metal in one direction at right angles to the line of striking (Fig 11)

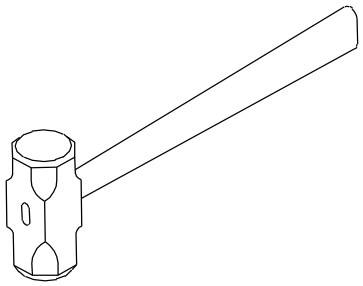
Fig 11



This hammer has a blunt wedge-shaped pein in line with the axis of the handle.

A lump hammer or club hammer is a small sledgehammer (Fig 12) whose relatively light weight and short handle allow single-handed use. It is useful for light demolition work, driving masonry nails, and for use with a steel chisel when cutting stone or metal. In this last application, its weight drives the chisel more deeply into the material being cut than lighter hammers.

Fig 12



MVN1206GC

## Wooden Mallet

**Objectives:** At the end of this lesson you shall be able to
- **name the different types of mallets**
- **state the uses of each type of mallets.**

### Mallets

Mallets are soft hammers and are made of raw hide, hard rubber copper, brace, lead or wood, and are used to strike a soft and light blow on the metal.

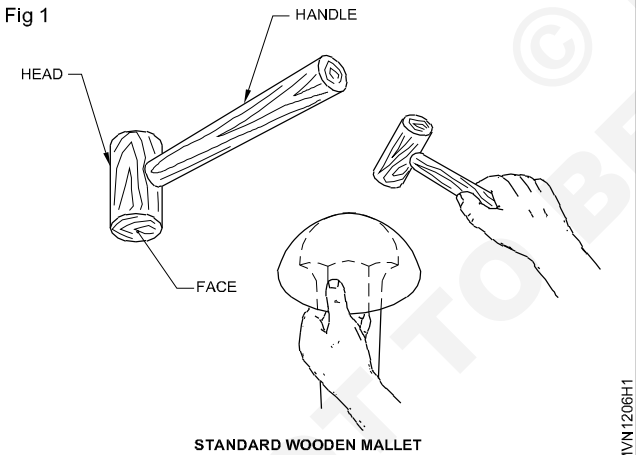
### Types and uses

Standard wooden mallets (Fig 1) are used for general purpose work like flattening, bending etc.

Bossing mallets (Fig 2) are used for hollowing panel beatings etc.

An end-faked mallet (Fig 3) is used for stretching, hammering etc.

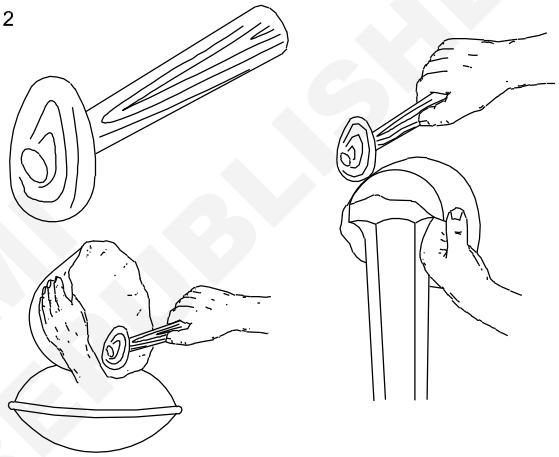
Fig 1




STANDARD WOODEN MALLET

MVN1206H1

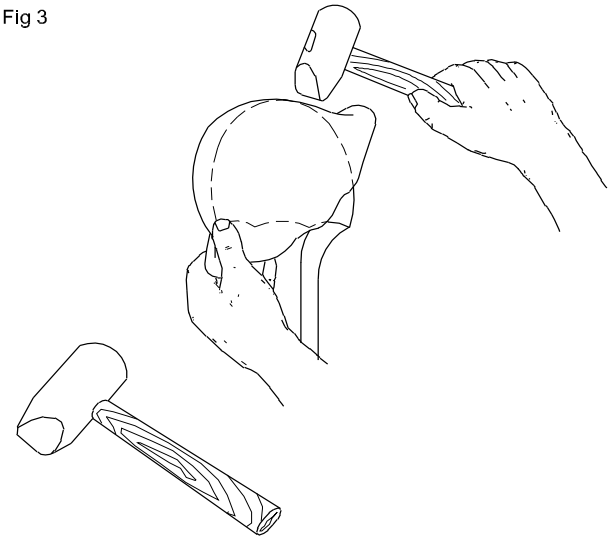
Fig 2



SHAPING THE HEMISPHERICAL BOWL BY RAISING
BOSSING MALLET

MVN1206H2

Fig 3



MVN1206H3

# Screwdrivers

**Objectives:** At the end of this lesson you shall be able to
- **classify the hand-held screwdrivers and state the features of standard screwdrivers**
- **list out the different types of special screwdrivers and their specific uses**
- **specify standard screwdrivers.**

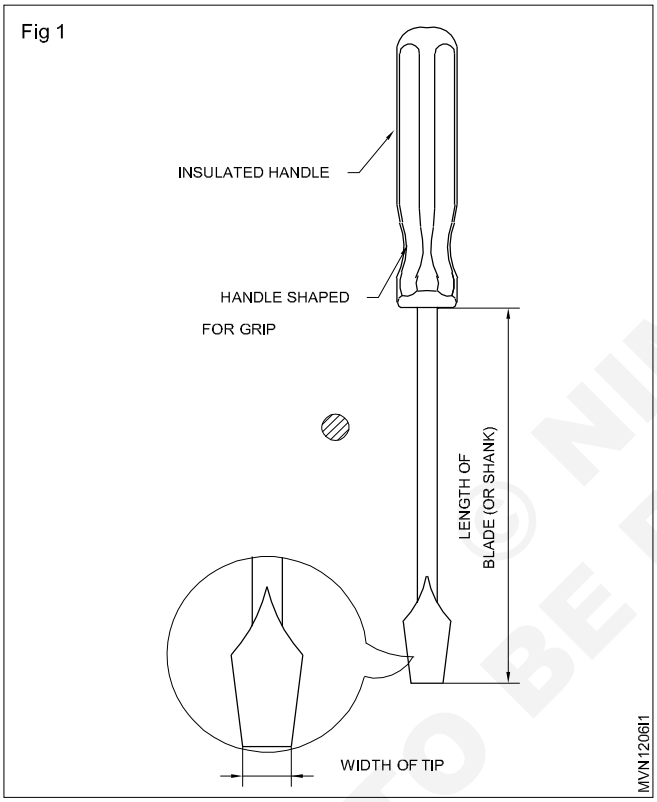
Screwdrivers are used to tighten or loosen screws which are fixed in the machine element.

**Classification**

- Standard type with tips to suit recessed head screw slots.
- Special type with tips to suit recessed head screws

**Features of Standard screwdrivers (Fig 1)**

Fig 1




Screwdrivers must have:

- tips (1) of turn screws with slotted heads
- handles of metals, wood or moulded insulating material(2), shaped to give a good grip for turning (3).
- blades of hardened and tempered carbon steel or alloy steel
- round or square blade with length (4) ranging from 40mm to more than 350mm.
- flared tips which vary in length and thickness with the length of the blade.

**Standard Screwdrivers:** Standard screwdrivers are classified as:

- heavy duty screwdrivers
- light duty screwdrivers
- stumpy screwdrivers

**Heavy duty screwdrivers (Fig 2 & 3)**

This screwdriver has a square blade for applying extra twisting force with the end of the spanner. Heavy duty screwdrivers of London pattern have a flat blade and are mostly used by carpenters.

Fig 2

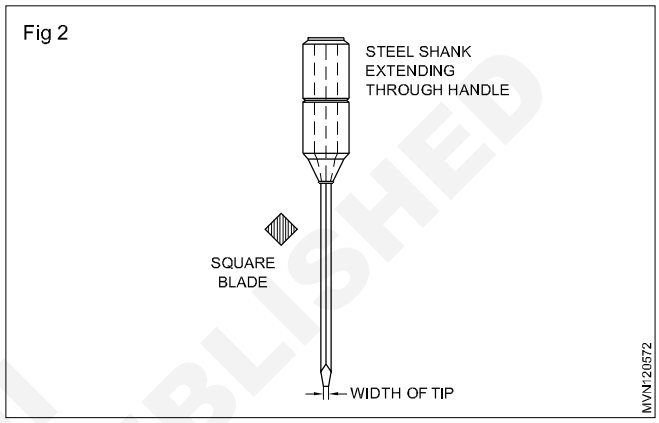
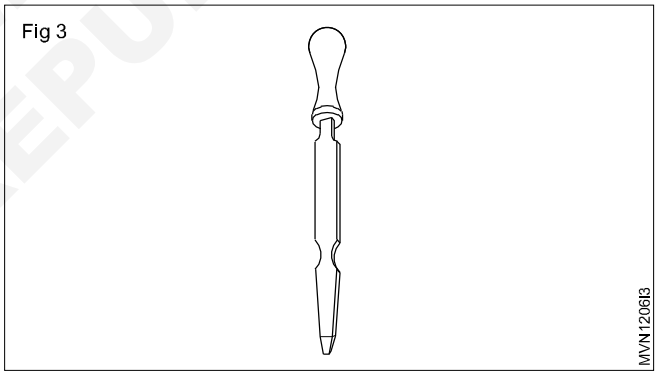


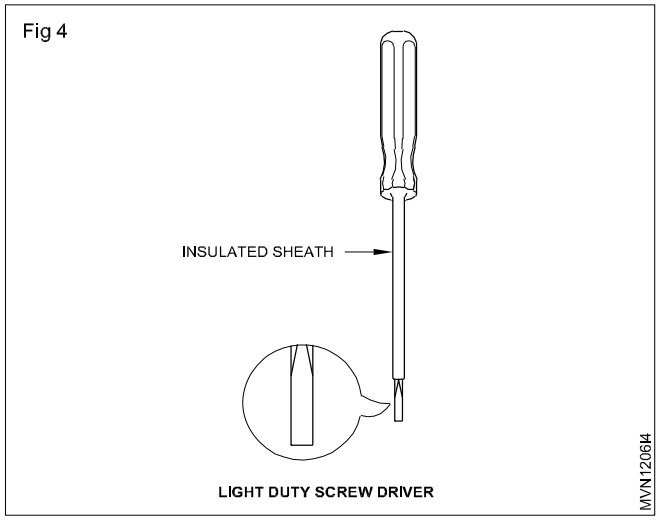

Fig 3




**Light duty screwdrivers (Fig 4)**

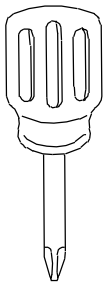
This screwdriver has a round blade with parallel tips. This screwdriver is used by electricians. The blades are sheathed in insulation to avoid short circuiting live parts.

Fig 4



**Stumpy screwdrivers (Fig 5):** These are small sturdy screwdrivers. They are used when other types of screwdrivers cannot be used due to the space limitations.

Fig 5



STUMPY SCREW DRIVER

MVN12065

**Special screwdrivers and their uses**

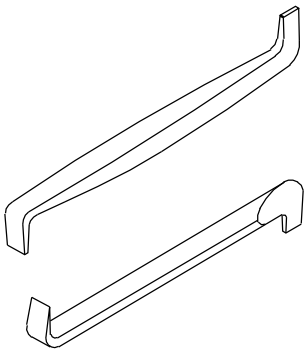
**Offset screwdriver (Fig 6)**

Offset screwdrivers are used on screws which are placed in blind spaces.

They are made with short blades and with the tips at right angle.

Greater turning force can be applied on screws by these screwdrivers because of their leverage.

Fig 6



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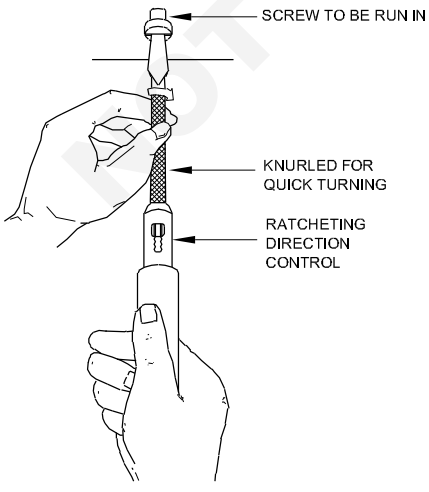
**Ratchet screwdriver (Fig 7)**

The following are the features of ratchet screwdrivers.

These screwdrivers are made with a three-position ratchet control for screwing, unscrewing of a screw and also providing a neutral position.

Fig 7




RATCHET SCREWDRIVER

MVN12067

They are used for tuning screws in confined spaces.

They can be operated without changing the hand grip.

They are used for slackening or tightening with a medium force.

They are used in mass production.

**Phillips (cross-recess) screwdrivers (Fig 8)**

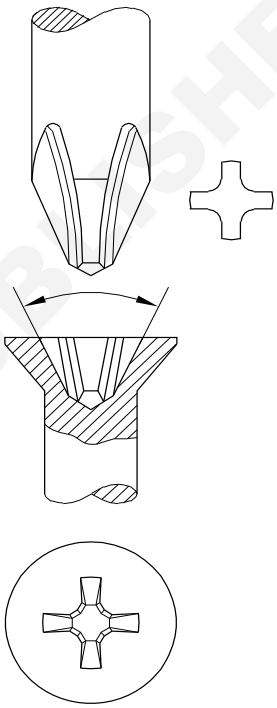
Phillips screwdrivers have cruciform or cross-shaped tips that are unlikely to slip from the cruciform slots in Phillips recessed head screws.

The end of the four flats is tapered to an angle of 53°

The extreme end is ground to 110°.

Four different sizes to cover the full range of screws are available. These are specified by point sizes 1,2,3 & 4 which correspond to the size of the Phillips screw heads.

Fig 8



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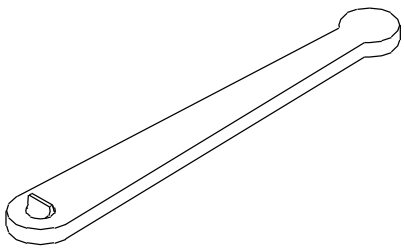
For quicker application ratchet offset screwdrivers are also available with renewable tips. (Fig 9)

Fig 9



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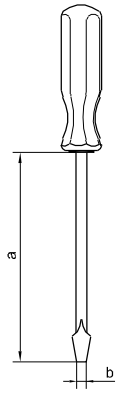
**Specification:** Screwdrivers are specified (Fig 10) according to the

- length of the blade (a)
- width of the tip (b).

Normal blade length : 45 to 300mm. Width of blade : 3 to 10mm.

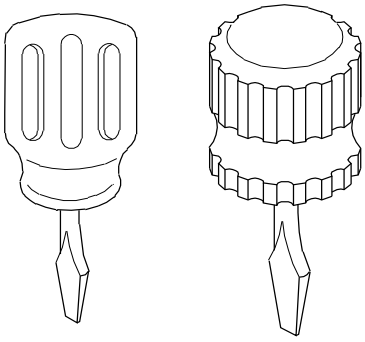
The blades of screwdrivers are made of carbon steel or alloy steel, hardened and tempered.

Fig 10



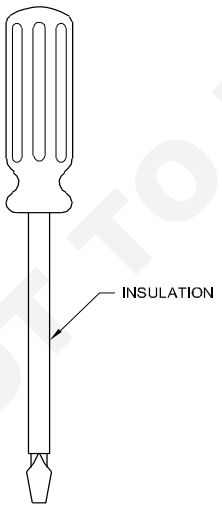

**Screwdrivers for special uses:** Small sturdy screwdrivers (Fig 11) are available for use where there is limited space.

Fig 11




Screwdrivers with blades sheathed in insulation are available for the use of electricians (Fig 12)

Fig 12



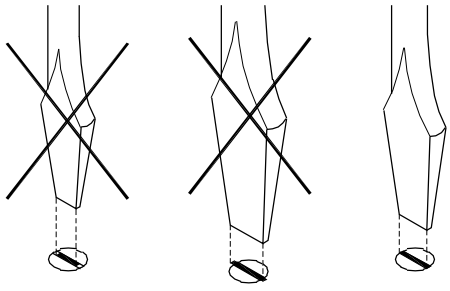

**Precautions**

Use screwdrivers with tips correctly fitting into the screw slot. (Fig 13)

Make sure your hand and the handle are dry.

Hold the screwdrivers axis in line with the axis of the screw.

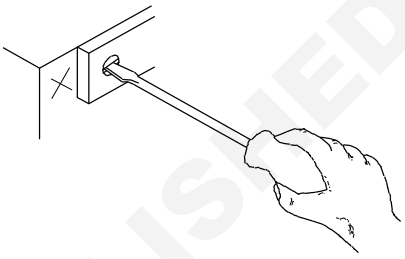
Fig 13




While using a Philips screwdriver apply more downward pressure.

Keep your hand away to avoid injury due to slipping of the screwdriver. (Fig 14)

Fig 14

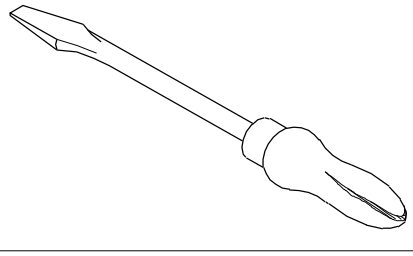



Do not use screwdrivers with split or defective handles. (Fig 15)

In the case of damaged screwdrivers, the blades can be ground (the faces will be parallel with the sides of the screw slot) and used. While grinding ensure the end of the tips is as thick as the slot of the screw.

While using screwdrivers on small jobs, brace the job on the bench or hold them in a vice.

Fig 15



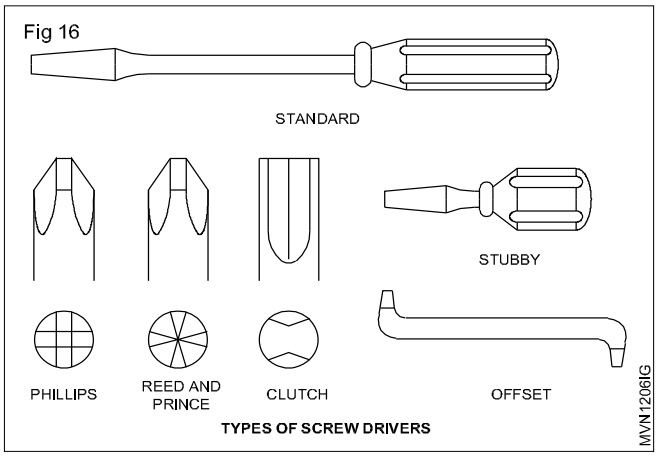

**Specification of a screwdriver:** Screwdrivers are specified according to the;

- length of the blade
- width of the tip

The normal blade length varies from 45mm to 300mm and the width of the blade varies from 3mm to 10mm.

**Screw driver (Fig 16):** There are several different size of screw drivers of the standard, reed & prince & phillips types.

The offset screw driver is useful in tight quarters where even a “Stubby” cannot be used.




**Safety**

1 Always use correct type and size screw drivers.

2 Don't do repair work by holding the job on the hand with the help of screw driver, if may slips it pierce the hand.

## Allen keys

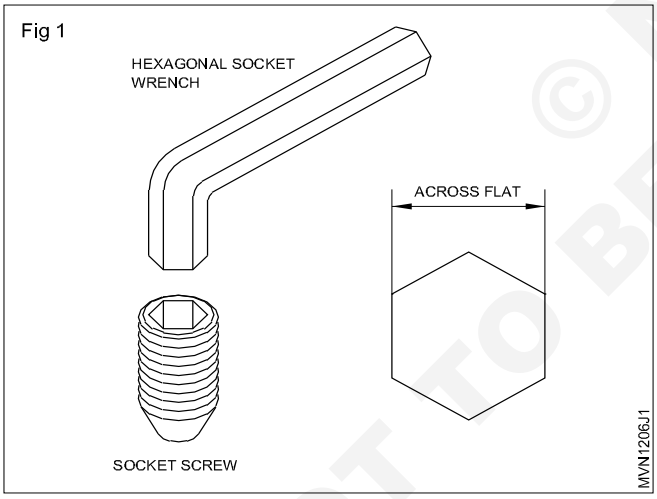
**Objectives:** At the end of this lesson you shall be able to
- **state the features and uses of hexagon socket screw keys**
- **specify hexagon socket screw keys**.

Hexagon socket screw keys/Allen keys are made from hexagonal section bars of chrom vanadium steel.

These are hardened and tempered. These are bent to `L' shape. The size of an Allen key is identified by the size across the flat of the hexagon.

**Uses**

They are used to tighten or loosen screws having internal hexagon sockets. (Fig 1)




Allen keys, available in different sets in plastic wallets, surprise of a set of 8 (2 to 10mm)

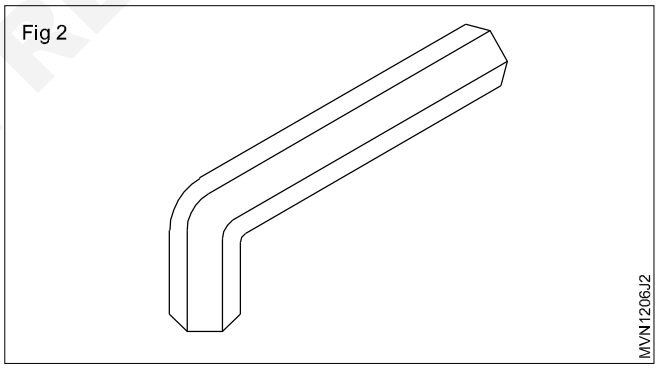
2,3,4,5,6,7,8 and 10mm

**Sizes of Allen keys (Fig 1)**

Individual pieces are available as follows 1, 1.5, 2, 2.5, 3, 4, 5, 6, 8, 10, 12, 14, 17, 19, 22, 24, 27, 32 and 36.

**Designation of Allen keys (Fig 2)**

A hexagonal socket screw key of width across flat 8 mm shall be designated as Key 8 IS:3082.




## Bench vice

**Objectives:** At the end of this lesson you shall be able to
- **name the parts and uses of a bench vice**
- **specify the size of a bench vice**
- **state the uses of vice clamps.**

Scan the QR Code to view the video for this exercise

Vices are used for holding workpieces. They are available in different types. The vice used for bench work is called as bench vice or (Engineer's vice)

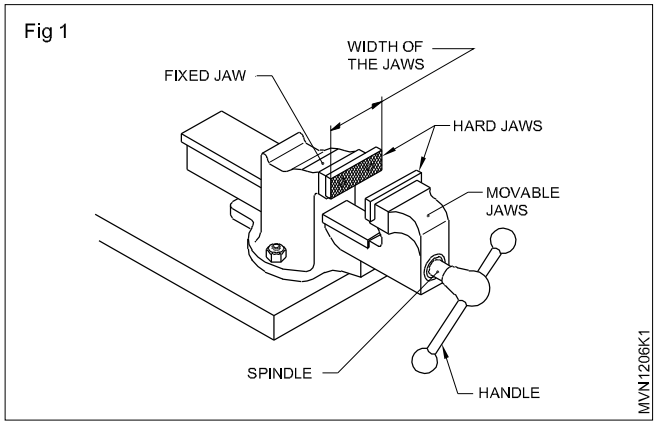
A bench vice is made of cast iron or cast steel and it is used to hold work for filling, sawing, threading and other hand operations.

The size of the vice is stated by the width of the jaws.

Parts of a bench vice (Fig 1)

The following are the parts of the vice

The Vice is generally bolted and secured in a wooden work table, and is useful for operations like filing, chipping, hacksawing, bending sheet metal etc.



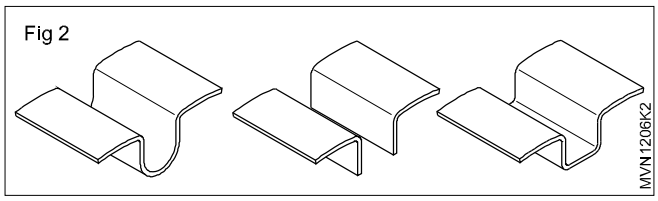

Fixed jaw, movable jaw, hard jaws, spindle, handle, box-nut and spring are the parts of vice.

The box-nut and the spring are the internal parts.

Vice clamps or soft jaws (Fig 2)

The hold a finished work use soft jaws (vice clamps) made of aluminium over the regular jaws. This will protect the work surface from damage.

Do not over-tighten the vice as, the spindle may get damaged.




Scan the QR Code to view the video for the exercise

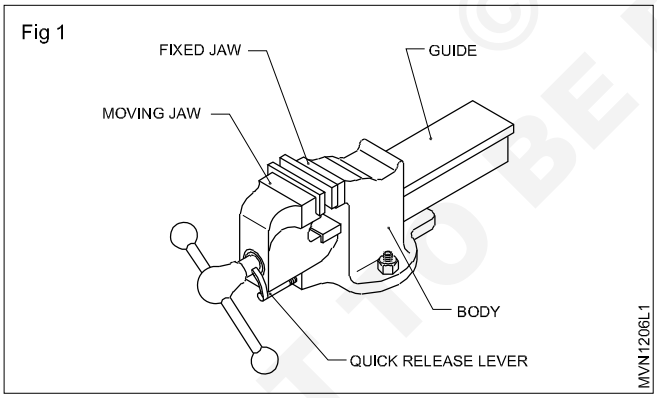
## Types of vices

**Objectives:** At the end of this lesson you shall be able to
- **state the construction and advantages of a quick releasing vice**
- **state the uses of pipe vice, toolmakers vice, hand vice and pin vice.**

There are different types of vices used for holding workpieces. They are quick releasing vice, pipe vice, hand vice pin vice and toolmaker's vice.

**Quick releasing vice (Fig 1)**

A quick releasing vice is similar to an ordinary bench vice but the opening of the movable jaw is done by using a trigger (lever). If the trigger at the front of the movable jaw is pressed, the nut disengages the screw and the movable jaw can be set in any desired place quickly.



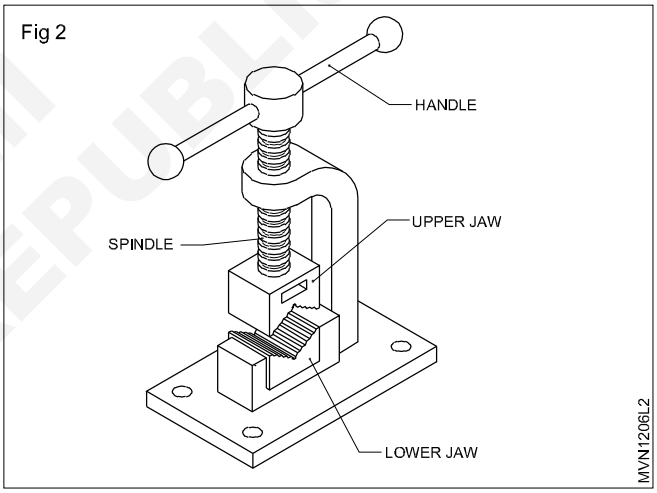

**Pipe vice (Fig 2)**

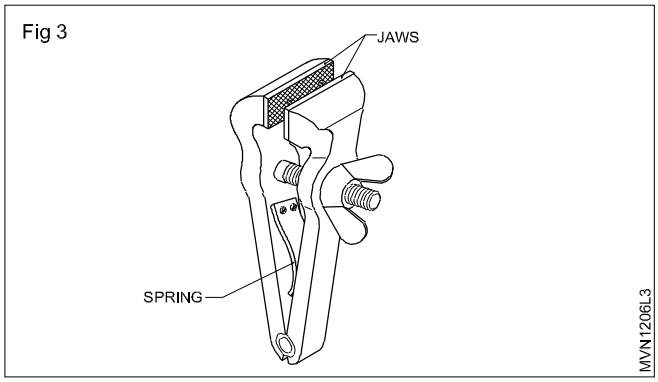
A Pipe vice is used for holding round sections of metal, and pipes. In this vice, the screw is vertical and movable. The jaw works vertically.

The pipe vice grips the work at four points on its surface. The parts of a pipe vice are shown in Fig 2.

**Hand vice (Fig 3):** Hand vices are used for gripping screws, rivets, keys, small drills and other similar objects which are too small to be conveniently held in the bench vice.

A hand vice is made in various shapes and sizes. The length varies from 125 to 150 mm and the jaw width from 40 to 44 mm.

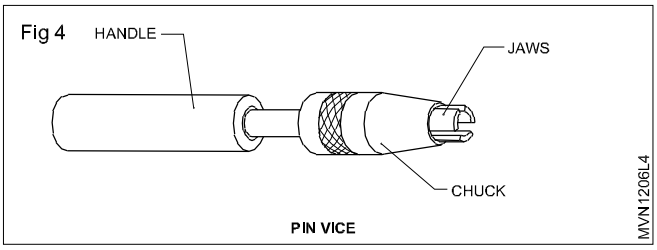



The jaws can be opened and closed using the wing nut on the screw that is fastened to one leg, and passes through the other.

**Pin vice (Fig 4)**

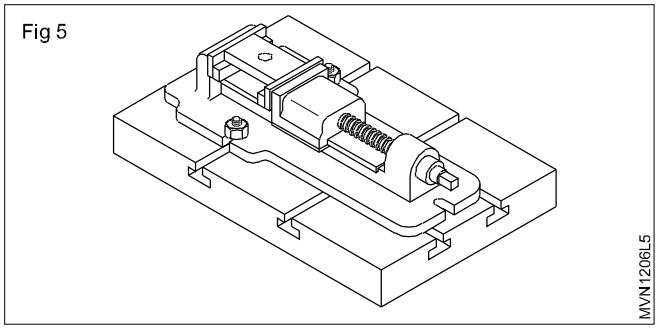
The pin vice is used for holding small diameter jobs. It consists of a handle and a small collect chuck at one end. The chuck carries a set of jaws which are operated by turning the handle.




**Toolmaker's vice (Fig 5)**

The toolmaker's vice is used for holding small work which required filing or drilling and for marking of small jobs on the surface plate. This vice is made of mild steel.

Toolmaker's vice is accurately machined.




## C - Clamps and toolmaker's clamps

**Objectives:** At the end of this lesson you shall be able to
- **state the purpose of using clamps**
- **specify the requirements of the clamping devices**
- **state the features and uses of 'C' clamps**
- **state the features of Toolmaker's clamps.**

**Purpose of using clamps:** Clamps are used for preventing the movement of work, and for holding the job tight.

**Requirements of clamping devices**

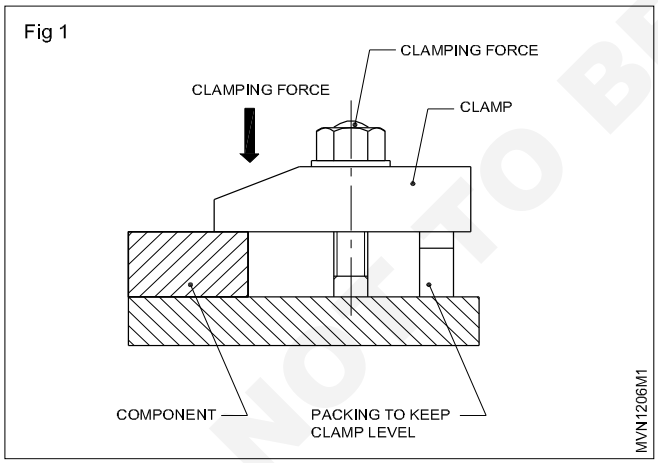
Should be able to manipulate for easy loading.

Should provide the required clamping force.

Should be capable of locking with minimum movement.

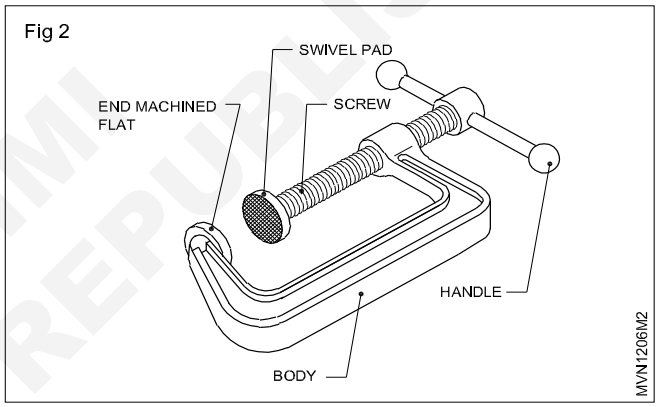
Should accommodate a range of sizes of jobs.

(Fig 1) shows a typical clamping device, employing a screw and nut to provide the clamping force.




**'C' Clamps:** These clamps are in the shape of a 'C'. The 'C' clamp has its body forged or cast. One end of the clamp is machined flat. The other end is drilled and threaded to accommodate a screw-rod which is operated by a handle. The screw-rod carries a swivel pad which is free to revolve. The clamp is hardened and the face is serrated. (Fig 2)

These clamps are used to hold work, on an angle plate or a drill press table, and also, for holding two or more workpieces together.



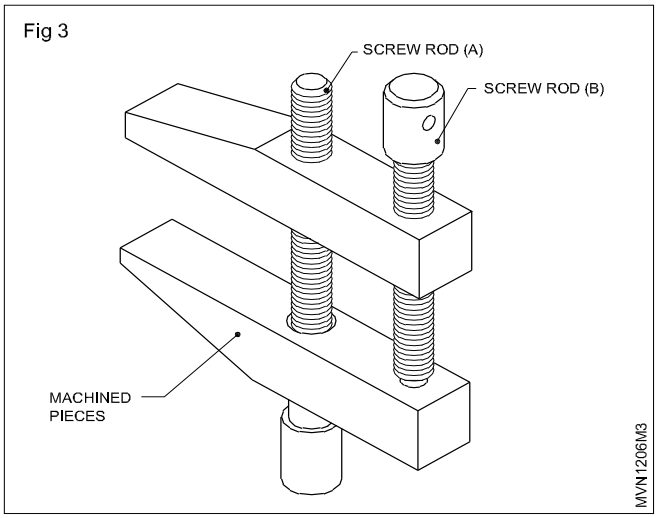

The swivel pad on the end of the clamping screw helps in clamping surfaces which are not parallel. 'C' clamps are available for light and heavy duty work.

**Toolmaker's clamps:** This is the type most commonly used by toolmakers for holding small, machined, flat pieces for further operations. They have two rectangular pieces of steel perfectly machined. The inner faces which come in contact with the workpiece are perfectly parallel.

They are assembled by means of two threaded rods. The screw-rod (A) is rotated in one direction to adjust the gap between the two holding faces. The other screw (B) when tightened maintains the required pressure. (Fig 3)

The head of the screw-rod (B) is provided with a hole through which a cylindrical pin may be passed for tightening purposes. The toolmaker's clamps are for holding a previously machined work which is flat and parallel.

The toolmaker's clamp is not suitable for doing any heavy operations on the workpiece since the contacting and holding area of the clamp is limited. It is meant for holding light jobs. It is also called as parallel clamp.




**'U' Clamps:** These are clamps used along with 'V' Blocks as an accessory. These clamps serve the purpose of holding the round work securely in the 'V' groove for layout operations as well as for machining operations.

## Spanners and their uses

**Objectives:** At the end of this lesson you shall be able to
- **state the necessity of spanners**
- **identify the different types of spanners**
- **specify the spanners**
- **list out the parts of adjustable spanners**
- **state the features of 'C' spanners and their uses.**

Spanners are used for operating threaded fasteners, bolts and nuts. They are made with jaws or opening that fit square on hexagonal nuts and bolts and screw heads. They are made of high tensile or alloy steel. They are drop-forged and heat-treated for strength. Finally they are given a smooth surface finish for ease of gripping.

Spanners are considerably in shape to provide ease of operation under different conditions.

**The basic types of spanners are (Fig 1)**

- Open end spanners (1)
- tube or tubular box spanners (2)
- Socket spanners (3)
- Ring spanners (4)

The correct spanner fits exactly and allows room for use. They should also permit the job to be done in a shorter time.

The following are the points to be noted for using spanners in a safe way. (Fig 2)

Use open end and ring spanners by pulling on the shank. It is safest to pull as there is less chance of hitting your knuckles if the spanner or nut slips suddenly. If you are forced to push the spanner, use the base of your hand and keep your hand open.

Use both hands for large spanners.

Keep yourself balanced and firm to avoid slipping yourself, if the spanner slips suddenly, Hold on to some support, if there is any chance of falling.

Use both hands as shown in the figure, when using tubular box spanners. (Fig 2)

Use two spanners as shown in the figure to stop the head of the bolt rotating as the nut is operated. (Fig 2)

Socket spanners may be turned by accessories which have square driving ends. (Fig 2)

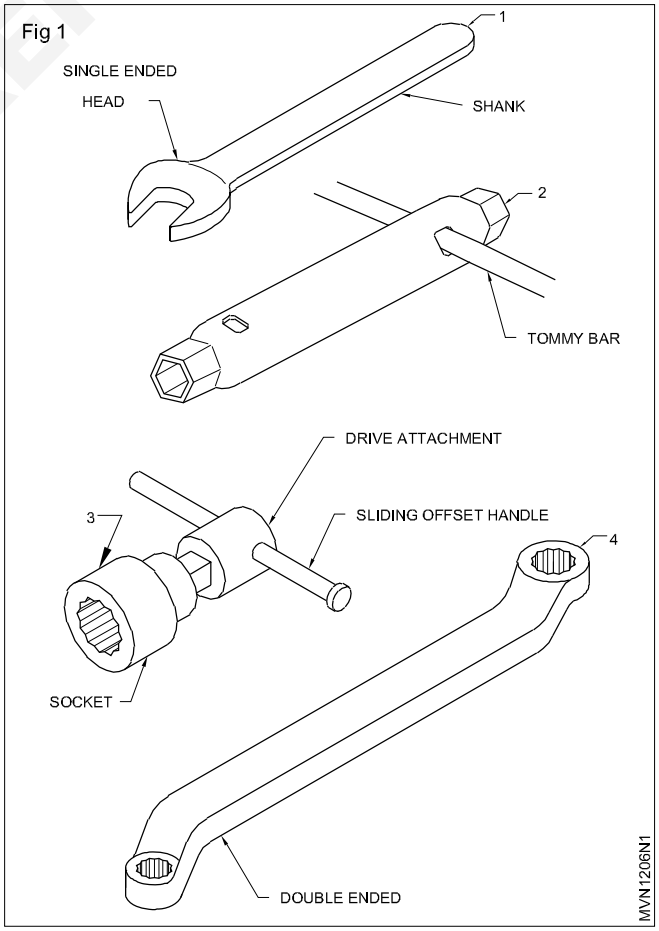
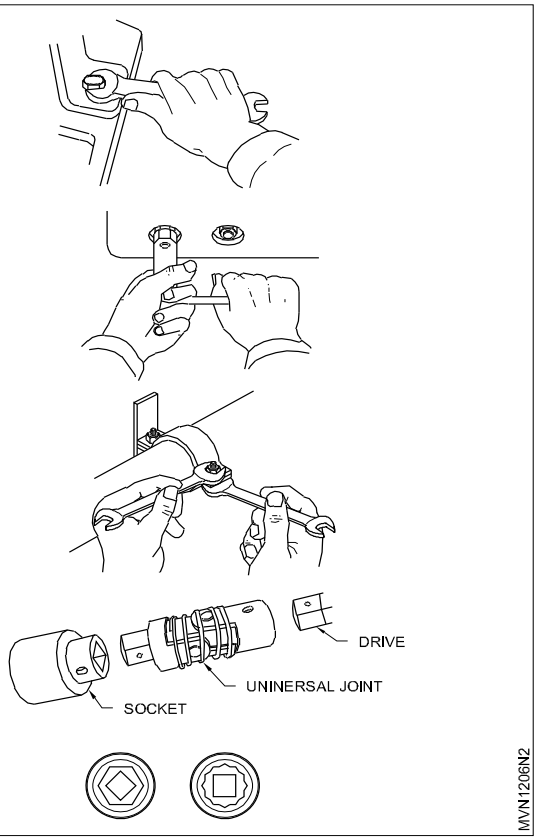


Fig 2

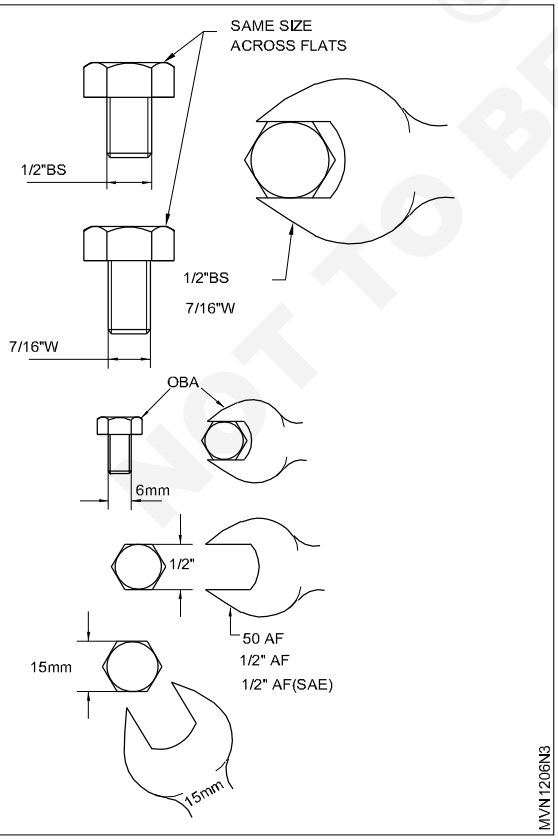



**Size and identification of spanners**

The size of a spanner is determined by the nut or bolt it fits. The distance across the flats of a nut or bolt varies both with the size and the thread system. (Fig 4)

In the British system the nominal size of the bolt is used to identify the spanner. (Fig 3)

Fig 3



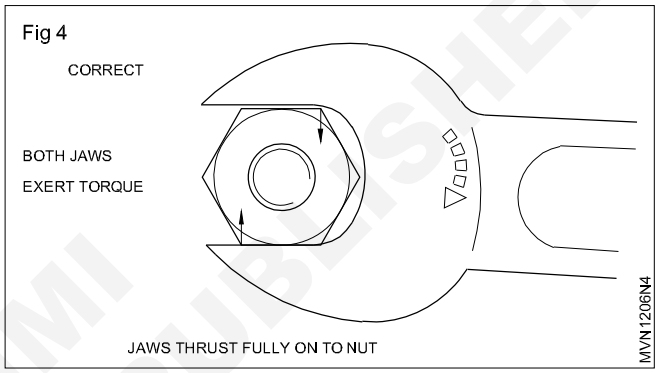

In the unified standard system (Fig 3), the spanners are marked with a number based on the gas requirement decimal equivalent of the nominal fractional size across the flats of the hexagon, following the sign A/F or with the fractional size across the flats following the sign A/F. In the metric system, spanners are marked with the size across the jaw opening followed by the abbreviation 'mm'.

To fit exactly, a spanner must be:

- of the correct size
- placed correctly on the nut
- in good condition.

Spanners have their jaws slightly wider than the width of the nut so that they can be placed into position easily. Any excess more than a few hundredths of a millimeter clearance could cause the spanner to slip under pressure.

Fig 4




**Place the spanner so that its jaws bearfully on the flats of the nut**

Incorrect use damages the spanners & the nuts too.

Discard any defective spanners. The spanners illustrated here are dangerous for use.

Choose spanners that allow room for use.

Nuts in inaccessible positions may be reached with socket spanners, with special drawing accessories. (Flg 5)

**Length of spanners (Fig 6)**

Normally spanners have a length that is about ten times the width of the jaw opening.

Never exert excessive pull on a spanner, particularly by using a pipe to extend the length of a spanner.

Excess turning effect of the spanner could result in:

- striping the thread
- shearing the bolt
- straining the jaws of the spanner
- making the spanner slip and cause an accident.

**Adjustable spanners (Fig 7 & 8)**

Most common types of adjustable spanners are similar to open and spanners, but they have one movable jaw. The opening between the jaws of a typical 250 mm spanner can be adjusted from zero to 28.5mm. Adjustable spanners may range in length from 100mm to 760mm. the type

illustrated has its jaws set an angle of 22 1/2$^0$ to the handle. Adjustable spanners are convenient for use where a full kit of spanners cannot be carried about.

They are not intended to replace fixed spanners which are more suitable for heavy service. If the movable jaw or knurled screw is cracked or worn out, replace them with spare ones.

Fig 5

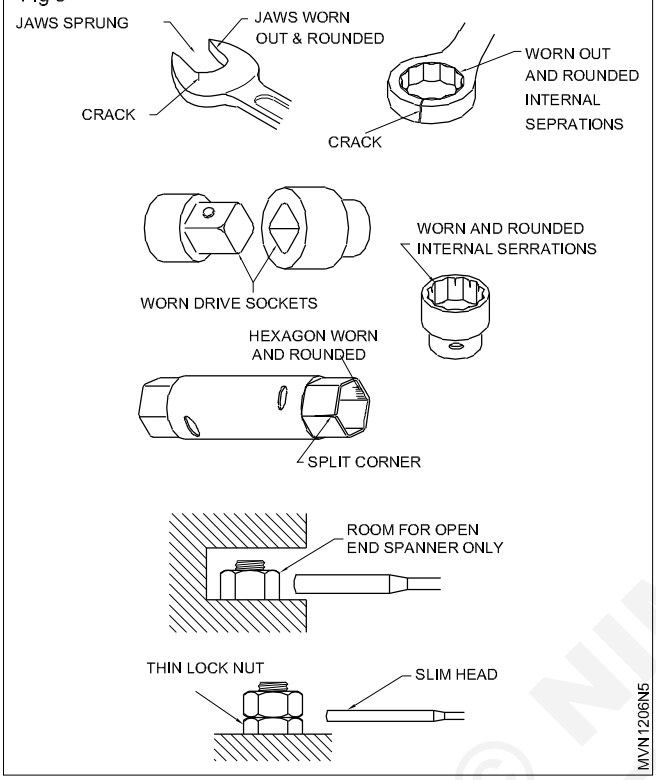



Fig 6

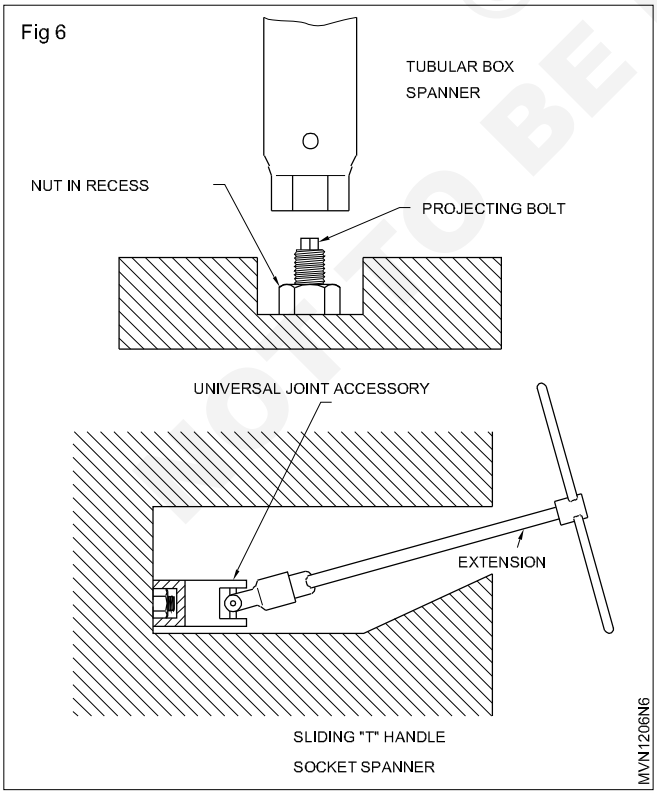



Fig 7

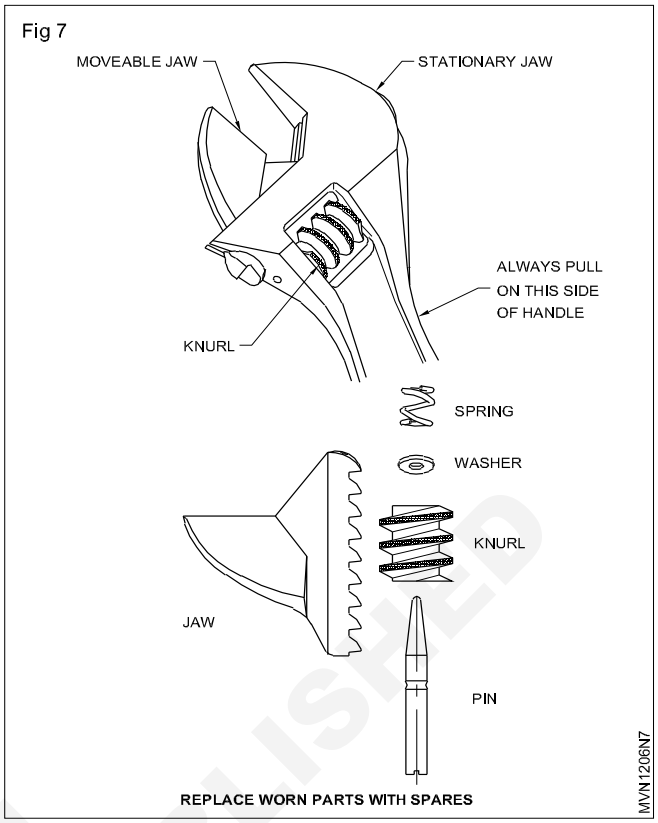
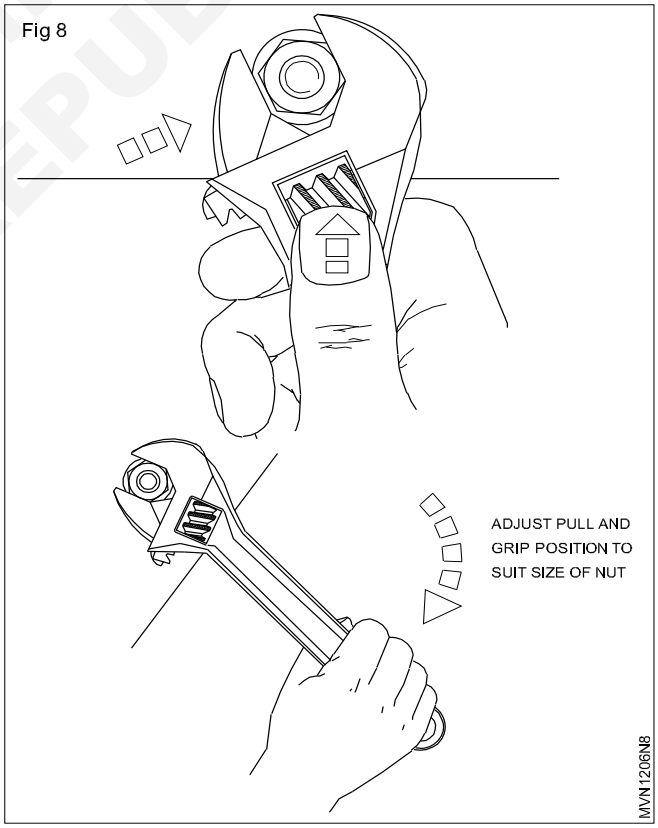



Fig 8




When using the adjustable spanner follow the steps given below.

Place it on the nut so that the jaw opening points in the same general direction the handle is to be pulled. In this position the spanners are less liable to slip and the required turning force can be exerted without damage to the moving jaw and knurl.

Push the jaws into full contact with the nut.

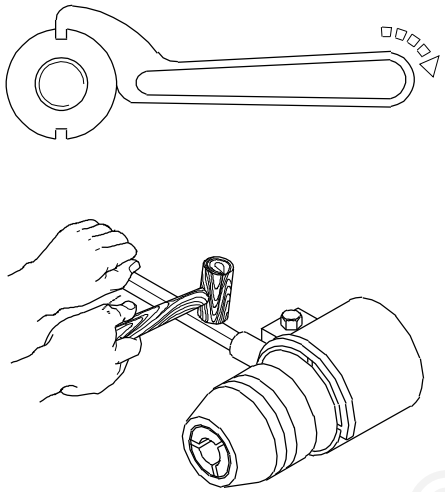
Use the thumb to tighten the adjusting knurl so that the jaws fit the nut strongly.

Pull continuously. The length of the handle is designed to suit the maximum opening of the jaws. With small nuts, a very small pull on the handle will produce the required torque.

**'C' spanners (Hook spanners) (Fig 9):** It has a lug that fits in a notch, cut in the outer edge of a round nut. The 'C' section is placed around the nut in the direction in which it is to be turned. In adjustable hook wrenches, part of the 'C' section pivots to fit nuts with a range of diameters. A set of three spanners is needed to cover diameters from 19 mm to 120 mm.

The applications of 'C' spanners are shown in the figure.

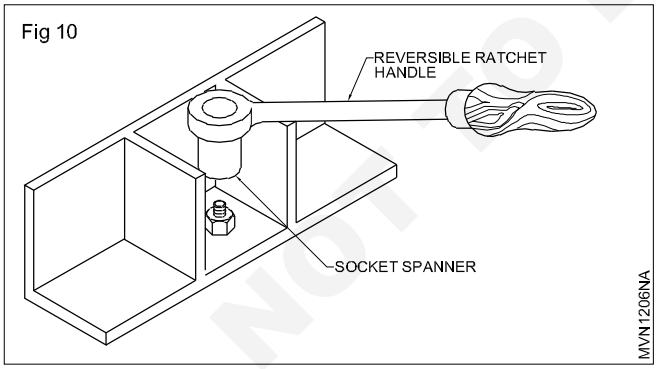
Fig 9




C' Spanners are also used for zero - setting of micrometer.

With socket spanners (Fig 10), use the reversible ratchet handle for doing fast work, where turning space is restricted.

Fig 10




**Ring or box spanner (Fig 11):** For critical tightening and loosening of nuts. For multi contact on bolts and nuts.

**Pliers (Fig 12):** Pliers are commonly used for cutting wires, holding parts, crimping electrical connections and bending cotter pins.

**Safety**

1 Avoid cutting hardened objects.

2 Never use pliers to turn nuts, bolts or tubing fitting.

Fig 11

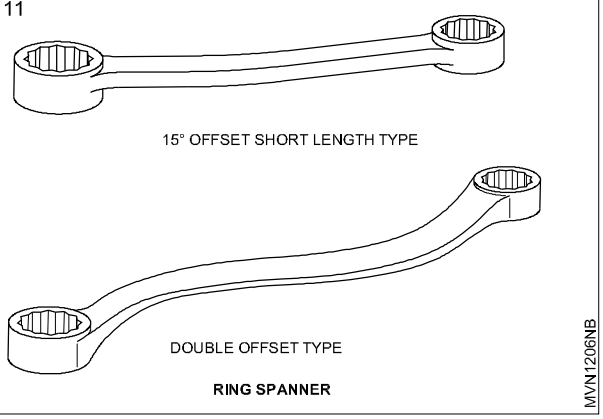
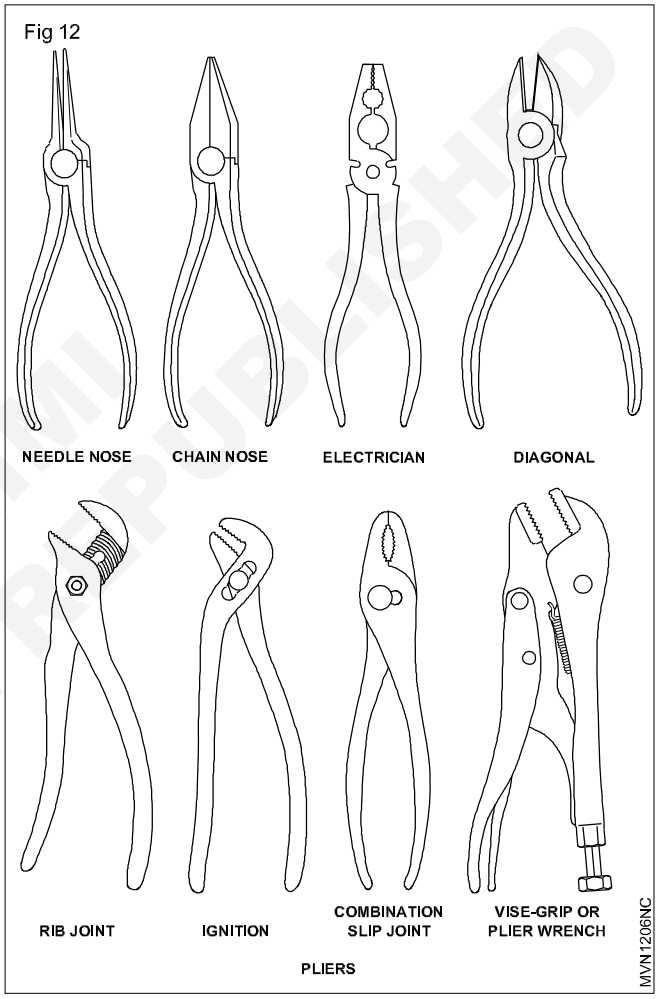
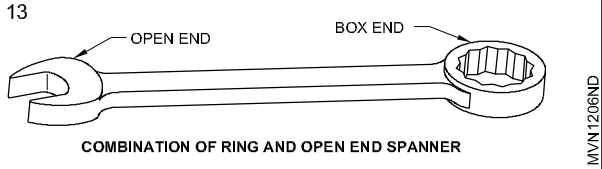



Fig 12



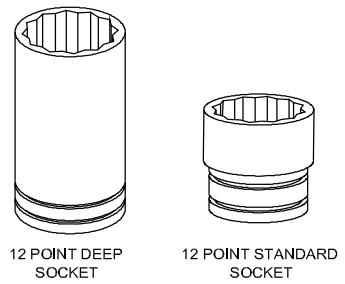

**Combination of ring and open end spanner (Fig 13):** This tool has a box end on one end and an open end on the other. Both ends are of the same size.

Fig 13




**Socket spanners (Fig 14):** The socket is one of the fastest and most convenient of all the spanners. Sockets come in two sizes; standard and deep.

Fig 14



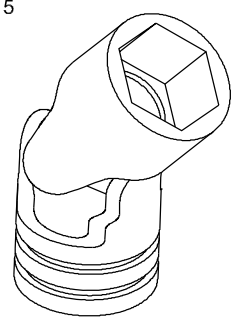

SOCKET SPANNER

MVN1206NE

Standard sockets will handle the most of the works, while the extra reach of the deep socket is occasionally needed.

**Swivel socket (Fig 15):** The swivel socket allows the user to turn fasteners at an angle.

Fig 15

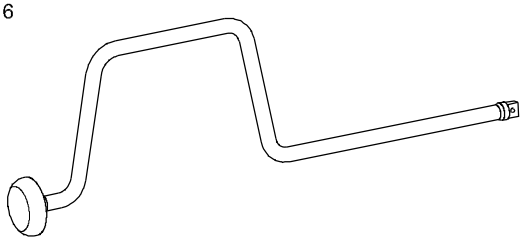



SWIVEL SOCKETS

MVN1206NF

**Socket handles:** Several different drive handles are used. The speed handle (Fig 16 & 17) is used whenever possible as it can be turned rapidly.

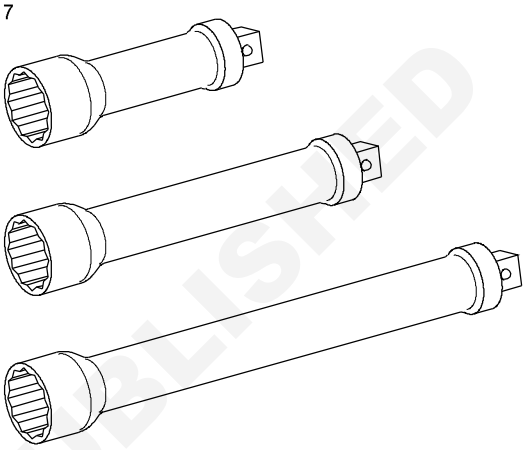
Fig 16



SOCKET SPEED HANDLE

MVN1206NG

Fig 17



SOCKET EXTENSION BARS

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## Pliers

**Objectives:** At the end of this lesson you shall be able to
- **state the features of pliers**
- **state the uses of pliers.**

**Features:** Pliers have a pair of legs joined by a pivot, hinge or fulcrum pin. Each leg consists of a long handle and a short jaw.

**Elements of pliers with two joint cutters (Fig 1) (Combination pliers)**

- Flat jaw
- Pipe grip
- Side Cutters
- Joint cutters
- Handles

**Features**

Flat jaw tips are serrated for general gripping.

Pipe grip is serrated for gripping cylindrical objects. (Fig 2)

Cutters are provided for cutting off soft wires. (Fig 3)

Two joint cutters are provided for cutting or shearing off steel wires (Fig 4)

Handles are used for applying pressure by hand.

Pliers are available in sizes from 150 mm to 230 mm. (Size = Overall length)

Fig 1

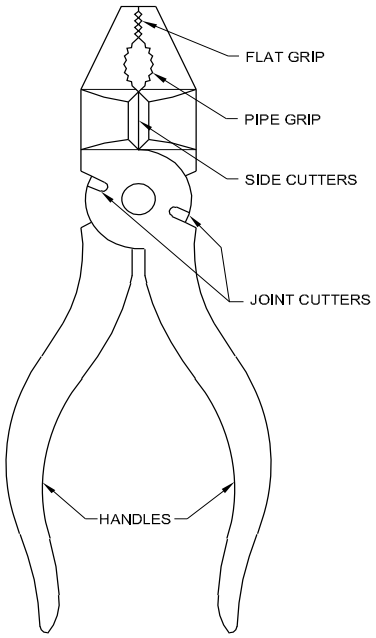


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Fig 2

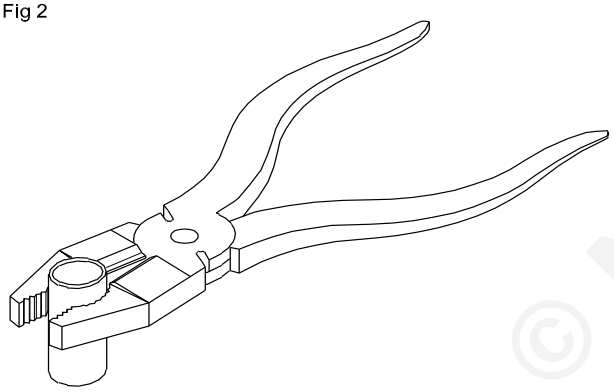

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Fig 3

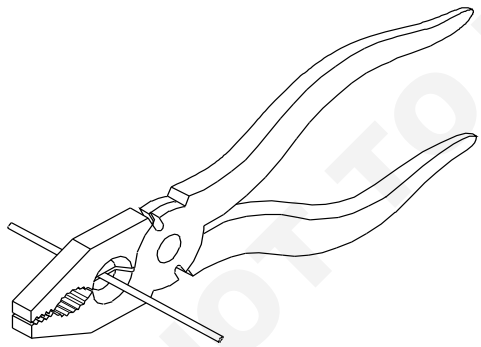

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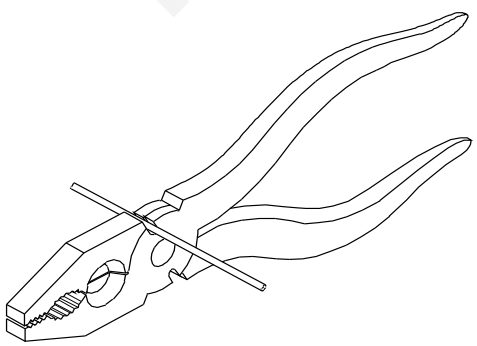
Fig 4



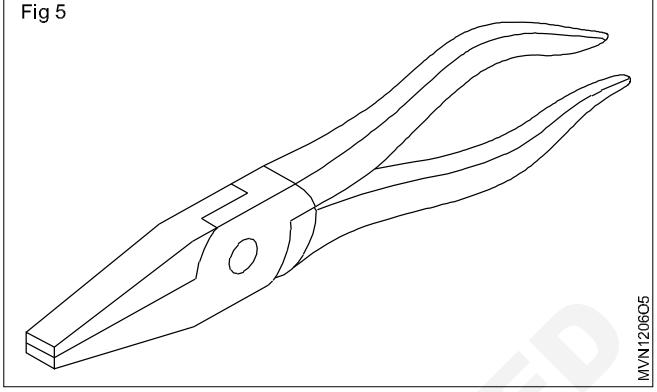
MVN1206O4

**Other types of pliers**

**Flat nose pliers**

It has tapered wedge jaws with flat gripping surfaces which may be either smooth or serrated. (Fig 5)

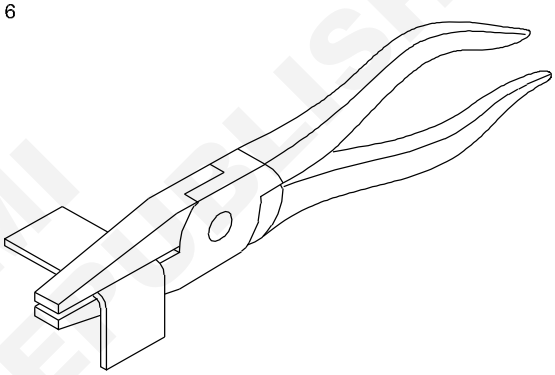
Fig 5



MVN1206O5

It is used for bending & folding narrow strips of thin (Fig 6)

Fig 6



MVN1206O6

**Roundnose Pliers**

This type of pliers is made with tapered round shaped (Fig 7) They are used to shape loops in wires and the form curves in light metal strips (Fig 8)

Fig 7

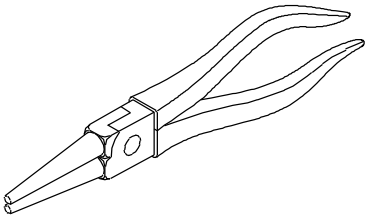


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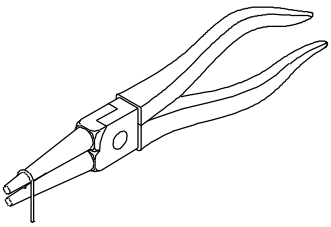
Fig 8

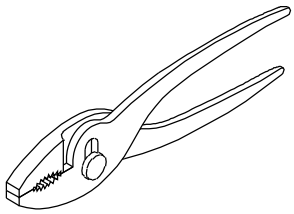


MVN1206O8

**Slip-joint pliers:** These pliers are available in various ranges of positions with different shapes of pivot pins so that they have various ranges of jaw opening.

Mainly used for gripping. (Fig 9)

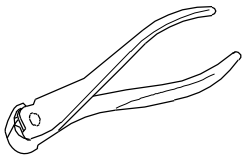
Fig 9



MVN1206O9

**End cutting pliers:** These pliers have the same uses as the side cutting pliers. (Fig 10)

Fig 10

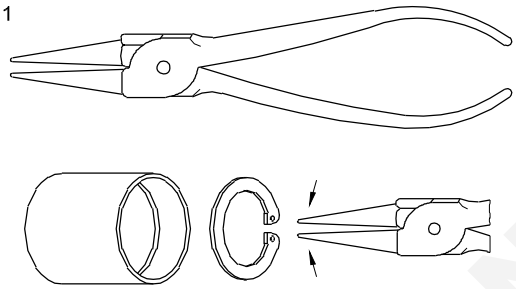


MVN1206OA

**Circlip pliers:** Circlip pliers are used for fitting and removing circlips in assembly works.

**Internal circlip plier:** It is used to fit and remove the internal circlip in the groove of the bore. (Fig 11)

Fig 11



MVN1206OB

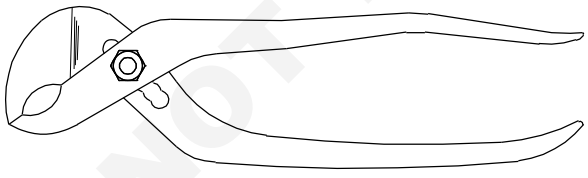
**Slip-joint, multi-grip pliers:** It is similar to the grip pliers but has more openings in the legs. It gives a range of jaw openings. It allows parallel gripping by the jaws in a number of positions. (Fig 12)

The shape and length of the leg are different from those of the slip-joint pliers. (Fig 13)

**Side cutting pliers**

It is made with jaws set at an angle (Fig 14).

Fig 12



MVN1206OC

Fig 13

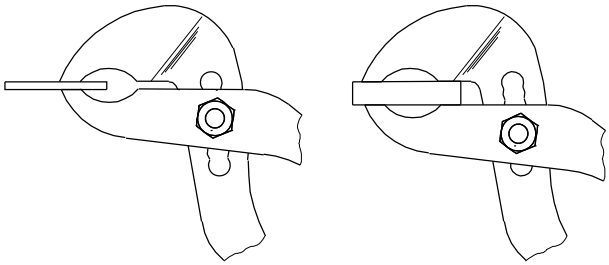


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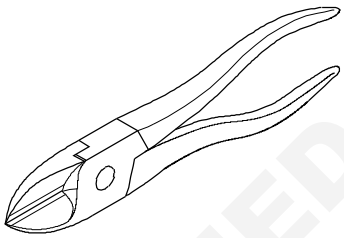
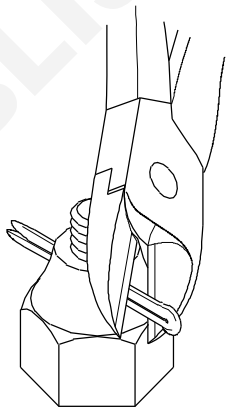
Fig 14



MVN1206OE

They are used for shearing off wires in confined spaces and cutting off wires close to the surface level. (Fig 15)

Fig 15



MVN1206OF

They are also used for spreading the cotter pin.

**External circlip pliers**

External circlip pliers are used to fit and remove the external circlip in the grooves of the shafts.

**Locking pliers**

The locking lever of the locking pliers is attached with a movable handle which clamps the jaws on to an object of any shape.

It has high gripping power.

The screw in the handle enables adjustment of the lever action to the work size.

# SNIPS (Straight & Bent)

**Objectives:** At the end of this lesson you shall be able to
- **state the uses of straight and bent snips**
- **state the features and use of lever shears**
- **state the uses of circle cutting machines.**

A snip, also called a hand shear and it is used like a pair of scissors to cut thin, soft metal sheets. Snips are used to cut sheet metal upto 1.2mm thickness.

**Types of snips (shears)**

There are several types of snips available for making straight or circular cuts, the most common being straight snips and curved snips.

The choice of shears (snips) depends on the shape and type of the cut required.

**Straight snips (Figs 1& 2)**

Fig 1

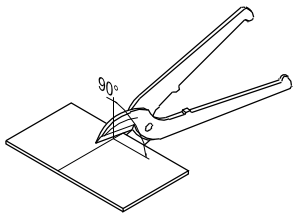
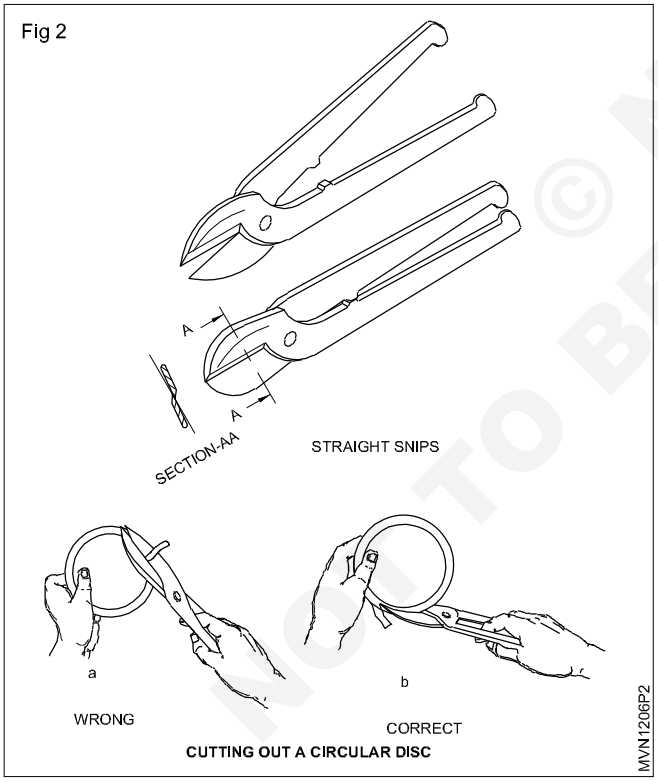



Fig 2




These are used for making straight cuts and large external curves.

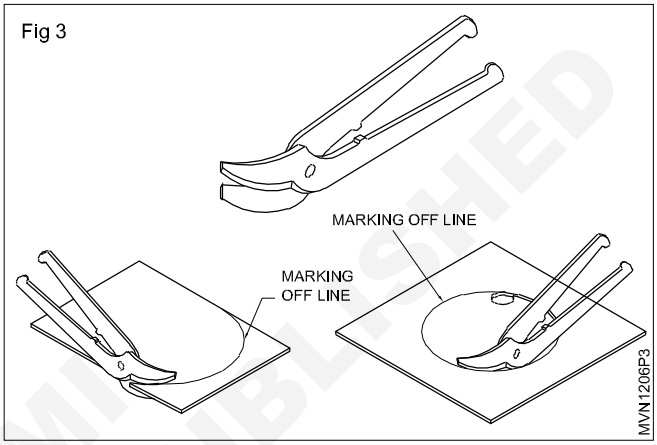
Straight snips have thin blades which are only strong on a vertical planes. They are, therefore, only suitable for straight cuts and external curves when surplus waste has to be removed.

While cutting, the blade of the snips should not cover the marking.

**Bent snips (Fig 3)**

These snips have curved blades for making circular cuts. They are also used for trimming cylindrical or conical work in sheet metal.

Fig 3

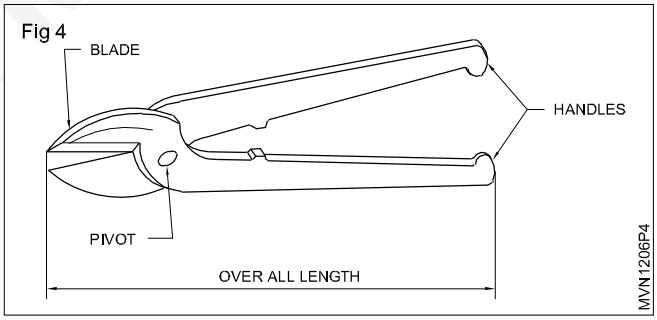



Snips are specified by the overall length and the shape of the blade.

**Example**

200mm straight snip (Fig 4)

Fig 4




**Screw Extractor** is a tool for removing broken or seized screws. There are two types one is spiral flute another is straight flute structure. It is made of hard, brittle steel, while applying twisting torque with screw extractor upon the broker screw, enter and bring out.

**Nipper** is a tool to 'nip' or remove small amount of hard material such as pieces of tiles which need to be fitted around an odd or irregular shape. Nipper is used to in railway line.

## Air impact wrench, air ratchet

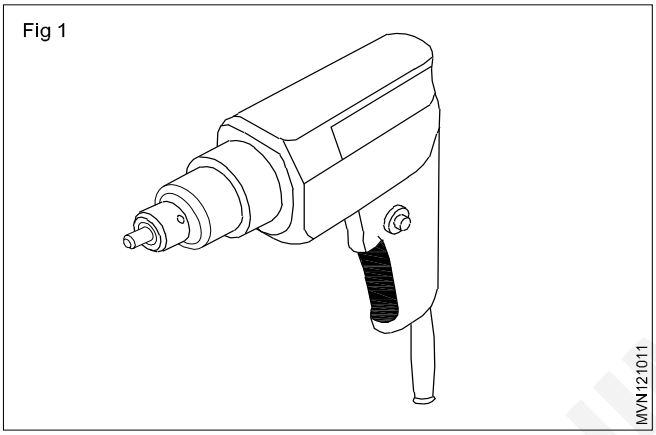
**Objectives:** At the end of this lesson you shall be able to
- **explain the use of air impact wrench**
- **explain the working principle of air impact wrench.**

**Air impact wrench (Fig 1)**

Air Impact Wrench (also known as an impact or, Air Rattle Gun windy gun), Air wrench is a socket wrench power tool, which is used to deliver high torque. It works by storing energy in rotating mass and suddenly delivering it to output shaft.

Compressed Air is commonly used as the power source. Electric power can also be used as the source of power. cordless Electric devices are also used, and are very popular due to ease of working.

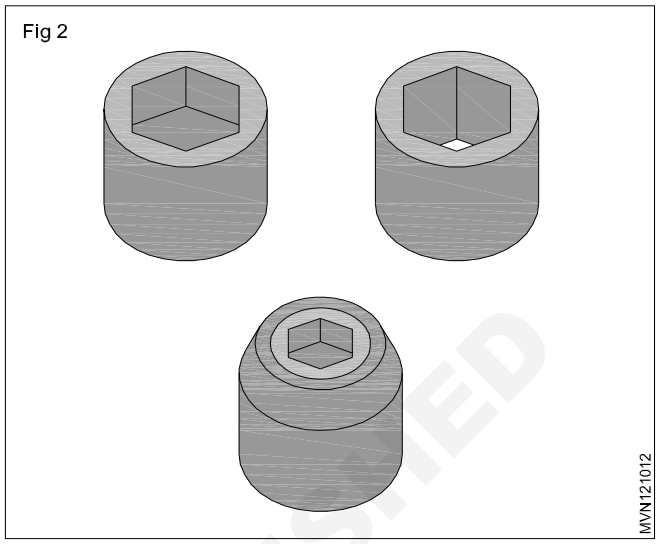
Fig 1




The Air impact wrench is to be used along with a specially hardened impact socket extension and joints to withstand sudden force.

Generally a special 6 inch pin socket is used with air impact wrench. (Fig 2)

Fig 2




**Air Ratchet :** An Air Ratchet is a quite identical to General ratchet wrench.

It is also having square drive at different sizes.

The socket drive is turned by a Air Motor. When we pull the trigger, Air motor gets activated it turns the socket drive.

The direction of socket drive can be changed to clockwise (or) anti clockwise as per the user requirement.

Air Ratchet operates with more speed unless torque. In case where more torque is required we should use Air impact wrench.

## Wrenches

**Objectives:** At the end of this lesson you shall be able to
- **name the different wrenches used**
- **state the features of each type of wrenches.**

**Types of wrenches**

- Stillson pipe wrench
- Footprint pipe wrench
- Tension wrench
- Hexagon socket wrench

**Stillson pipe wrenches (Fig 1 & 2)**

These are used for gripping and turning pipes of a wide range of diameters.

The parts and their names are shown in the

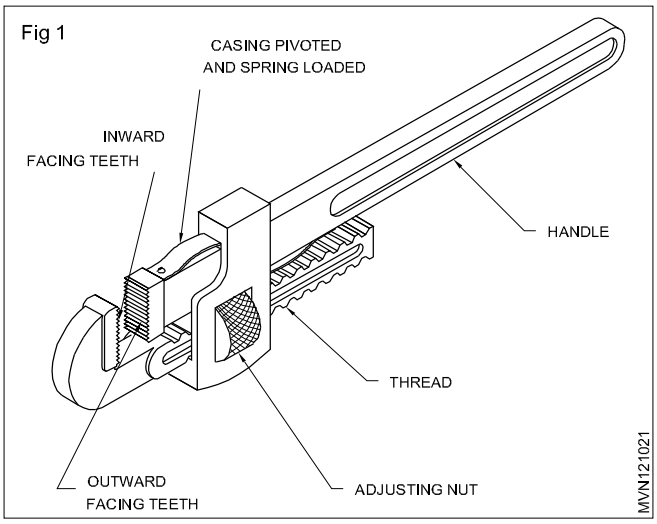
A jaw is fixed to the handle with outward facing teeth. Attached to the handle by a pivot pin is a spring-loaded casing that carries a knurled adjusting nut. This engages with a thread on the adjustable arm of a jaw with inward facing teeth.

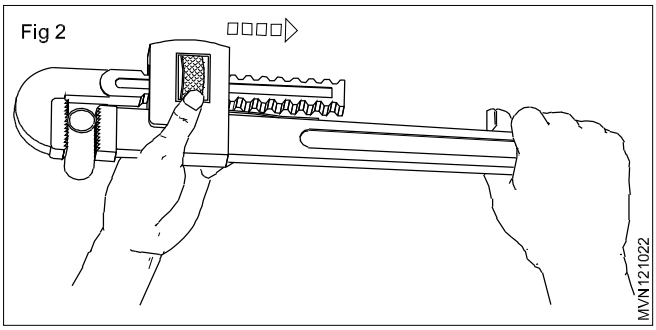
Once the jaws are adjusted, the spring loading keeps them in contact with the work, and the toggle action causes the hardened serrations to bite into the work.

The jaws will mark the work. File off any burrs. Never use them on polished or plated surfaces. Never grip hardened materials with this type of wrench as this will damage the serrations.

**Torque wrench (Fig 3):** A torque wrench is necessary to tighten bolts, nuts etc. To the exact torque as specified by the manufacturers. Excessive tightening may lead to breakage of the fast tenner/parts and loose tightening will lead to leakage/breakage during operation.

Torque wrenches are available in special shapes and sizes. Selecting the torque wrench of the appropriate size and range is very important.




Torque wrenches are available in pound feed (lb-ft), pound inch (lb-in), kilogram metre (Kg-m) kilogram - centimetre (Kg-cm) and Newton metre (N-m). Newton metre is the preferred metric unit, although others are still used by the manufactures.

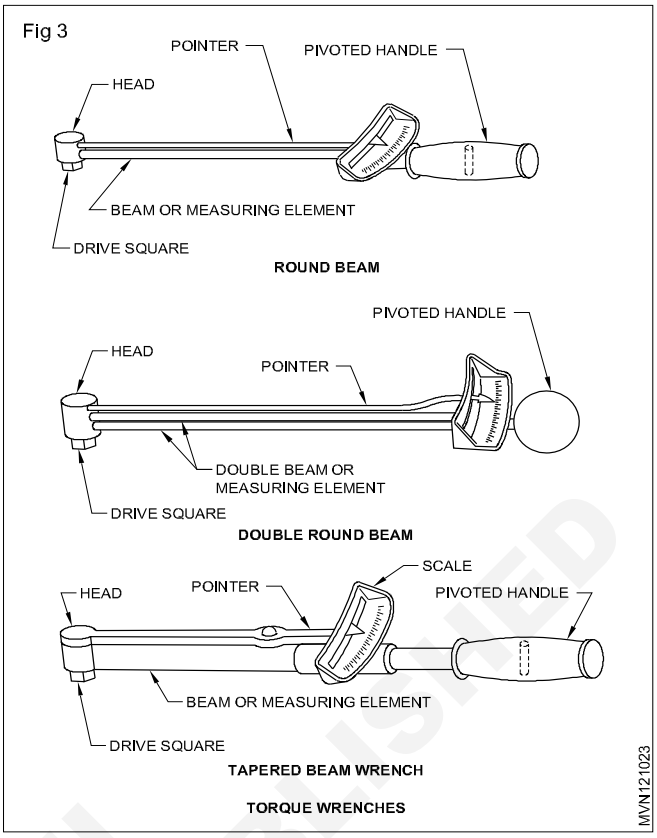
To convert pound feet to kilogram-metres by 0.138 and to convert to Newton-metres multiply the pound feed by 1.35.

**Dial type:** It has a scale and the torque can be read directly.

**Brake over (Micrometer):** It contains a micrometer scale (1) on the handle and a ratchet head (2). In this the torque can be set on the micrometer scale (Ref.job sequence). (Both pound-feet and metric scales are marked on the graduated barrel). The wrench makes a metallic 'click' that is heard and felt on the handle when fasteners are tightened at the correct.

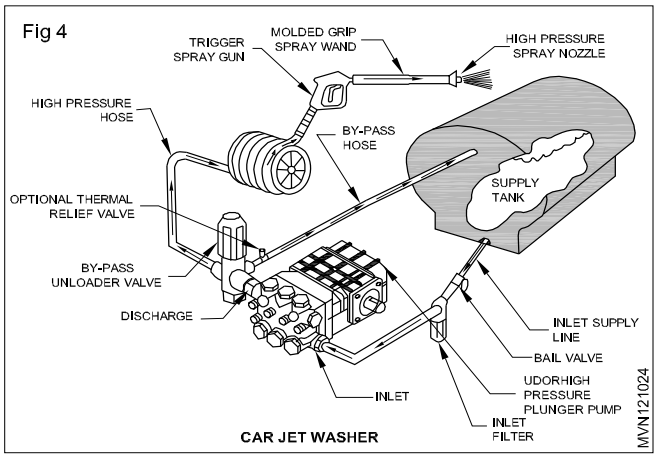
**Torsion bar torque wrench:** Its gauge is a simple pointer (3) that moves across a graduated scale (4) which shows the amount of torque being applied.

Digital read out torque wrenches are also available.




## Car jet washer (Fig 4)

- Car jet washer is used to clean the interior and exterior of motor vehicle different type of car washer are available in the market
- It is also used for pressure wash the auto mobile employments in workshop
- Car jet washer is used for cleaning the dirty floor and wall of floor mates
- It is also used is ear service station for commercial purpose



# Flaring, flare fittings and testing the joints

**Objectives:** At the end of this lesson you shall be able to
- **illustrate necessity, types of flaring methods**
- **list the types and applications of flare fittings**
- **pressures the joint system and test for leaks.**

**Flaring necessity:** When connecting tubing to fittings, it is common practice to flare the end of the tube and to use fittings designed to grip the flare for a vapour tight seal. Special tools are used for making flares.

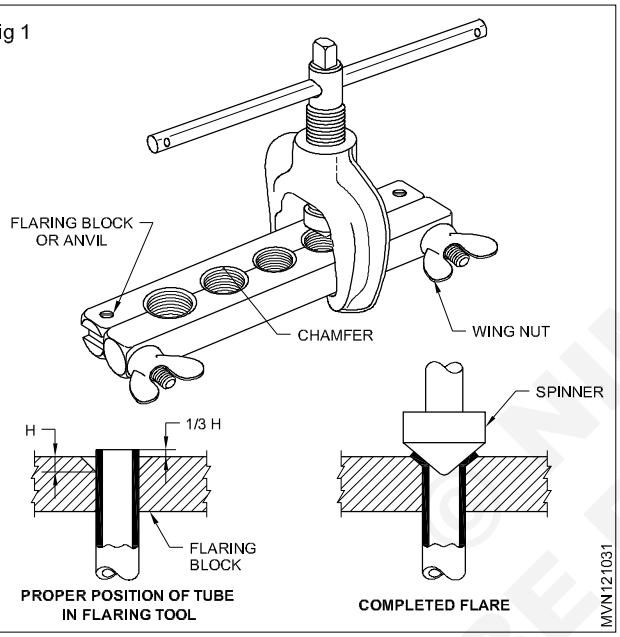
**Types of flaring** : There are two types of flaring

Single thickness flare

Double thickness flare

**Single thickness flare** : It can be made on smaller size copper tubing (Fig 1)

Fig 1




**Double thickness flare**: Double thickness flares are recommended for only the larger size tubing 5/16 inch (9mm) OD and over. Such flares are not easily formed on smaller tubing. The double flare makes a stronger joint than a single flare.

**Pressurising the joint on tubing** : A flared joint or brazed joint needs to be tested for its firm. If it leaks while working it will put the whole system into problem. Before putting the joint into a system after it is made pressure test must be done.

Air pressure from

Air compressor - 150 PSI

or - 10Kg/cm$^2$

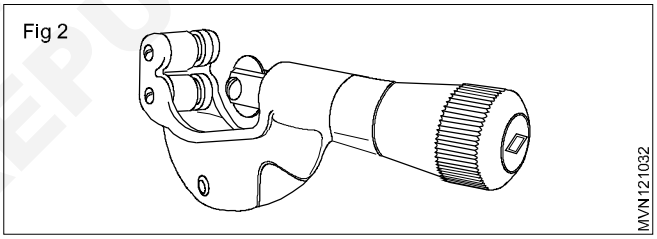
The gas which is employed can be used for testing.

Leak can be detected with the use of soap solution. There are also other methods for leak detection.

Pressure tests are usually made on the joints above the working pressure.

**A pipe cutter** is more convenient and better than a saw when cutting pipes and metal tubing. (Fig 2)

Fig 2




The sharpened wheel does the cutting as the tool turns around the pipe, the screw increases the pressure, driving the wheel deeper and deeper through the pipe until it finally cuts right through.

# Puller

**Objectives:** At the end of this lesson you shall be able to
- **state the function of puller**
- **state the types of puller.**

**Puller**

The puller is a General Workshop tool which is used to remove Gears, bearings pulleys, flanges, bushes.

The puller is made out of steel material, generally with two or three legs and they are adjusted to hold the outside of the gears or bearing sleeves while the central threaded shaft is screwed forward exerting force on the gear/bearing. This enables to remove the bearing without damaging the shaft.

Pullers are classified according to the application and the number of leg.

Another classification is based on the power utilized i.e. Mechanical puller and Hydraulic puller.

Two legs puller is generally used for removing the gears. Where as puller with three legs are for removing pulleys. flanges and bearings. It is also called gear puller. Special pullers: These are mainly used for specialised application such as crank shaft bearing removal brake drum, removal pilot bearing removal.

**Hydraulic puller :** These pullers eliminate time consuming and unsafe hammering, heating or prying. Damage to past is minimised through the use of Hydraulic. pullers.

**Safety**

To avoid personal injury during system operation,

Always wear proper PPE gear

never use a tool to strike a puller

make sure that items are pulled is well and adequately supported

do not apply heat to a puller

before every use lubricate the centre bolt threads, with graphite - based lubricant

use puller only with recommended attachment

do not over load a pulley which may cause to break

**Important: Always keep the guide parts of the lifting plate greased.**

Hydraulic pullers are designed to help you extend bearing life in your applications through proper installation, removal and service.

Hydraulic pulling systems are available with capacity ranging from 4 tons to 30 tons, and are ideal for removing all kinds of shaft filled parts.

Hydraulic pulling system comprises of integrated pump. cylinder, hose, puller with safety-release valve. The pullers have self-contained hydraulic pump and are compact, handy. There are ideal for pulling variety of press-fit parts including bearing, wheels bushings, gears, pulleys.

In Automotives Hydraulic Puller especially used for marine engine liner from the cylinder block during engine Reconditioning Work.

**Mechanical Puller Operation (Fig 1)**

1 Ensure that the spindle is clean and applied grease before use.

2 The Shaft (A) must have a center hole (B) as shown in the figure. If it does not, use a shaft protector (C) as shown in (Fig.1)

3 Tighten strap bolts to hold jaws lightly in place

4 Position the puller that the spindle as shown in fig 2.

5 Tighten the spindle slightly by turning the spindle nut with proper wrench

6 Check that the jaws are fully contacting the part to be pulled.

7 Tighten the strap bolts.

8 Apply pulling force by turning the spindle.

**Post lock puller operation (Manual pullers) (Fig 2)**

1 Make sure that all items being pulled are supported by a means other than the puller. NO LOOSE PIECES!!!

2 Before each use, lubricate the center bolt of the puller with a graphite-based lubricant.

3 To operated the puller, grasp the puller with one hand and turn the T-handle counter-clockwise with the other hand until the jaw opening is big enough to fit over the component to be pulled.

4 Turn the T-Handle clockwise with the other hand until the jaw firmly onto the component. (Fig 2A)

5 Make sure that the center of the puller is aligned with the center of the component to be pulled. Using hand tools only, tighten the center bolt to pull the component off of its shaft. Never exceed the maximum torque ratings of the puller's drive bolt. (Fig 2B)

6 Turn the T-handle counter-clockwise to remove the puller from the component. (Fig 2C)

Fig 1

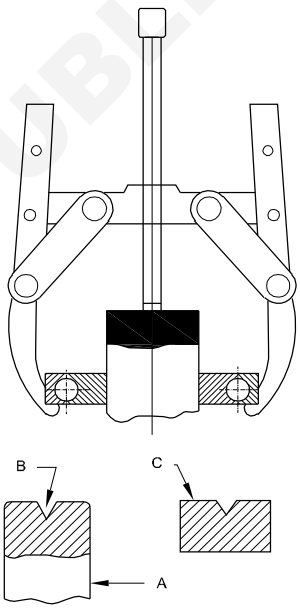
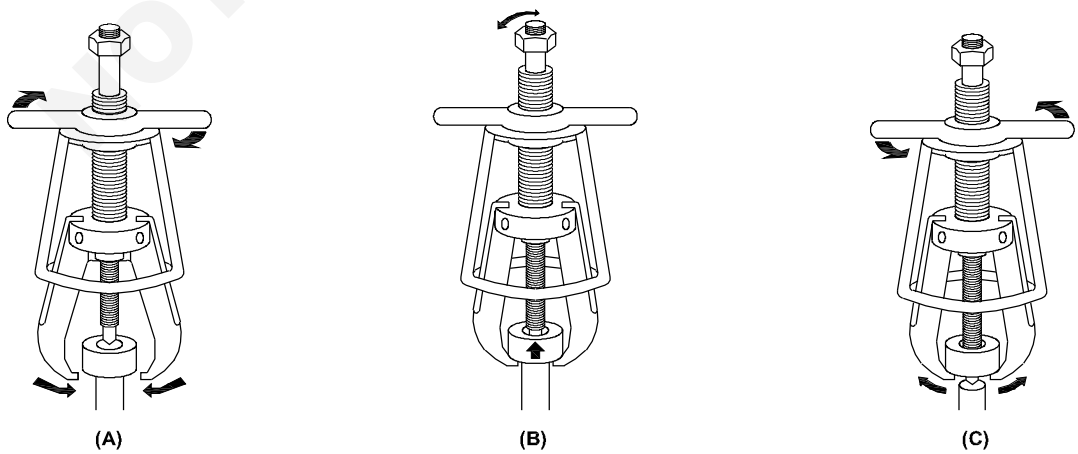



Fig 2

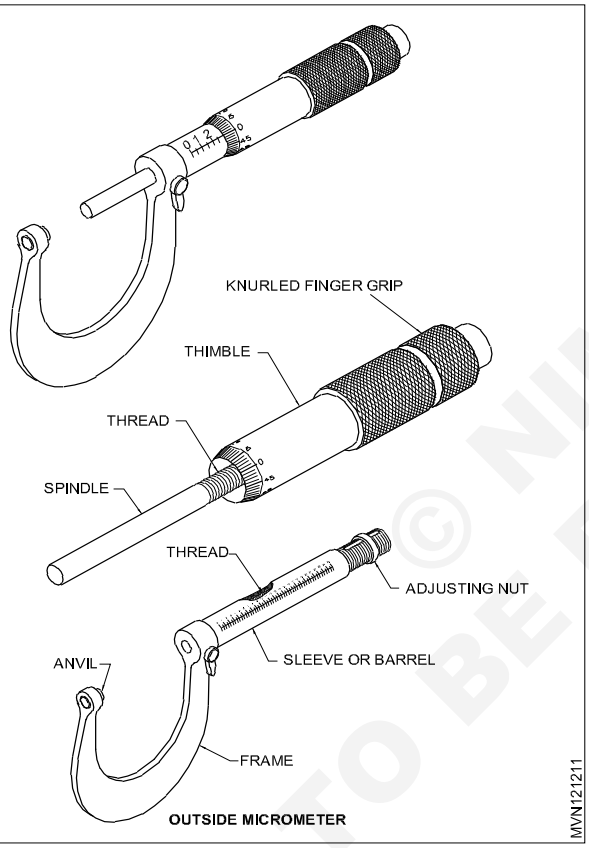


## Outside micrometer

**Objectives**: At the end of this lesson you shall be able to
- **name the main parts of an outside micrometer**
- **derive the least count of metric micrometer**
- **determine the reading by using a metric micrometer**
- **solve the reading and give the measurement**
- **state the features of a large micrometers.**

The purpose of a metric micrometer is to read an accuracy of 0.01 mm of an object. It is available in various sizes. However, the measuring range is limited to the length of the threaded spindle. (Fig 1)

Fig 1

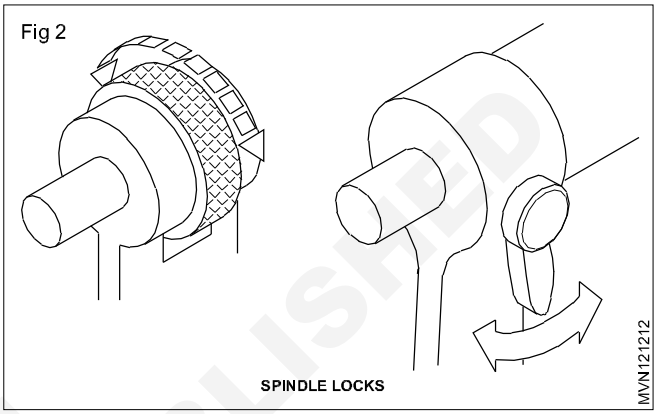



OUTSIDE MICROMETER

The main parts of a micrometer are the frame, anvil, spindle and the thread, sleeve or barrel and the thimble, there is a knurled collar or small lever on the frame to lock the spindle in the barrel. (Fig 2) In addition to this, a ratchet stop is provided to the spindle in order to prevent a possible excess pressure on the screw treads.

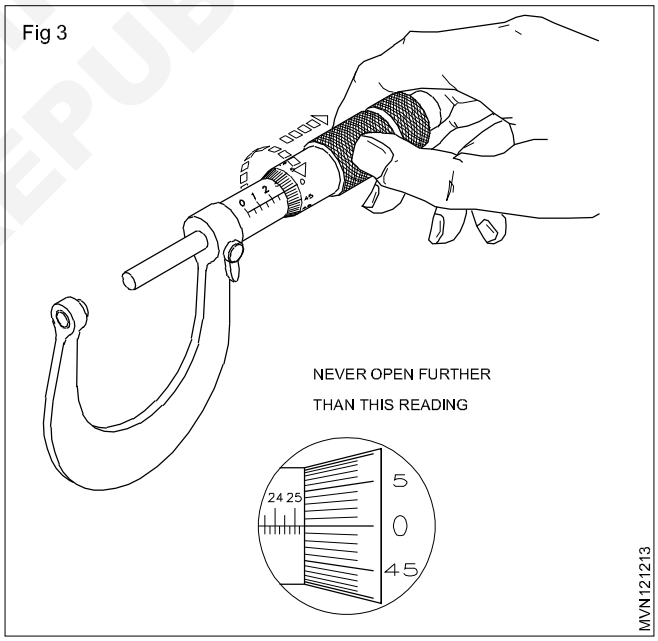
The sleeve or barrel is marked (Fig 3) with the main scale in full mm and half mm. The thimble bevel end is graduated with the thimble scale. Fifty equal divisions are made on the circumference of the thimble bevel end. Every 5th division of the graduation is indicated with the number. Normally, the anvil face is fitted with a carbide tip to resist the wear. The spindle with the screw is attached to the thimble of the micrometer. The corresponding threaded nut is fitted to the barrel or sleeve of the micrometer. The other measuring face of the micrometer is the anvil, which is normally fitted with a carbide tip to resist the wear.

Fig 2




SPINDLE LOCKS

Fig 3




The range of micrometers are 0-5 mm, 25-50 mm, 50-75, 75-100 mm etc. The spindle can be easily screwed down in the barrel. In order to have the reference point for reading the micrometer, the datum or index line is marked on the sleeve.

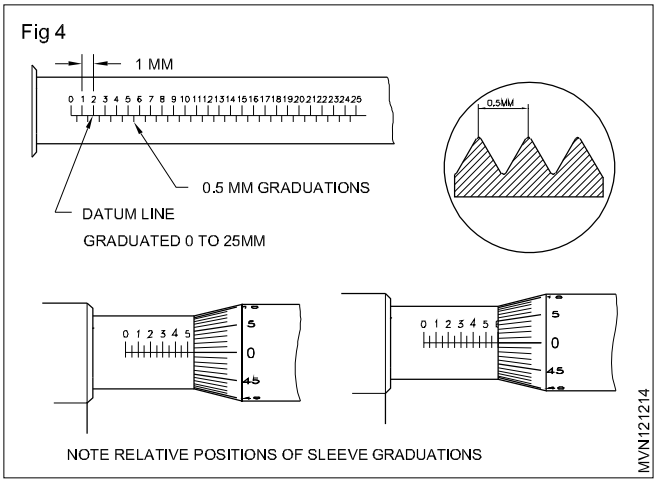
When the face of the anvil and the face of the spindle are in contact, the O graduations of the index line and O graduation of the thimble coincide with each other.

The spindle may be withdrawn by rotating the thimble in an anticlockwise direction. The thimble portion is knurled to provide a good grip for holding as well as for rotating the spindle.

### Deriving the least count of a metric micrometer

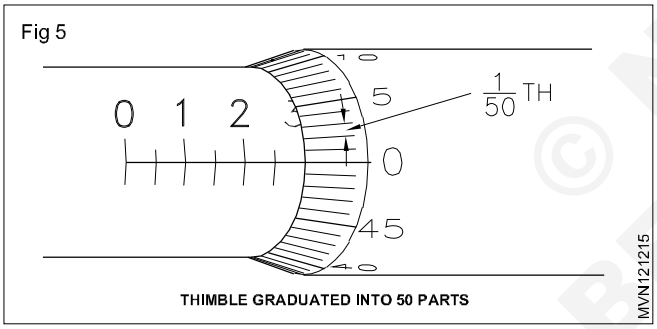
The main scale is graduated in ½ mm. Every 5th mm is shown with the reading. The pitch of the screw thread is accurately maintained to ½ mm. (Fig 4)

Fig 4




By turning one complete revolution of the thimble in a clockwise or an anticlockwise direction, the spindle moves exactly ½ mm in the forward direction or the reverse direction. As the circumference of the thimble graduated into 50 equal divisions, the advancement of the spindle for each division of the thimble scale is ½ mm - 50 i.e. 1/100 mm or 0.01 mm. Therefore, the least count of a metric micrometer is 1/100 mm or 0.01 mm. (Fig 5)

Fig 5




### Determining the reading of a metric micrometer

Before using the micrometer for measurement, it is necessary to ascertain that there is no error in the micrometer.

The faces of the anvil spindle must be free from dust.

While reading the micrometer, the spindle must be locked with the reading.

### Method of reading

Read on the barrel scale the number of whole millimeters that are completely visible from the bevel edge of the thimble. It reads 4 mm. (Fig 6)

Add to this any half millimeters that are completely visible from the bevel edge of the thimble.

The figure reads ½ = 0.5 mm (Fig 7)

Add the thimble reading to the two earlier readings (Fig 7)

Fig 6

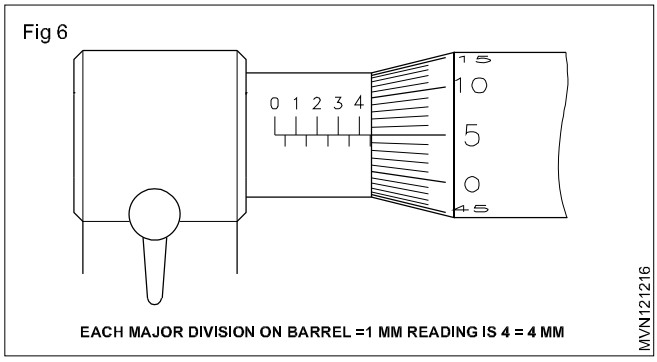
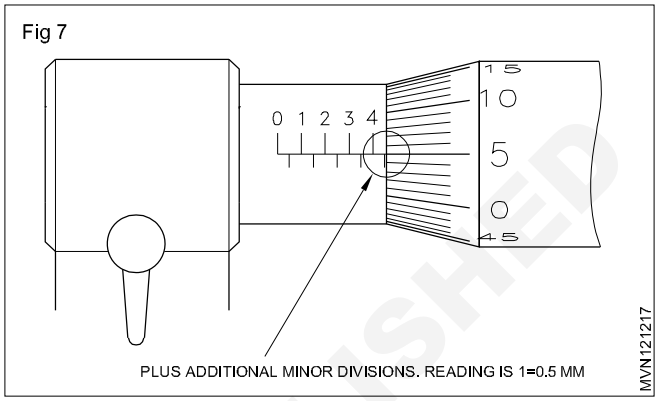
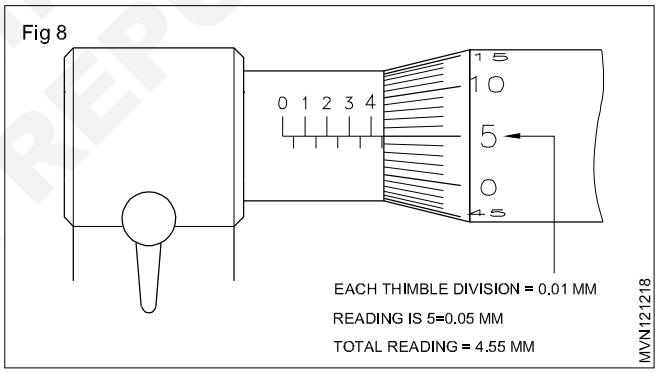



Fig 7




The figure shows the 5th division of the thimble is coinciding with the index line of the sleeve. Therefore the reading of the thimble is 5 8 0.01 mm = 0.05 mm. The total reading of the micrometer. (Fig 8)

Fig 8




a 4.00 mm

b 0.50 mm

c 0.05 mm

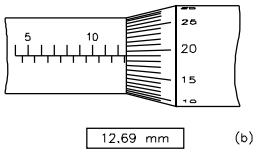
Total reading 4.55 mm

A 0-25 mm capacity outside micrometer can read a A 0-25 mm capacity outside micrometer can read a maximum

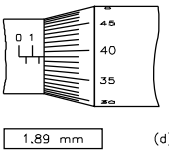
Some examples of metric micrometer readings and their solution. (Fig.9)

| | | |
|---|---|---|
| i) | 5.00 mm | |
| | 0.50 mm | |
| | 0.12 mm | |
| Total | 5.62 mm | |

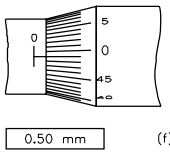
ii) 12.00 mm
0.50 mm
0.19 mm
Total 12.69 mm



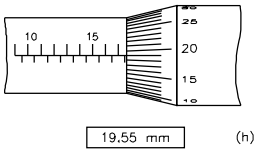

iii) 01.00 mm
0.50 mm
0.39 mm
Total 1.89 mm



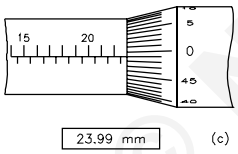

iv) 0.00 mm
0.39 mm
Total 0.49 mm



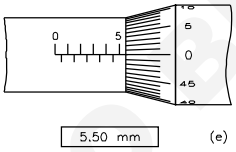

v) 17.00 mm
0.50 mm
0.19 mm
Total 17.69 mm



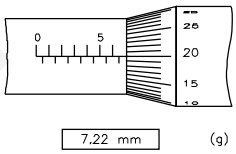

vi) 22.00 mm
0.50 mm
0.49 mm
Total 7.22 mm




vii) 5.00 mm
0.50 mm
0.00 mm
Total 5.50 mm



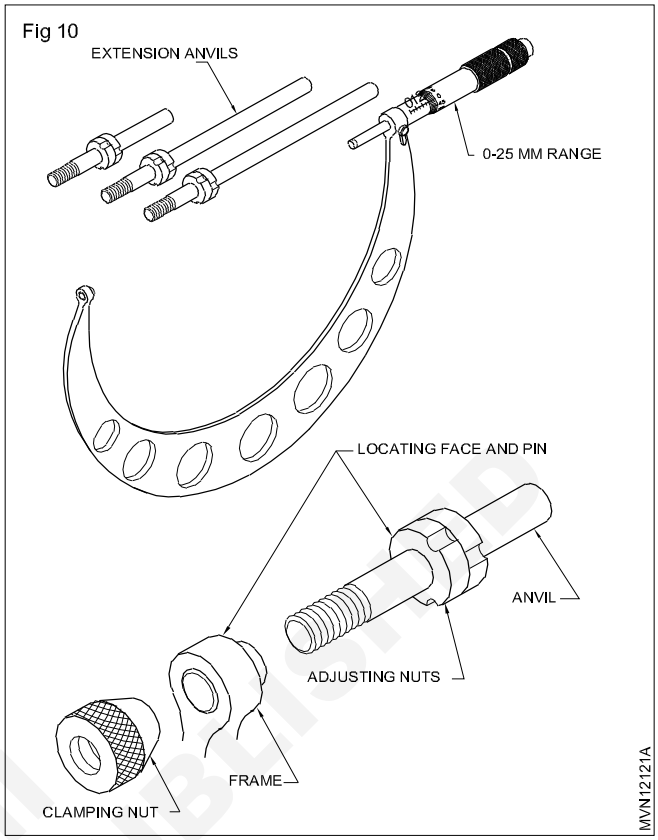

ix) 6.00 mm
0.50 mm
0.20 mm
Total 6.70 mm




A 0-25mm capacity outside micrometer can read a maximum dimension of 25mm. For measuring sizes over and above this, we have to change to the next capacity micrometer 25-50 mm, then 50-75 mm and so on depending on the size of the job. As such, a good number of micrometers will have to be used for finishing jobs of various dimensions. In order to eliminate this problem, a large micrometer is used for measurements.

**Large micrometers (Fig 10)**

Fig 10

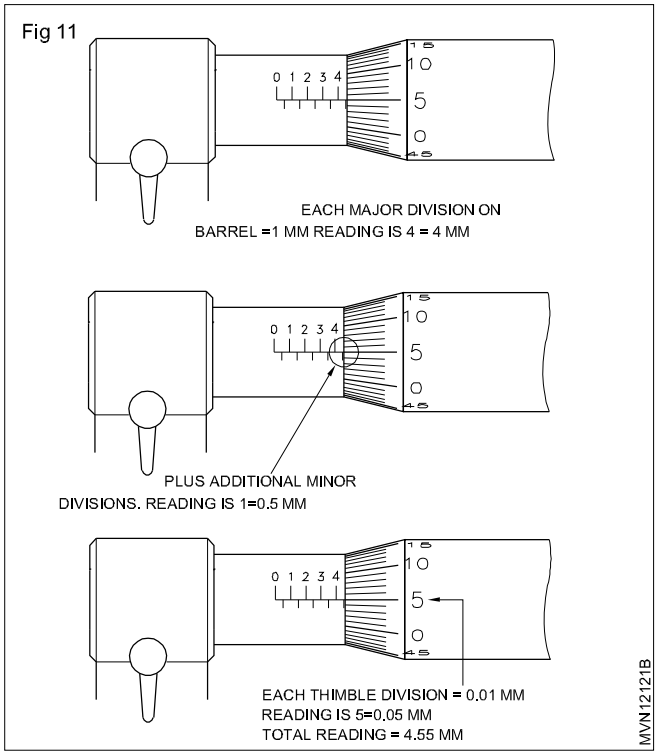



**Method of reading the micrometer 0-25 range (Fig 11)**

Look at the reading which has been taken from the workplace.

Read on the barrel scale the number of whole millimeters that are completely visible from the bevel edge of the thimble. Figure 'a' shows 4 divisions = 4 mm.

Fig 11



Add any half millimeters that are completely visible from the bevel edge of the thimble.

Figure 'b' shows 1 division = 0.5 mm.

Add the thimble reading to the main scale reading which has already been taken. Figure 'c' shows the 5th division of the thimble scale is coinciding with the index line. So thimble reading = 5 * 0.01 = 0.05 mm.

| | |
|---|---|
| | 4. 00 mm |
| | 0.50 mm |
| | 0.05 mm |
| Total reading | 4.55 mm |

## Depth micrometer

**Objectives:** At the end of this lesson you shall be able to
- **name the parts of a depth micrometer**
- **state the constructional features of a depth micrometer**
- **read the depth micrometer measurement.**

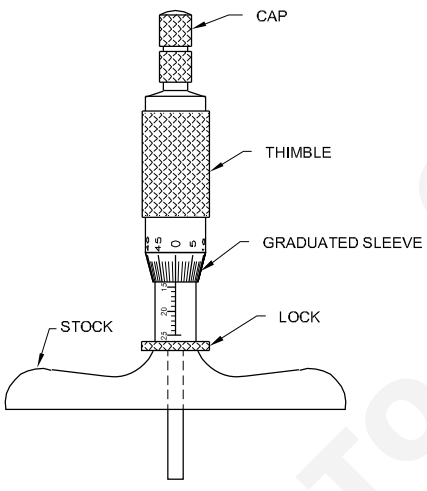
### Constructional features (Fig 1)

A depth micrometer consists of a stock on which a graduated sleeve is fitted.

The other end of the sleeve is threaded with 0.5 mm pitch 'V' thread.

A thimble, which is internally threaded to the same pitch and form, mates with the threaded sleeve and slides over it.

Fig 1




DEPTH MICROMETER

The other end of the thimble has an external step machined and threaded to accommodate a thimble cap.

A set of extension rods are generally supplied. On each of them, the range of sizes that can be measured with that rod is engraved as 0-25 mm, 25-50 mm, 50-75 mm, 75-100 mm, 100-125 mm and 125-150 mm.

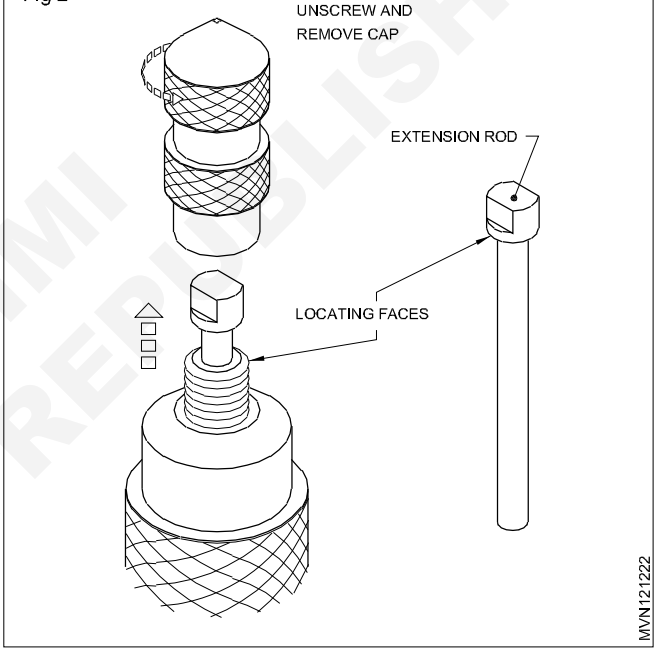
These extension rods can be inserted inside the thimble and the sleeve.

The extension rod has a collar head which helps the rod to be held firmly. (Fig 2)

The measuring faces of the stock and the rods are hardened, tempered and ground. The measuring face of the stock is machined perfectly flat.

The extension rods may be removed and replaced according to the size to be measured.

Fig 2




### Graduation and least count

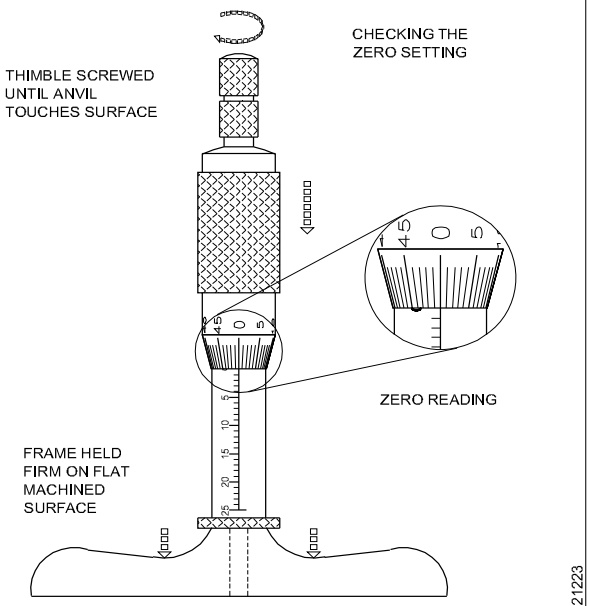
On the sleeve a datum line is marked for a length of 25 mm. This is divided into 25 equal parts graduated. Each line represents one millimeter. Each fifth line is drawn little longer and numbered. Each line representing 1mm is further subdivided into two equal parts. Hence each subdivision represents 0.5 mm. (Fig 2)

The graduations numbered are in the reverse direction to that marked on an outside micrometer.

The zero graduation of the sleeve is one the top and the 25 mm graduation is near the stock.

The bevel edge of the thimble is also graduated. The circumference is divided into 50 equal parts and every 5th division line is drawn longer and numbered. The numbering is in the reverse direction and increases from 0 to 5, 10, 15, 25, 30, 35, 40, 45 and 50 (0). (Fig 3)

Fig 3




The advancement of the extension rod for one full turn of the thimble is one pitch which is 0.5 mm.

Therefore the advancement of the extension rod for one division movement of the thimble will be equal to 0.5 / 50 = 0.01 mm.

This will be the smallest measurement that can be taken with this instrument, and so this is the accuracy of measurement of this instrument.

Uses of a depth micrometer

Depth micrometers are special micrometers used to measure:

- Depth of holes
- depth of grooves and recesses
- heights of shoulders and projections.

## The universal vernier caliper and its application

**Objectives:** At the end of this lesson you shall be able to
- **list out the parts of a universal caliper**
- **state the constructional features of the universal vernier caliper**
- **state its functional features**
- **list out the points for taking the measurements.**

One of the precision instruments having the principle of vernier applied to it is the universal vernier caliper. It is known as a universal vernier caliper because of its application to take outside, inside and depth measurements. Its accuracy is 0.02 mm.

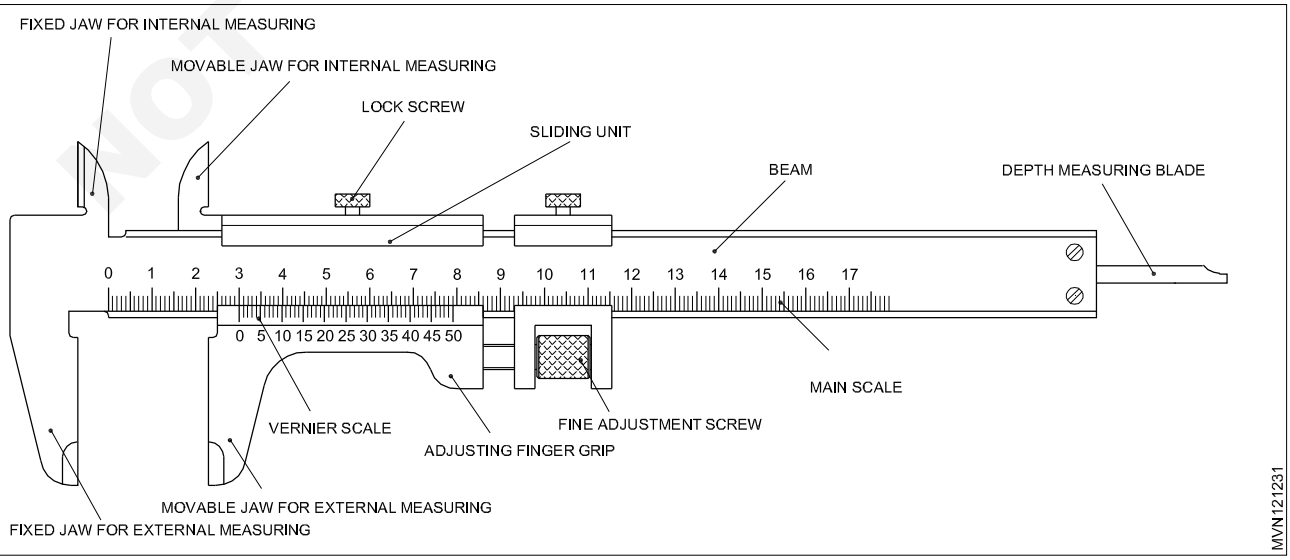
**A universal vernier caliper consists of a**

- Beam
- Fixed jaw for external measurements
- Movable jaw for external measurements
- Movable jaw for internal measurements
- Blade for depth measurement
- Main scale
- Vernier scale
- Fine adjustment screw
- Set of locking screws.

All parts are made out nickel-chromium steel, heat-treated and ground. They are machined to a high accuracy. They are stabilized to avoid distortion due to temperature variations.

**Constructional features (Fig 1)**

Fig 1



The beam is the main part and the main scale graduations are marked on it. The markings are in millimeters and every tenth line is drawn a little longer and brighter than the other graduations and numbered as 1,2,3 ….

To the left of the beam the fixed jaws for external and internal measurements are fixed as integral parts., The vernier unit slides over the beam.

At the bottom face of the beam a keyway-like groove is machined for its full length, permitting the blade to slide in the groove.

At the bottom right hand end, a unit is fixed serving as a support for the blade when it slides in the groove.

The vernier unit has got the vernier graduations marked on it. The movable jaws for both external and internal measurements are integral with this.

The fixed and movable jaws are knife-edged to have better accuracy during measurement. When the fixed and movable jaws are made to contact each other, the zero of the vernier scale coincides with the zero of the main scale.

At this position in the blade will be in line with the right hand edge of the beam.

When the vernier scale unit slides over the beam, the movable jaws of both the measurements as well as the blade advance to make the reading.

To slide the vernier unit, the thumb lever is pressed and pulled or pushed according to the direction of movement of the vernier unit.

**Least count**

In the vernier scale illustrated here, 19 mm are divided into 10 equal parts on the vernier scale. The value of 1 vernier scale division will then be

$$\frac{19}{10} = 1.9\text{mm}$$

The difference of the two main scale divisions and 1 vernier scale division gives the least count and it is equal to 2*1m -1.9 mm = 0.1 mm.

For better accuracy, a 49 mm space is divided into 50 equal parts on the vernier scale so that one vernier scale division value will be

$$\frac{49}{50} = 0.98\,\text{mm}$$

Here the least count will be 1 main scale division - 1 vernier scale divisions = 1 mm-0.98 mm= 0.02 mm.

The application of the universal vernier caliper is taking external, internal and depth measurements is shown in (Fig 2)

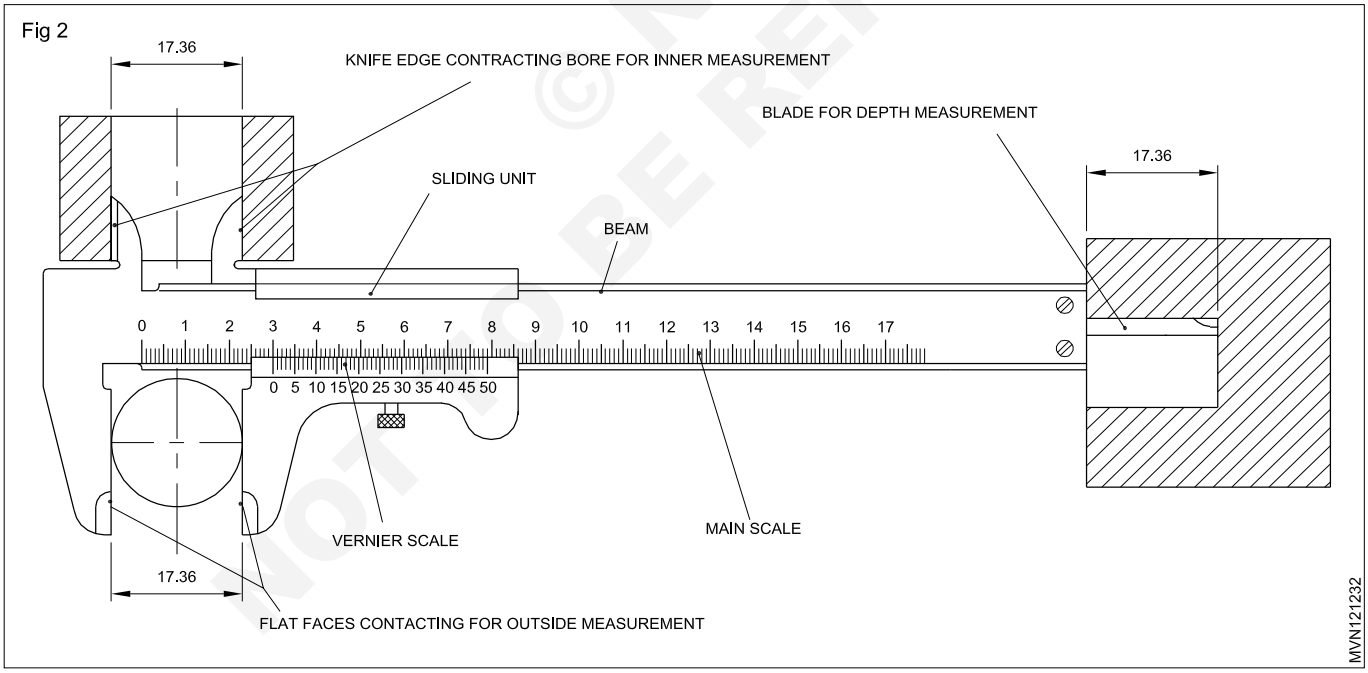
**Advantages**

No need to have separate precision instruments for taking external, internal and depth measurements.

**Disadvantages**

Accuracy of reading depends on the skill of the operator.

Fig 2




Loses its accuracy by constant usage as slackness in the sliding unit develops.

Cannot be used to measure components having deviations less than +/-0.02 mm.

Possibility of parallax error during noting down the coinciding line may cause the reading of the measurement to be wrong.

**To read a measurement**

Note the number of graduations on the main scale passed by the zero of the vernier. This gives the full mm.

Note which of the vernier scale division coincides with any one line on the main scale.

Multiply this number with the least count.

Add the multiplied value to the main scale reading.

## Telescope gauge

**Objectives:** At the end of this lesson you shall be able to
- **name the parts of telescope gauge**
- **measuring technique how to telescope gauge reading on outside micrometer.**

**Telescopic Gauge (Fig 1):** This is an instrument used for measuring the inside size of slots or holes. It consists of a handle and two plungers, one of which telescopes into the other. Both the plungers are kept under spring tension. In order to lock the plungers in position, a knurled screw at the end of the handle is tightened. If the diameter of a hole is to be measured, the plungers are first compressed and then locked. The plunger end is put into the hole and the end is allowed to expand so that the plungers touch the opposite edges.

Then the plungers are locked in position and taken out of the hole. The diameter is measured with the help of an outside micrometer. The telescopic gauge does not have graduations of its own.

The precaution to be taken in the telescopic gauge in that they should be inserted squarely on to the bore and centralised properly.

**Measuring Technique**

a Compress the fixed and telescopic legs and lock them by locking screw.

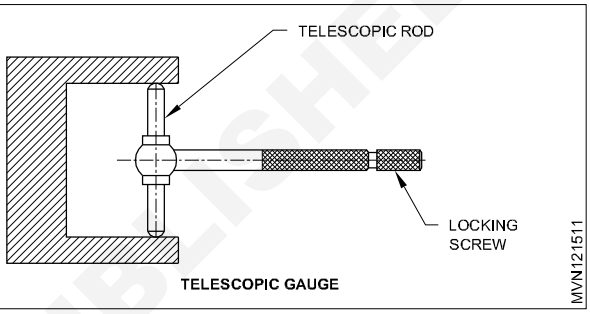
b Insert the gauge ends into the hole to be measured.

c Unlock the legs by unscrewing the locking screw for expanding the legs to the inner diameter of the hole.

d Measure with feel and lock the legs in position.

e Transfer the measurement to an outside micrometer for reading.

Fig 1




TELESCOPIC GAUGE

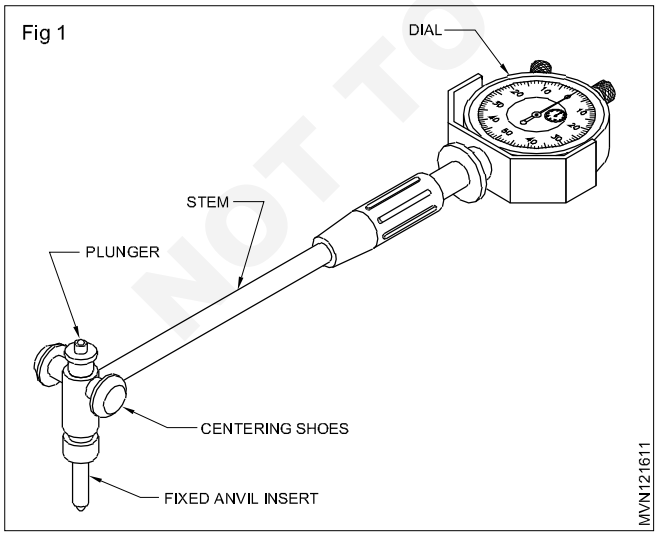
## Dial bore gauge

**Objectives:** At the end of this lesson you shall be able to
- **name the parts of a bore dial gauge**
- **state the features of a bore dial gauge**
- **read the measurement using a graduated dial.**

This is a precision measuring instrument used for measuring the internal dimensions. The dial bore gauge is normally available as a two-point, self-cantering type

**Dial bore gauge (Fig 1)**

Fig 1




**Stem**

This holds all the components together and contains the mechanism for transmitting the plunger motion to the dial.

**Fixed anvil/inserts**

These anvils are interchangeable. The selection of the anvil is made depending on the diameter of the bore to be measured. For certain types of bore dial gauges, extension rings/washers are provided for extending the range of measurement.

**Sliding plunger**

This actuates the movement of the dial for reading the measurement.

**Centering shoes/spherical supports**

Certain types of bore dial gauges are provided with a pair of ground discs. (Fig 2)

This maintains the alignment of the measuring faces in the centre of the bore. For some types, two spherical supports which are spring-loaded are provided.

**Dial Indicator (Fig 3)**

This has graduations marked on the dial. The graduations has marked in clockwise and anticlockwise directions.

Bore dial gauges are available in various sizes with different measuring ranges. These are interchangeable measuring rods (external rods or combination washers) for measuring different sizes. (Fig 4)

Fig 2

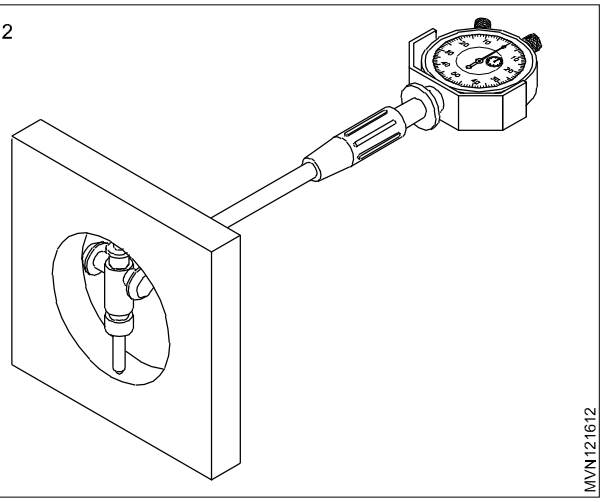


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Fig 3

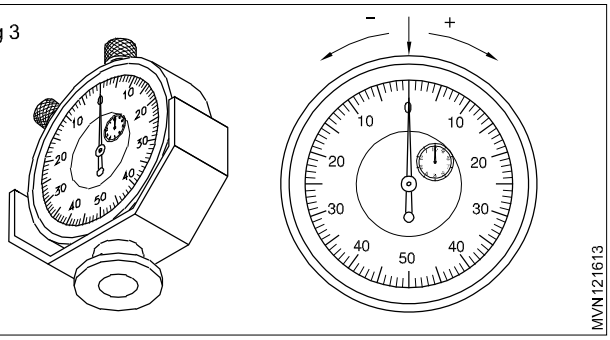

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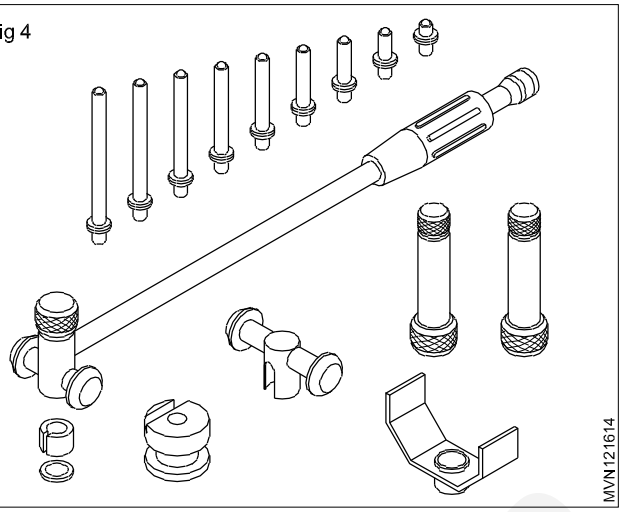
Fig 4



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The accuracy of the instrument depends on the type of graduations on the dial. The most frequently used instruments have accuracies of 0.001 mm and 0.01 mm.

**The dial gauge should be set to zero before taking measurement. Setting rings are available for zero setting. (Fig 5)**

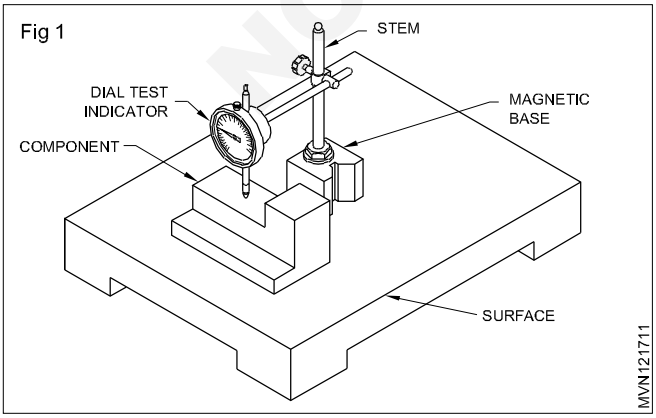
## Dial test indicators

**Objectives:** At the end of this lesson you shall be able to

- **state the principle of a dial test indicator**
- **state the types of dial test indicator**
- **identify the parts of a dial test indicator**
- **state the important features of a dial test indicator**
- **state the functions of a dial test indicator**
- **identify the different types of stands**
- **state the important of straight edge.**

**Dial test indicators:** Dial test indicators are instruments of high precision, used for comparing and determining the variation in the sizes of a component. These instruments cannot give the direct reading of the sizes like micrometers and vernier calipers. A dial test indicator magnifies small variations in sizes by means of a pointer on a graduated dial. This indirect reading of the deviations gives an accurate picture of the conditions of the parts being tested. (Fig 1)

Fig 1

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**Principle of working:** The magnification of the small movement of the plunger or stylus is converted into a rotary motion of the pointer on a circular scale.

**Types:** Two types of dial test indicators are in use. They are the

- Plunger type (Fig 2)
- Lever type (Fig 3)

**The plunger type dial test indicator**

The external parts and features of a dial test indicator are as shown in the (Fig 2).

Pointer (A)

Rotatable bezel (B)

Bezel clamp (C)

Back lug (D)

Transparent dial cover (E)

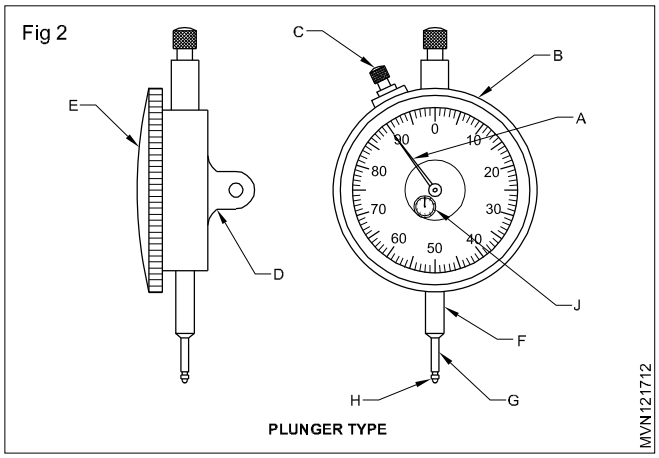
Stem (F)

Plunger (G)

Anvil (H)

Revolution counter (J)

For converting the linear motion of the plunger, a rack and pinion mechanism is used.

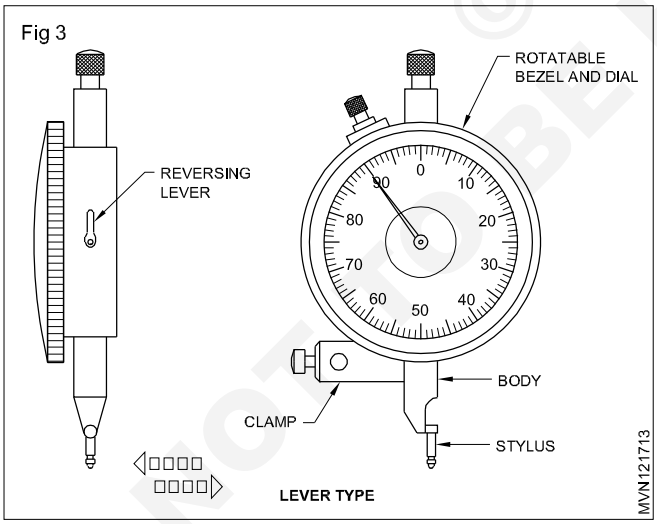



**The lever type dial test indicator (Fig 3 to 5)**

In the case of this type of dial test indicators, the magnification of the movement is obtained by the mechanism of the lever and scroll.

It has a stylus with a ball-type contact, and it has an oscillating movement as against the reciprocating movement in the plunger type indicator.

This can be conveniently mounted on a surface gauge stand, and can be used in places where the plunger type dial test indicator application is difficult.




**Important features of dial test indicators**

An important feature of the dial test indicator is that the dial can be rotated by a ring bezel, enabling the zero to be get in any position.

Many dial test indicators read plus in the clockwise direction from zero, and minus in the anticlockwise direction so as to give plus and minus indications.

**Uses**

- To compare the dimensions of workpiece against a known standard, eg. Slip gauges.
- To check plane surfaces for parallelism and flatness.
- To check straightness of shafts and bars.
- To check concentricity of holes and shafts.

**Indicator stands (Fig 4 & 5)**

Dial test indicators are used in conjunction with stands for holding them so that the stand itself may be placed on a datum surface or machine tool. The different types of stands are:

- Magnetic stand with universal clamp
- Magnetic stand with flexible post
- General purpose holder with cast iron base.

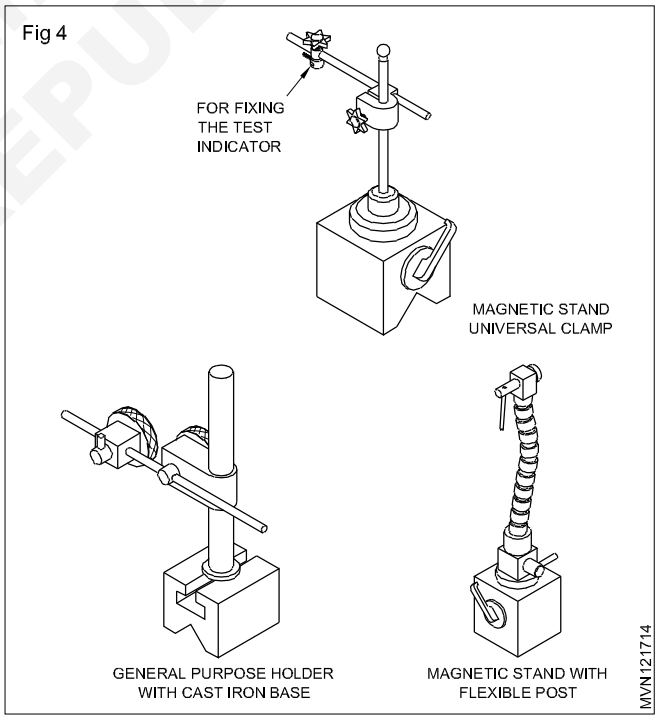
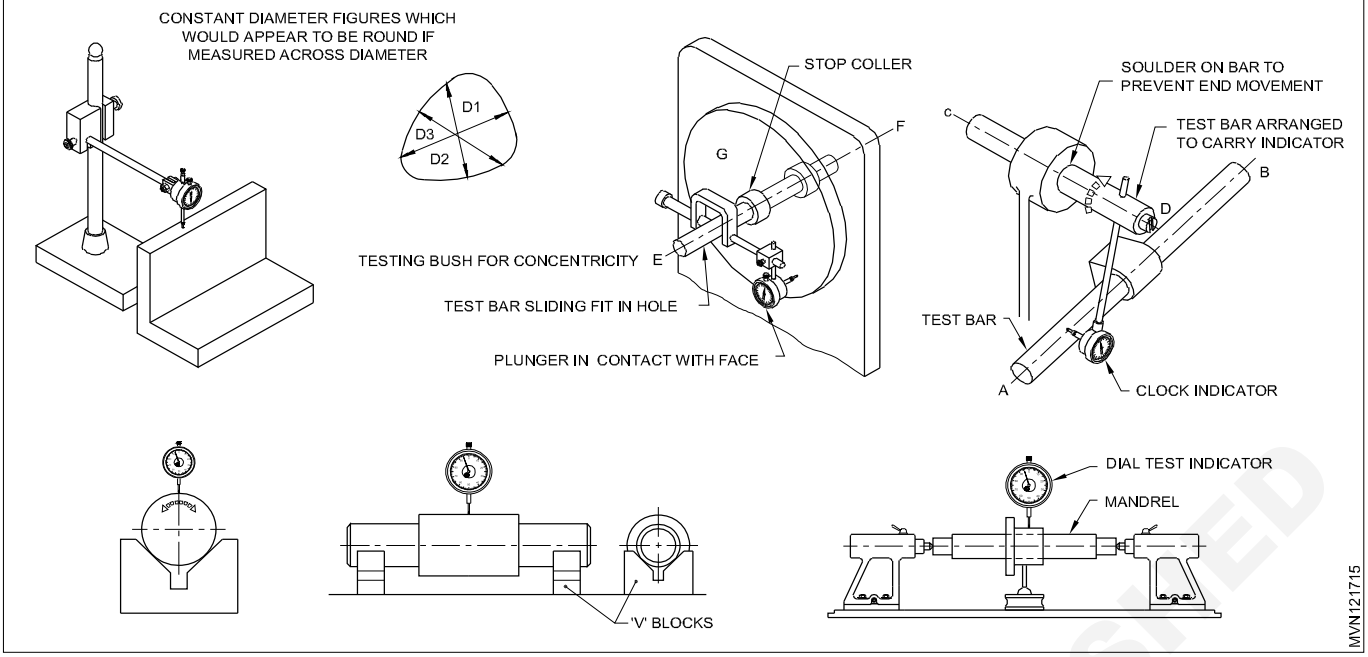


Fig 5




## Straight edges

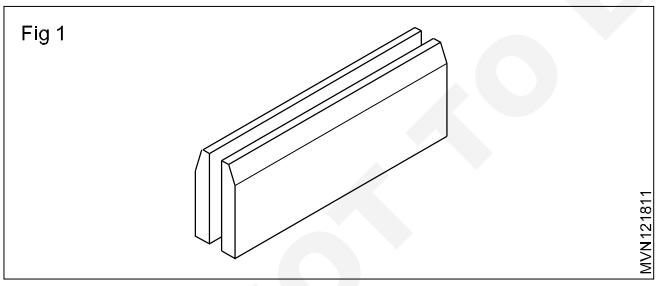
**Objectives:** At the end of this lesson you shall be able to
- **name the different types of straight edge**
- **state the straight edge uses edge**
- **state the different method of testing straightness.**

For testing straightness and to use a guide for marking long straight lines. Straight edges made of steel or cast iron are used.

### Steel straight edges

These are usually available up to 2 meters in length and may be rectangular in cross-section or have one edge beveled (Fig 1)

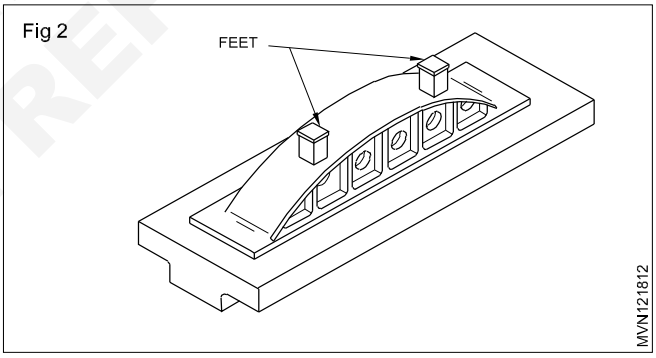
Fig 1




### Cast iron straight edges (Fig 2)

These are made from close- grained, grey, cast iron and can be considered as narrow surface plates. They are available up to 3 meters length and are used for testing machine tool sideways, cast iron straight edges have ribs, and bow-shaped tops to prevent distortion. These straight edges are-shaped tops to prevent distortion. These straight edges are provided with feet to prevent distortion under their own weight.

Fig 2

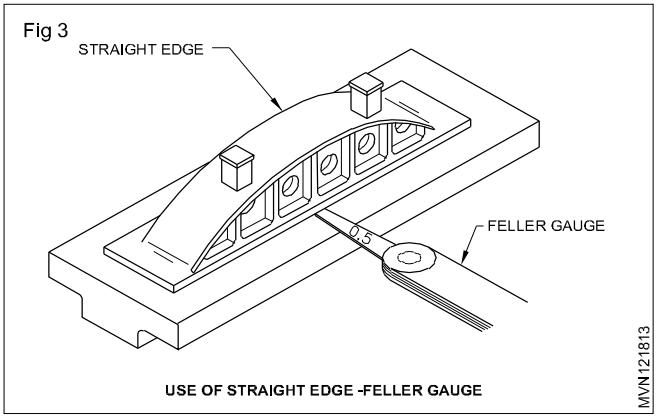



### Use of straight edges

### Checking with feeler gauges

In certain situations when the gap between the surface and the straight edge is more. A feeler gauge can be used (Fig 3) to determine the extent of deviation.

Fig 3




USE OF STRAIGHT EDGE -FELLER GAUGE

# Feeler gauge and uses

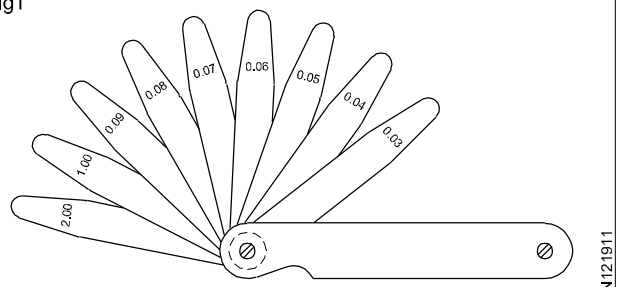
**Objectives:** At the end of this lesson you shall be able to
- **state the constructional features of a feeler gauge**
- **state the method of indicating different ranges of feeler gauges**
- **state the method of setting a feeler gauge**
- **state the different uses of feeler gauges.**

**Features**

A feeler gauge consists of a number of hardened and tempered steel blades of various thicknesses mounted in a steel case.

The thickness of individual leaves is marked on it. (Fig 1)

Fig1




The sizes of the feeler gauges in a set are carefully chosen in order that a maximum number of dimensions can be formed by building up from a minimum number of leaves.

The dimension being tested is judged to be equal to the thickness of the leaves used. When a slight pull is felt while with drawing them. Accuracy in using these gauges requires a good sense of feel. (Fig.2)

B.I.S

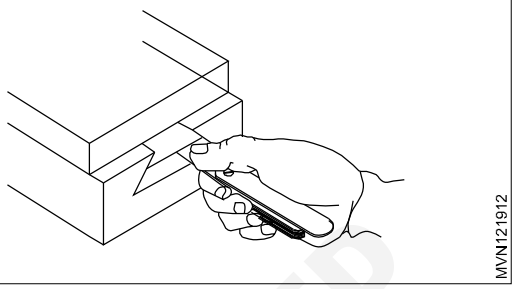
The Indian standard establishes four sets of feeler gauges Nos.1,2,3 and 4 which differ by the number of blades in each and by the range of thickness(minimum) is 0.03mm

Example

Set No.4 of Indian standard consists of 13 blades of different thicknesses.

0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.010, 0.015, 0.20, 0.30, 0.040, 0.50.

Fig 2




**Uses**

Feeler gauges are used:

- to check the gap between the mating parts
- to check and set the spark plug gaps and tappet clearance in an engine etc.
- to set the clearance between the fixture (setting block) and the cutter/tool for machining the jobs. (Fig 2)
- to check and measure the bearing clearance, and for many other purposes where a specified clearance must be maintained.

**Types of feeler gauge**

1 universal master gauge

2 standard feeler gauge

3 ignition and wire gauge

**Classification of feeler gauge**

- Universal master gauge containing 25 leaves
- Standard feeler gauge containing 10 leaves

# Screw pitch gauge

**Objectives:** At the end of the lesson you shall be able to
- **state the purpose of a screw pitch gauge**
- **state the features of a screw pitch gauge.**
- **state the importance of straight edge**
- **state the sizes of uses of feeler gauge.**

Scan the QR Code to view the video for this exercise

**Purpose:** A screw pitch gauge is used to determine the pitch of a thread.

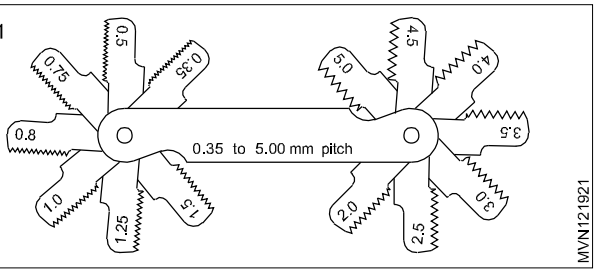
It is also used to compare the profile of threads.

**Constructional features:** Pitch gauges are available with a number of blades assembled as a set. Each blade is meant for checking a particular standard thread pitch. The blades are made of thin spring steel sheets, and are hardened.

Some screw pitch gauge sets will have blades provided for checking British Standards threats (BSW, BSF etc.) at one end and the Metric Standard at the other end.

The thread profile on each blade is cut for about 25 mm or 30 m. The pitch of the blade is stamped on each blade. The standard and range of the pitches are marked on the case. (Fig 1)

Fig 1




For obtaining accurate results while using the screw pitch gauge, the full length of the blade should be placed on the threads. (Fig 2)

**Feeler gauge & uses**

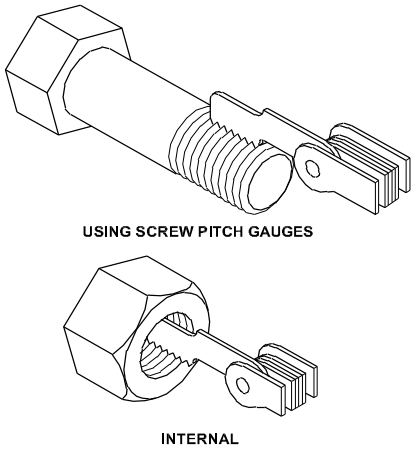
A feeler gauge consists of a number of hardened and tempered steel blades of various thicknesses mounted in a steel case.

The thickness of individual leaves is marked on it.

The sizes of the feeler gauges in a set are carefully chosen in order that a maximum number of dimensions can be formed by building up from a minimum number leaves.

The dimension being tested is judged to be equal to the thickness of the leaves used, when a slight pull is felt while withdrawing them. Accuracy in using these gauges requires a good sense of fell.

Fig 2




**B.I.S. set**

The Indian Standard establishes four sets of feeler gauges Nos. 1,2,3 and 4 which differ by the number of blades in each and by the range of thickness (minimum is 0.03 mm to 1 mm in steps of 0.01 mm). The length of the blade is usually 100 mm.

**Example**

Set No.4 of Indian Standard consist of 13 blades of different thicknesses.

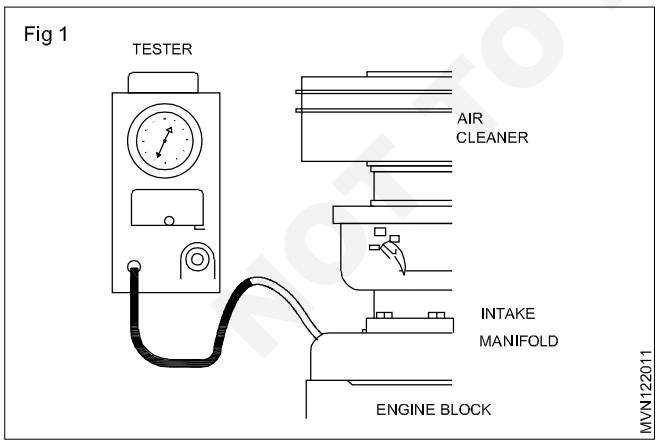
0.03,0.04,0.05,0.06,0.07,0.08,0.09,0.10,.0.15,0.20,0.30,0.40,0.50.

## Vacuum gauge

**Objectives:** At the end of this lesson you shall be able to
- **state the purpose of vacuum gauge**
- **state the vacuum gauge attachment in an engine.**

A vacuum gauge (Fig 1) is a useful diagnostic and time-up tool.

Fig 1




It is used to detect vacuum leaks at idle speed, sticking valves, worn rings, clogged exhaust, incorrect timing and positive crank case ventilation (PCV)

**Attaching Vacuum Gauge:** At normal operating temperature connect the vacuum gauge to the intake manifold. Some manifolds incorporated a plug that may be removed so that vacuum line adopter may be installed.

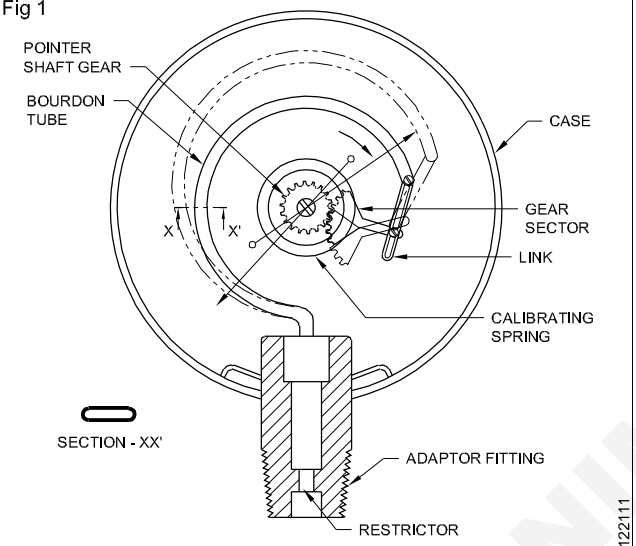
- A relative study high vacuum reading indicate an absence vacuum leak in the system (i.e) values and rings are in good sealing.
- Fairly study vacuum reading indicate vacuum leak in the system (i.e) value and rings are not in good sealing.
- Vacuum reading indicate uneven, valve are burned or sticky and damaged piston or blown gasket.

# Tyre pressure gauge

**Objectives:** At the end of this lesson you shall be able to
- **state the construction and features of tyre pressure gauge**
- **use a tyre pressure gauge to check & set tyre pressure.**

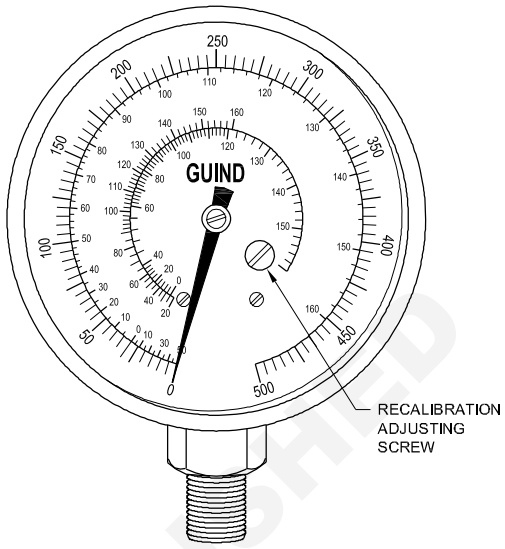
**Pressure gauge (Fig 1&2):** It is used to check the pressure of tyre unit. Bourdon tube pressure gauges made by stainless steel. A Pressure rise in bourdon tube makes it tend to straighten. This movement will pull on the link which will turn the gear sector counter clockwise. The pointer shaft with then turn clockwise to move needle on a graduated scale to indicate pressure.

Fig 1



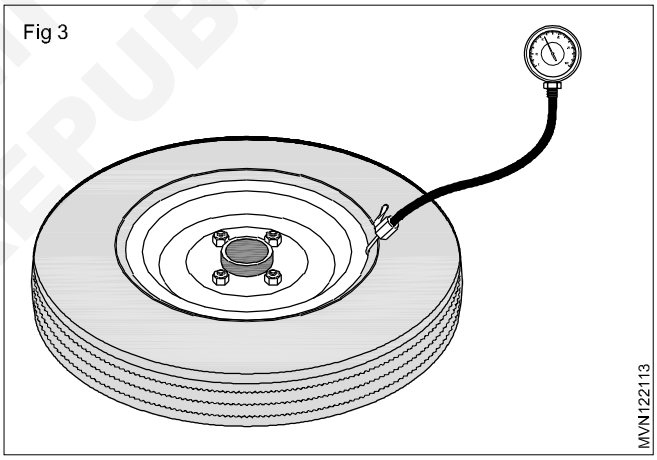

INTERNAL CONSTRUCTION OF PRESSURE GAUGE

Fig 2




PRESSURE GAUGE

Fig 3




**Special features**

- Excellent load-cycle stability and shock resistance.
- All stainless steel construction
- Positive pressure ranges 0-200 P.S.I (Fig 3)

The pressure gauge hose has a adapter, which depresses the valve pin of tyre and compressed air get into the tube of the gauge. The pressure is indicated in the dial. Compare the pressure to the recommended pressure by the manufacturer. If it is less, refill the tyre with compressed air by operating the trigger (Fig.3). When the required pressure is shown in the gauge stop filling.

# Drilling machine (Portable type)

**Objectives:** At the end of this lesson you shall be able to
- **name the different types of portable drilling machines**
- **state their distinctive features and uses.**

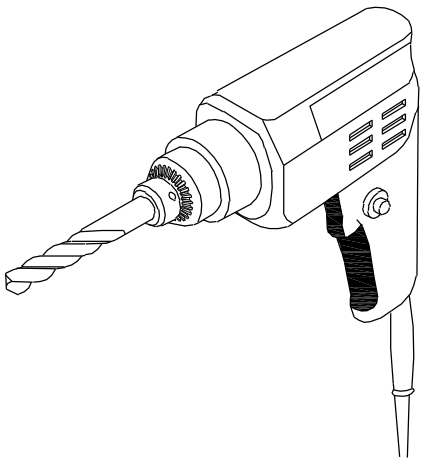
**Necessity:** Portable hand drills of different types are used for certain jobs which cannot be handled on stationary drilling machines.

**Types of portable drilling machines:** There are two types of portable drilling machines,

**Power operated drilling machines**

**Electric hand drill (light duty) (Fig 1)**

Fig 1

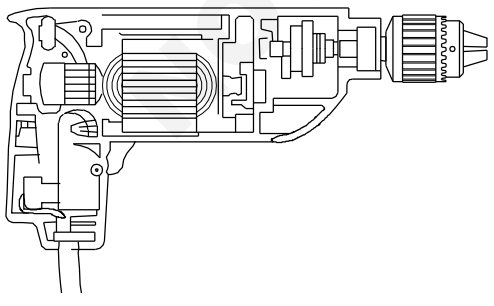



These are available in different forms. The electric hand drill has a small electrical motor for driving the drill. On the end of the spindle, a drill chuck is mounted. Electric hand drills used for light duty will have, usually, a single speed.

**Electric hand drill (heavy duty) (Fig 2&3)**

This drill has an additional feature by which the drill speed can be varied through a system of gears. This is particularly useful for drilling larger diameter holes.

Fig 2




**Pneumatic hand drill (Fig 4)**

This type of drill is operated by compressed air. An air driven motor is housed in the casing, and a handle is fitted along with an air pipe to operate the drill conveniently.

Fig 3

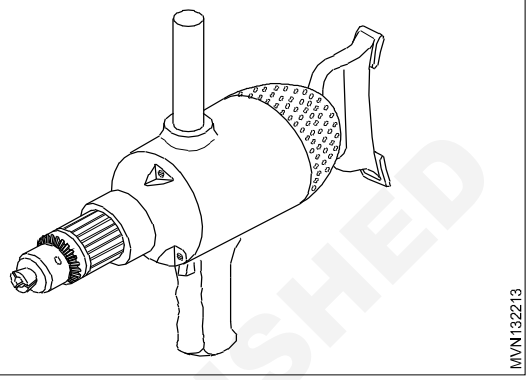
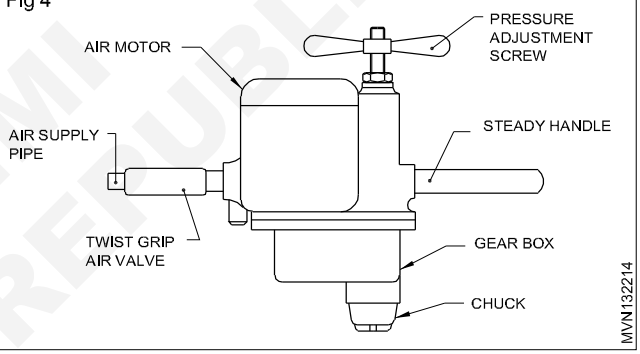



Fig 4

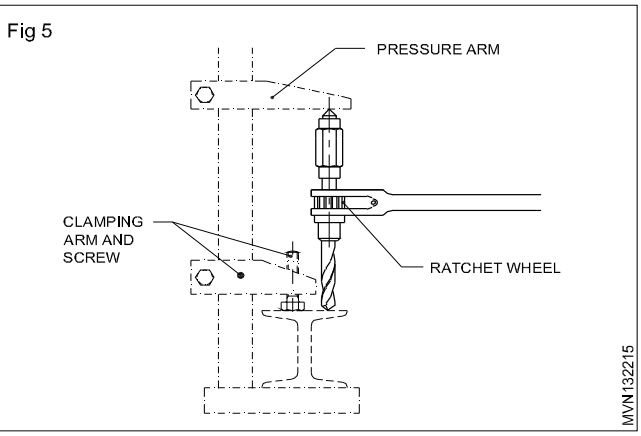



This drill is used where electrically operated drills are prohibited i.e. explosives factories, petroleum refineries etc.

**Hand operated drilling machines:** Different types of hand operated drilling machines are shown below. They are used in structural fabrication, sheet metal and carpentry, particularly where electricity or pneumatic supply is not available.

The ratchet drilling machine (Fig 5) is commonly used in structural fabrication. Square head, taper shank drills are used on these machines.

Fig 5



The bevel gear type drilling machine (Fig 6) is used for drilling small diameter holes up to 6mm.

The breast drilling machine (Fig 7) is used for drilling holes of larger diameter as more pressure can be exerted. Drills between 6 mm to 12 mm can be used on these machines.

Fig 6

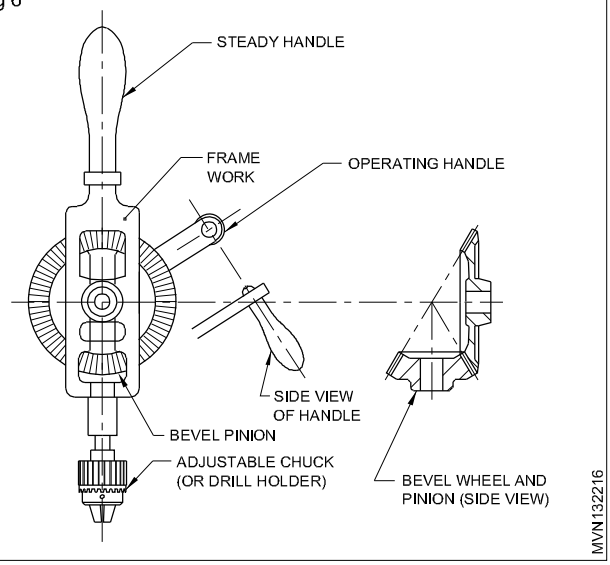
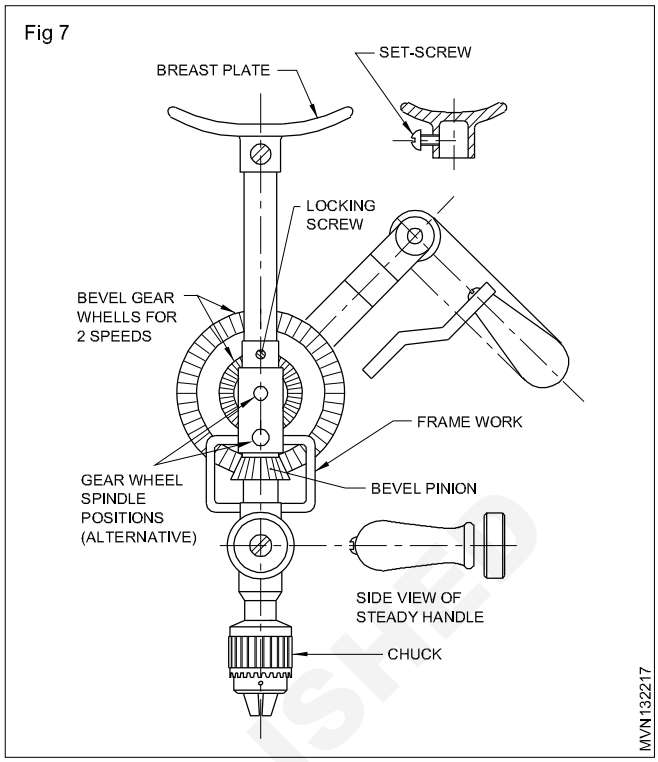



Fig 7




## Drilling machines

**Objectives:** At the end of this lesson you shall be able to

- **name the types of drilling machines**
- **list out the parts of bench type, pillar type and radial drilling machines and state the features.**

**Types of drilling machine:** The principle types of drilling machines are;

- the sensitive bench drilling machine
- the pillar drilling machine
- the column drilling machine
- the radial arm drilling machine (radial drilling machine)

(You are not likely to use the column and radial types of drilling machines now. Therefore, only the sensitive and pillar type machines are explained here)

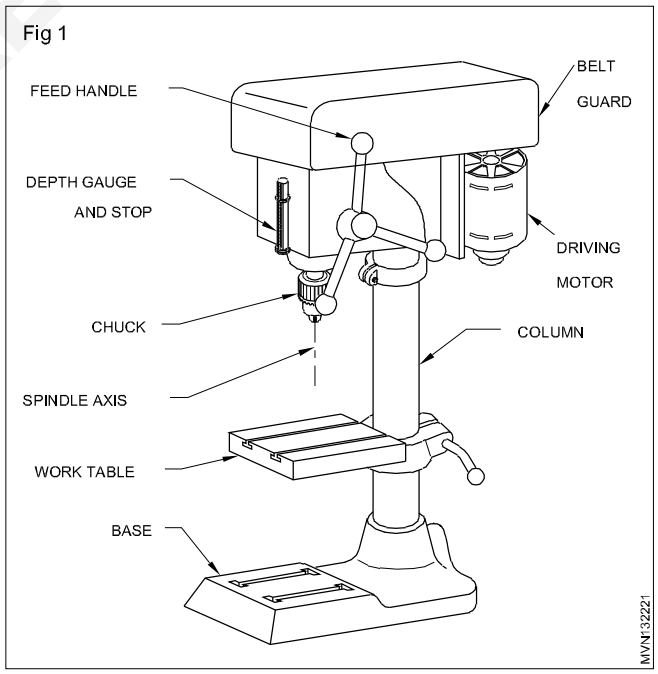
**The sensitive bench drilling machine (Fig 1)**

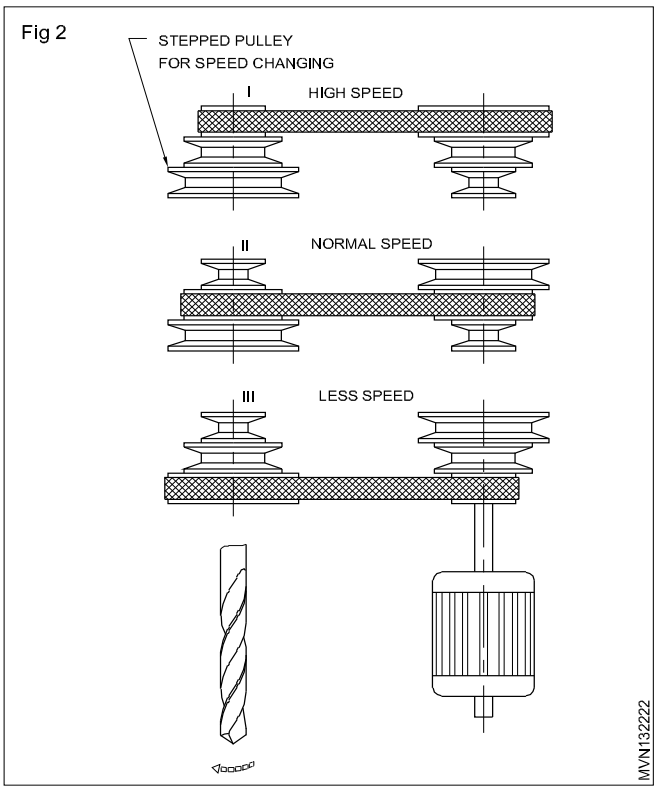
The simplest type of sensitive drilling machines is shown in the figure with its various parts marked. This is used for light duty work.

This machine is capable of drilling holes upto 12.5 mm diameter. The drills are fitted in the chuck or directly in the tapered hole of the machine spindle.

Different spindle speeds are achieved by changing the belt position in the stepped pulley. (Fig 2)

Fig 1



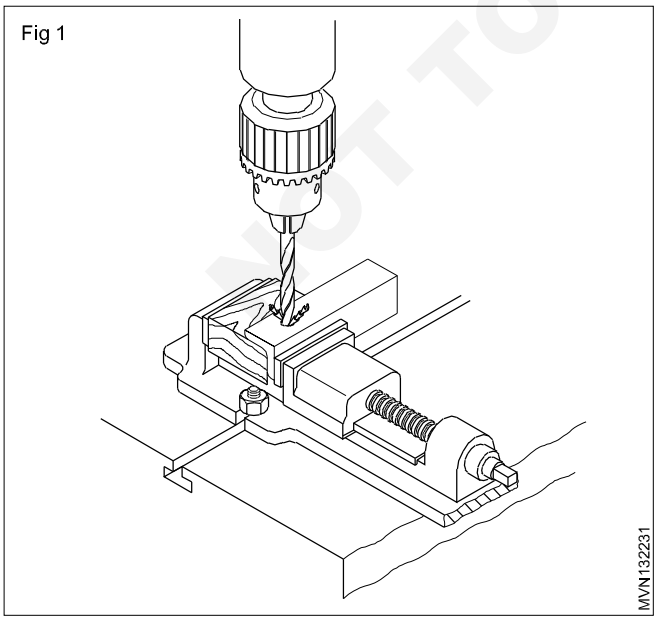



## Work - Holding devices

**Objectives:** At the end of this lesson you shall be able to
- **state the purpose of work-holding devices**
- **name the devices used for holding work**
- **state the precautions to be observed while using.**

Workpieces to be drilled should be properly held or clamped to prevent them from rotating along with the drill. Improperly secured work is not only a danger to the operator but can also cause inaccurate work, and breakage to the drill. Various devices are used to ensure proper holding.

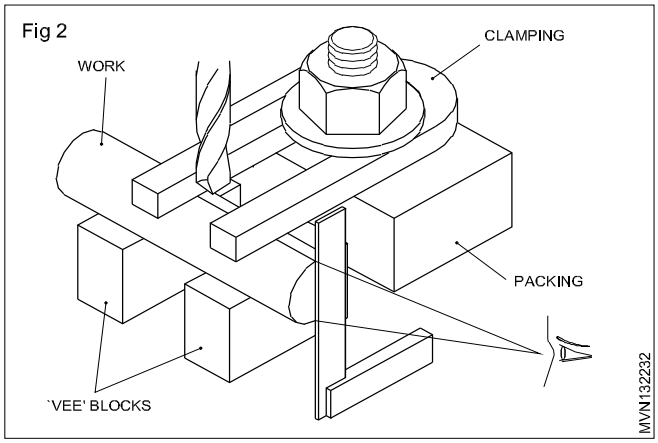
**The machine vice (Fig 1)**

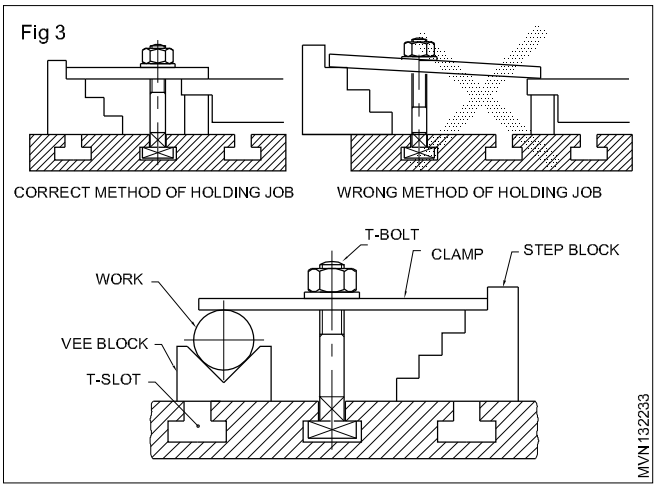



Most of the drilling work can be held in a machine vice. Ensure that the drill does not drill through the vice after it has passed through the work. For this purpose, the work can be lifted up and secured on parallel blocks providing a gap between the work and the bottom of the vice.

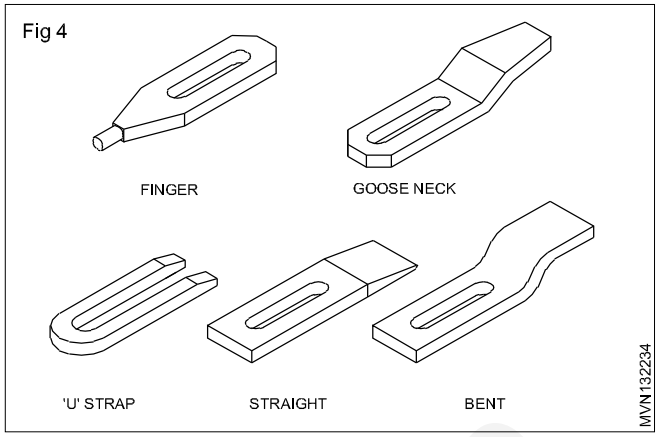
Workpieces which are not accurate may be supported by wooden pieces.

**Clamps and bolts (Fig 2 & 3):** Drilling machine tables are provided with T-slots for fitting bolt heads. Using clamps and bolts, the workpieces can be held very rigidly. While using this method, the packing should be, as far as possible, of the same height as the work, and the bolt nearer to the work.






There are many types of clamps (Fig 4) and it is necessary to determine the clamping method according to the work.




## Drill - Holding devices

**Objectives:** At the end of this lesson you shall be able to
- **name the types of drill-holding devices**
- **state the features of drill chucks**
- **state the functions of drill sleeves**
- **state the function of drift.**

For drilling holes on material, the drills are to be held accurately and rigidly on the machines.

The common drill-holding devices are drill chucks and sleeves and sockets.

**Drill Chuck:** Straight shank drills are held in drill chucks. For fixing and removing drills, the chucks are provided either with a pinion and key or a knurled ring.

The drill chucks are held on the machine spindle by means of an arbor fitted or the drill chuck. (Fig 1)

**Taper Sleeves and Sockets (Fig 1):** Taper shank drills have a morse taper.

Sleeves and sockets are made with the same taper so that the taper shank of the drill. When engaged, will give a good wedging action. Due to this reason morse tapers are called self-holding tapers.

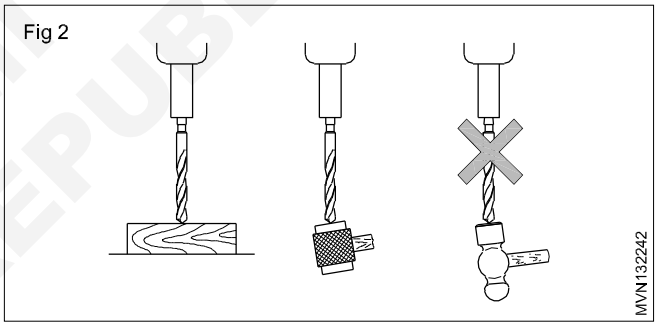
Drills are provided with five different sizes of morse tapers, and are numbered from MT 1 to MT5.

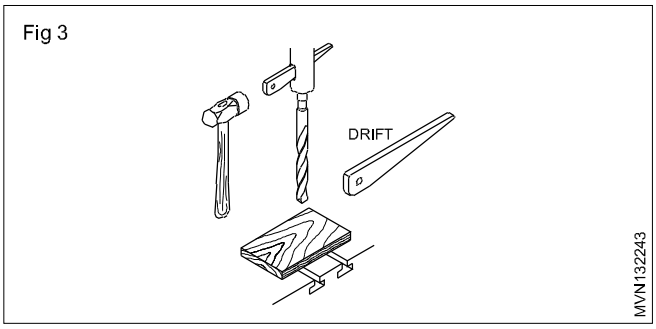
In order to make up the difference in sizes between the shanks of the drills and the type of machine spindles, sleeves of different sizes are used. When the drill taper shank is bigger than the machine spindle, taper sockets are used. (Fig 1)

While fixing the drill in a socket or sleeves the tang portion should align in the slot (Fig 2). this will facilitate the removal of drill or sleeve from the machine spindle.

Use a drift remove drills and sockets from the machine spindle. (Fig 3)

**While removing the drill from the sockets sleeves, don't allow it to fall on the table or jobs. (Fig 4)**



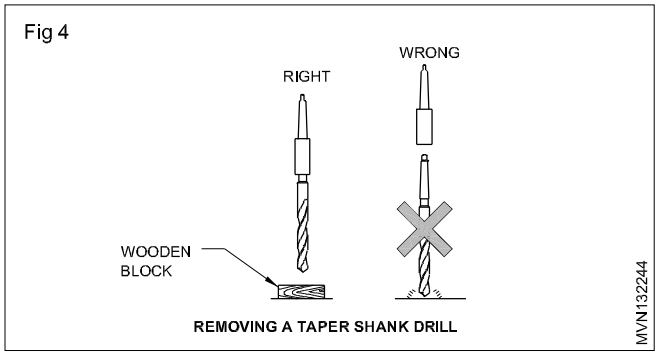
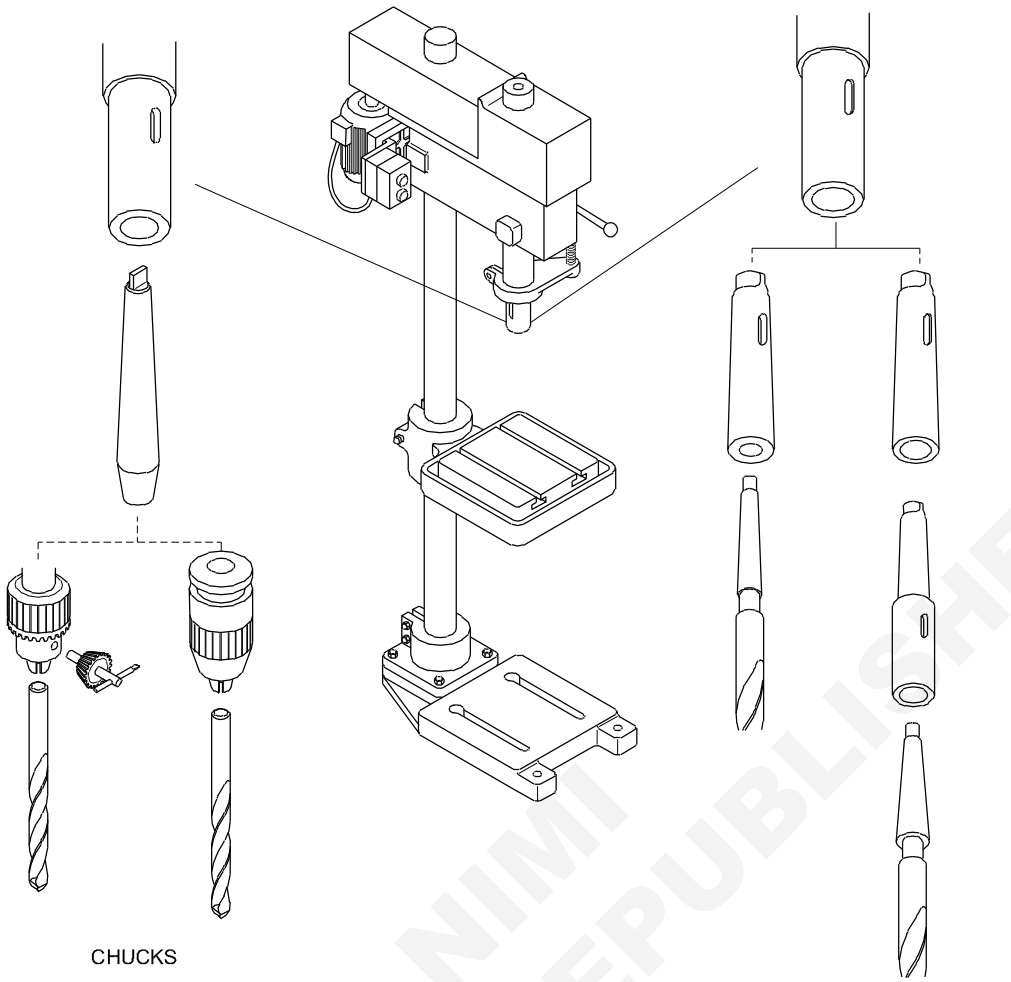



Fig 1





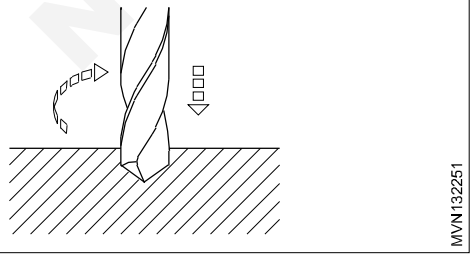

## Drill bits

**Objectives:** At the end of this lesson you shall be able to
- **state the functions of drills**
- **name the parts of a drill and their function.**

**Function of drills:** Drilling is a process of making holes on workpieces. The tool used is a drill. For drilling the drill is rotated with a downward pressure causing the tool to penetrate into the material (Fig 1)

**Parts of a Drill (Fig 2):** The Various parts of a drill can be identified from Fig 2

Fig 1




**Point:** The cone shaped end which does the cutting is called point. It consists of a dead centre, lips or cutting edges and a heel.

**Shank:** This is the driving end of the drill which is fitted on to the machine. Shanks are of two types.

Taper shanks, used for larger diameter drills, and straight shank, used for smaller diameter drills.

**Tang:** This is a part of the taper shank drill which fits into the slot of the drilling machine spindle.

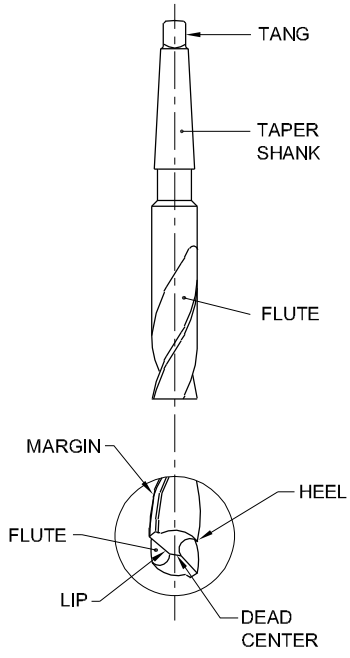
**Body (Fig 3):** The portion between the point and the shank is called the body of a drill.

The parts of the body are flute, land/margin, body clearance and web.

**Flutes:** Flutes are the spiral grooves which run to the length of the drill. The flutes help,

- to form the cutting edges
- to curl the chips and allow these to come out
- the coolant to flow to the cutting edge.

Fig 2




**Land/Margin**

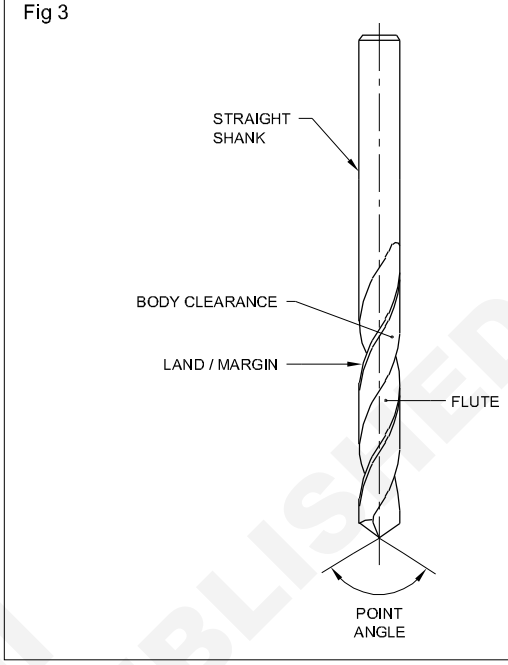
The land/margin is the narrow strip which extends to the entire length of the flutes.

The diameter of the drill a measured across the land margin.

**Body Clearance:** Body clearance is the part of the body which is reduced in diameter to cut down the function between the drill and the hole being drilled.

**Web:** Web is the metal column which separates the flutes. It gradually increases in thickness towards the shank.

Fig 3




## Hand taps and wrenches

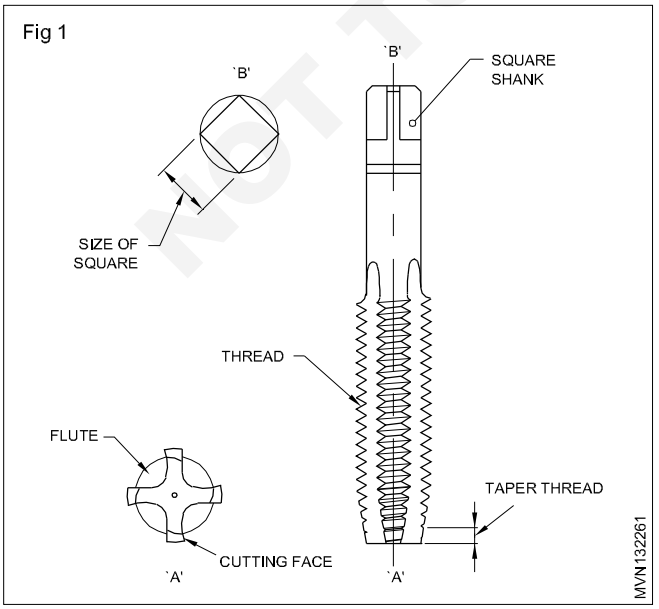
**Objectives:** At the end of this lesson you shall be able to
- **state the uses of threading hand taps**
- **state the features of hand taps**
- **distinguish between different taps in a set**
- **name the different types of tap wrenches**
- **state the uses of different types of wrenches.**

**Use of Hand Taps**

Hand taps are used for internal threading of components.

**Features (Fig 1)**

Fig 1




They are made from high carbon steel of high speed steel hardened and ground

Threads are cut on the surface and are accurately finished.

To form the cutting edges, the flutes are cut across the thread.

For holding and turning the taps while cutting threads the ends of the shanks are squared.

The ends of the taps are chamfered (taper lead) for assisting aligning and starting of the thread.

The size of the taps and the type of the thread are usually marked on the shank.

In certain cases the pitch of the thread will also be marked.

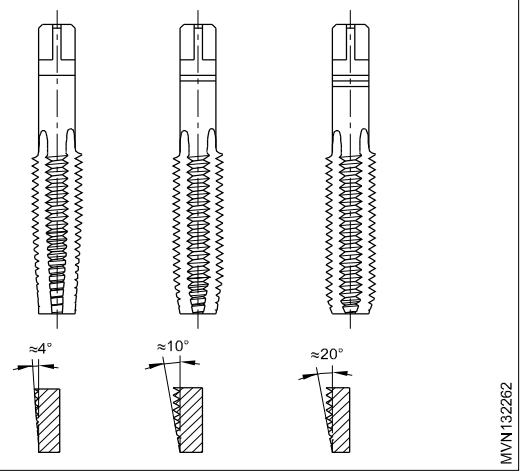
Markings are also made to indicate the type of tap i.e first, second final or plug tap.

**Types of Taps in a set**

Hand taps for a particular thread are available as a set consisting of three pieces (Fig 2). These are

- first tap or taper tap
- second tap or intermediate tap
- plug or bottoming tap

Fig 2




These taps are identical in all features except in the taper lead.

The taper tap is to start the thread. It is possible to form full threads by the taper tap in through holes which are not deep.

The bottoming tap (plug) is used to finish the threads of a blind hole to the correct depth.

for identifying the type of taps quickly - the taps are either numbered as 1,2 and 3 or rings are marked on the shank.

The taper tap has one ring the intermediate tap has two rings and the bottoming tap has three rings (Fig 3)

**Tap Wrenches:** Tap Wrenches are used to align and drive the hand taps correctly into the hole to be threaded.

**Tap Wrenches are of different types**

1 **Double ended adjustable wrench:** Double ended adjustable tap Wrench or Bar Type Tap Wrench. This is shown in Fig 3.

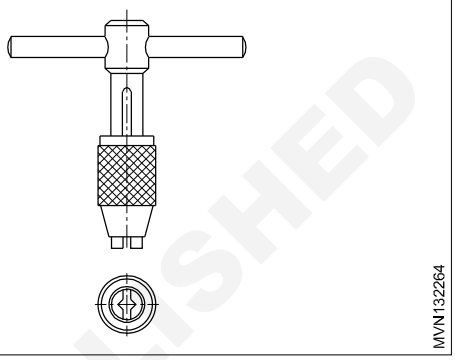
This is the most commonly used type of tap wrench. It is available in various sizes. These tap wrenches are more suitable for large diameter taps and can be used in open places where there is no obstruction to turn the tap. It is important to select the correct size of wrench.

2 **T- Handle tap wrench (Fig 4):** These are small adjustable chucks with two jaws and a handle to turn the wrench.

This tap wrench is useful to work in restricted places and is turned with one hand only.

This is not suitable for holding large diameter taps.

Fig 4




3 **Solid type tap wrench (Fig 5):** These Wrenches are not adjustable

They can take only certain sizes of taps. This eliminates the use of wrong length of the tap wrenches and thus prevents damage to the taps.

Fig 5

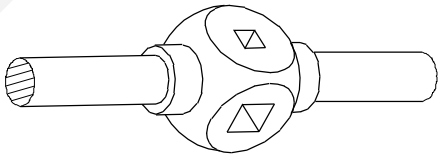
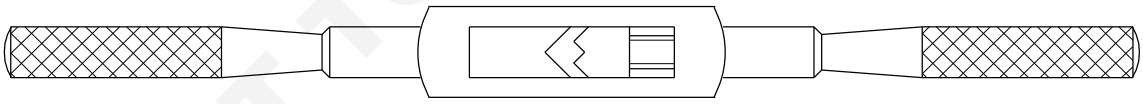



Fig 3




## Tap Drill Size

**Objectives:** At the end of this lesson you shall be able to
- **state what is tap drill size**
- **choose the tap drill sizes for different threads from tables**
- **calculate the tap drill sizes for ISO metric and ISO inch.**

**What is a tap drill Size?**

Before a tap is used for cutting internal threads, a hole is to be drilled. The diameter of the hole should be such that it should have sufficient material in the hole for the tap to cut the thread.

**Tap Drill Sizes for Different Threads**

ISO Metric Thread

Tapping drill size

for M10 x 1.5 thread

Minor diameter = Major diameter – 2 x depth

depth of thread = 0.6134 x pitch of a screw

2 depth of thread = 0.6134 x 2 x pitch

=1.226 x 1.5 mm = 1.839 mm

Minor dia (D1)=10 mm – 1.839 mm

=8.161mm or 8.2 mm

This tap drill will produce 100% thread because this is equal to the minor diameter of the thread. For most fastening purposes a 100% formed thread is not required.

A standard nut with 60% thread is strong enough to be tightened until the bolt breaks without stripping the thread. Further it also requires a greater force for turning the tap if a higher percentage formation of thread is required.

Considering this aspect, a more practical approach for determining the tap drill sizes is

Tap drill size = Major diameter – pitch

= 10 mm - 1.5 mm; = 8.5 mm.

**Compare this with the table of tap drill sizes for ISO metric threads.**

ISO Inch (Unified) threads Formula

Tap Drill size =

$$\text{Major diameter} - \frac{1}{\text{Number of threads per inch}}$$

For calculating the tap drill size for 5/8" UNC thread

Tap drill size = 5/8" – 1/11"

= 0.625" – 0.091" ; = 0.534"

The next drill size is 17/32" (0.531 inches)

Compare this with the table of drill sizes for unified inch threads.

What will be the tapping size for the following threads?

a M 20 b UNC 3/8

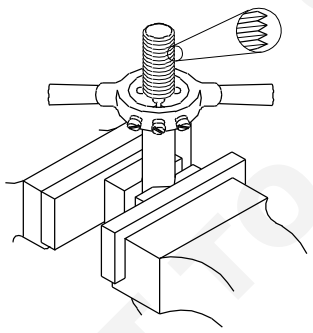
**Refer to chart for determining the pitches of the thread.**

## Die and die stock

**Objectives:** At the end of this lesson you shall be able to
- **state the use of each type of die**
- **name the different types of dies**
- **state the features of each type of die**
- **name the type of diestock for each type of die.**

**Uses of Dies:** Threading dies are used to cut external threads on cylindrical workpieces. (Fig 1)

Fig 1



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**Types of Dies:** The following are the different types of dies.

Circular Split Die (Button die)

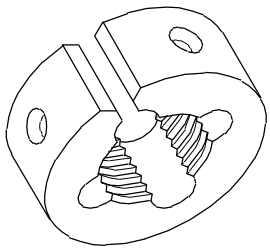
Half Die

Adjustable Screw Plate Die

**Circular Split Die/Button Die (Fig 2):** This has a slot cut to permit slight variation in size.

When held in the diestock, variation in the size can be made by using the adjusting screws. This permits increasing or decreasing of the depth of cut. When the side screws are tightened the die will close slightly. (Fig 3)

Fig 2



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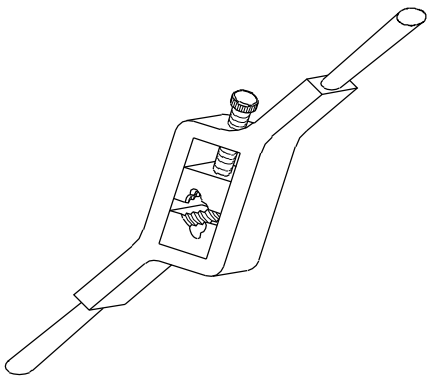
For adjusting the depth of the cut, the centre screw is advanced and locked in the groove. This type of die stock is called button pattern stock.

**Half Die (Fig 4)**

Fig 4



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Half dies are stronger in construction.

Adjustments can be made easily to increase or decrease the depth of cut.

These dies are available in matching pairs and should be used together.

By adjusting the screw of the diestock, the die pieces can be brought closer together or can be moved apart.

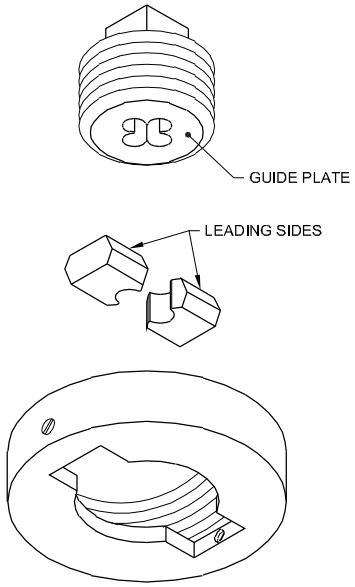
They need a special die holder.

**Adjustable Screw Plate Die (Fig 5)**

This is another type of a two piece die similar to the half die.

This provides greater adjustment than the split die.

Fig 5




The two die halves are held securely in a collar by means of a threaded plate (guide plate) which also acts as a guide while threading.

When the guide plate is tightened after placing the die pieces in the collar, the die pieces are correctly located and rigidly held.

The die pieces can be adjusted, using the adjusting screws on the collar. This type of die stock used is called quick cut diestock. (Fig 6)

The bottom of the die halves is tapered to provide the lead for starting the thread. On one side of each die head, the serial number is stamped.

Both pieces should have the same serial numbers.

**Die Nut (Solid Die) (Fig 7)**

The die nut is used for chasing or reconditioning the damaged threads.

**Die nuts are not to be used for cutting new threads.**

The die nuts are available for different standards and sizes of threads.

The die nut is turned with a spanner.

Fig 7

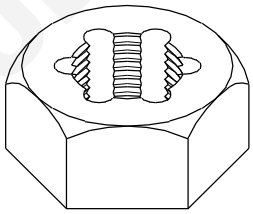



Fig 3

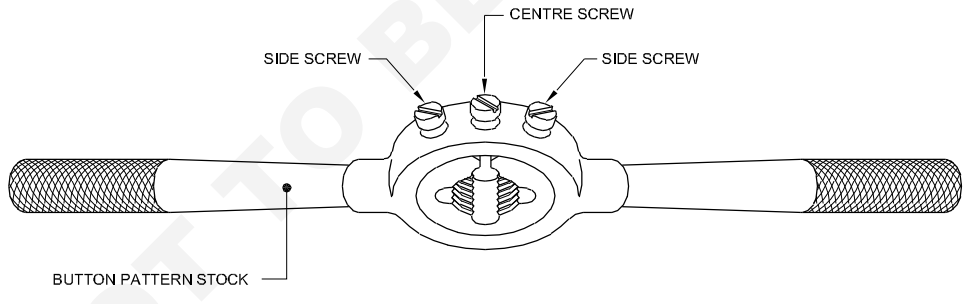
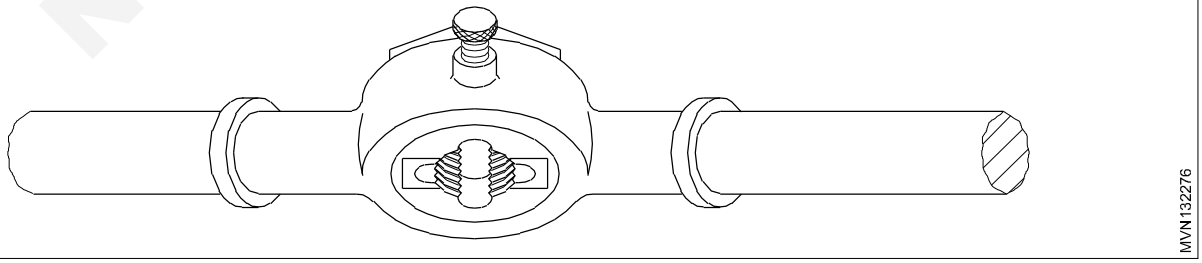



Fig 6



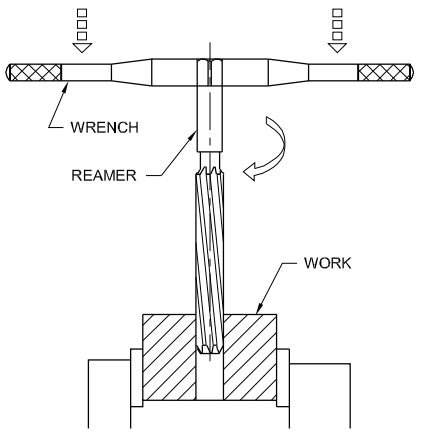
# Reamers

**Objectives:** At the end of this lesson you shall be able to
- **define reamers**
- **state the advantages of reaming**
- **distinguish between hand and machine reaming**
- **name the elements of a reamer.**

### What is reamer?

A reamer is a multi-point cutting tool used for enlarging and finishing previously drilled holes to accurate sizes. (Fig 1)

Fig 1




### Advantages of 'reaming'

Reaming produces high quality surface finish and dimensional accuracy to close limits.

Also small holes which cannot be finished by other processes can be finished.

### Classification of reamers

Reamers are classified as hand reamers and machine reamers. (Fig 2 and 3)

Reaming by using hand reamers is done manually for which great skill is needed.

Fig 2

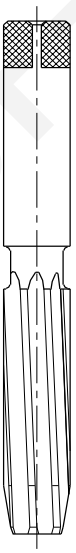
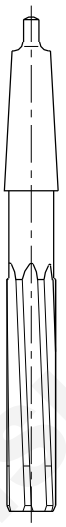



Fig 3




Hand reamers have straight shanks with 'square' at the end for holding with tap wrenches. (Fig 2)

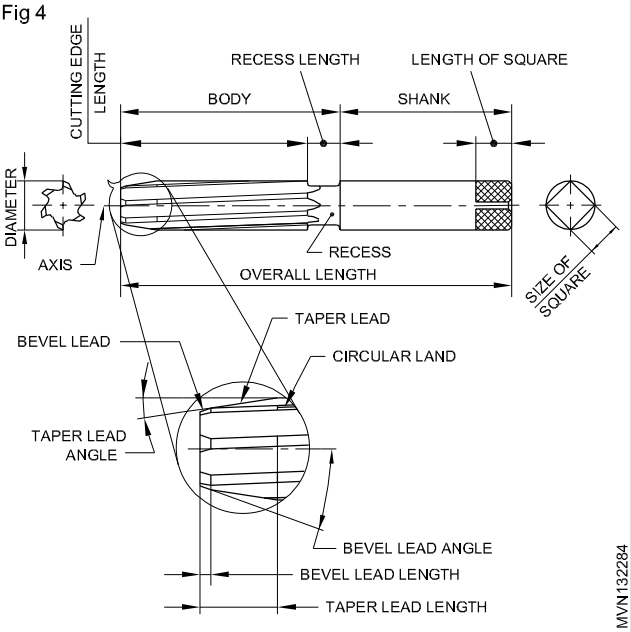
Machine reamers are fitted on spindles of machine tools by means of a floating chuck and are rotated for reaming.

Machine reamers are provided with Morse taper shanks for holding on machine spindles. (Fig 3)

### Parts of a hand reamer

The parts of an hand reamer are shown in Fig 4.

Fig 4



# Hole size for reaming

**Objective:** At the end of this lesson you shall be able to
- **determine the hole size for reaming.**

For reaming with a hand or machine reamer the hole drilled should be smaller than the reamer size.

The drilled hole should have sufficient metal for finishing with the reamer. Excessive metal will impose a strain on the cutting edge of the reamer and damage it.

**Calculating drill size for reamer**

A method generally practised in workshops is by applying the following formula.

Drill size = Reamed size - (undersize+oversize) of drilled hole.

**Finished size**

Finished size is the diameter of the reamer.

**Undersize**

Undersize is the recommended reduction in size for different ranges of drill diameter. (Table 1)

**TABLE 1**

**Undersizes for reaming**

| Diameter of ready hole (mm) | Undersizes of bored board hole (mm) |
|---|---|
| under 5 | 0.1...0.2 |
| 5....20 | 0.2...0.3 |
| 21....50 | 0.3....0.5 |
| over 50 | 0.5....1 |

**Oversize of drilled hole:** It is generally considered that a twist drill will make a hole larger than its diameter. The oversize for calculation purposes is taken as 0.05 mm, for all diameters of drills.

For light metals the undersize will be 50% larger.

**Example**

A hole is to be reamed on mild steel with a 10mm reamer. What will be the diameter of the drill for drilling the hole before reaming?

Drill size = Reamer size - (undersize + oversize)

(finished size) = 10mm

Undersize as per table = 0.2 mm

Oversize = 0.05 mm

Finished size = 0.05+0.2 = 0.25mm

Drill size = 10mm - 0.25mm = 9.75 mm

**Determining the drill hole sizes for the following reamers**

i) 15mm ii) 44mm

iii) 4mm iV) 19mm

**Answer**

i) _____

ii) _____

iii) _____

iv) _____

**If the reamed hole is undersize, the cause is that the reamer is worn out.**

**Always inspect the condition of the reamer before commending reaming.**

For obtaining good surface finish, use a coolant while reaming. Remove metal chips from the reamer frequently advance the reamer slowly into the work.

**Defects in reaming - Cause and Remedies Reamer hole undersize**

If a worn out reamer is used, it may result in the reamed hole being undersize. Do not use such reamers.

Always inspect the condition of the reamer before using.

**Surface finish rough**

The causes may be anyone of the following are combination thereof.

- incorrect application
- Swarf accumulated in reamer flutes
- in adequate flow of coolant
- feed rate too fast

While reaming apply a steady and slow feed rate.

Ensure a copious supply of the lubricant.

Do not turn the reamer in the reverse direction.

# Lapping

**Objectives:** At the end of this lesson you shall be able to
- **state the purpose of lapping**
- **state the features of a flat lapping plate**
- **state the use of changing a flat lapping plate**
- **state the method of charging a cast iron plate.**

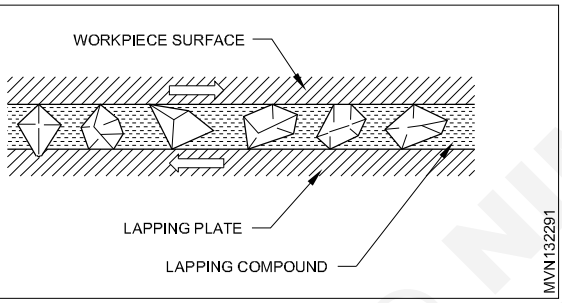
Lapping is a precision finishing operation carried out using line abrasive materials.

**Purpose :** This process

- improves geometrical accuracy
- refines surface finish
- assists in achieving a high degree of dimensional accuracy.
- improves the quality of fit between the mating components.

**Lapping process:** in the lapping process small amounts of material are removed by rubbing the work against a lap charged with a lapping compound. (Fig 1)

Fig 1



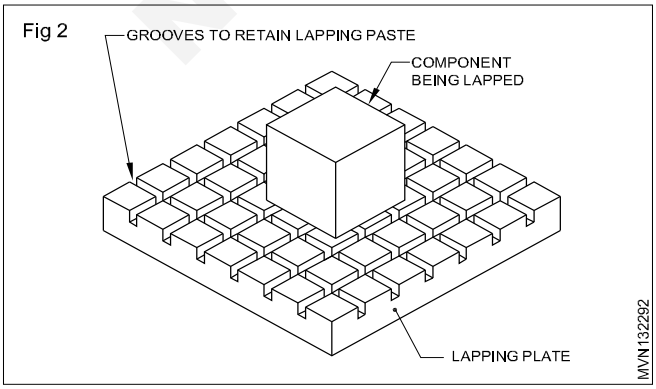

The lapping compound consists of the abrasive particles. Suspended in a base such as oil, paraffin, grease etc.

The lapping compound which is introduced between the workpiece and the lap chips away the material from the workpiece. Light pressure is applied when both are moved against each other. The lapping can be carried out manually or by machine.

**Hand lapping of flat surfaces:** Flat surfaces are hand lapped using lapping plates made out of close grained cast iron. (Fig 2) The surface of the plate should be in a true plane for accurate results in lapping.

The lapping plate generally used in tool rooms will have narrow grooves out on its surface both lengthwise and crosswise forming a series of squares.

Fig 2




These grooves are usually about 12mm apart.

While lapping the lapping compound collects in the serrations and rolls in and out as the work a moved.

Before commencing lapping of the component, The cast iron plate should be CHARGED with abrasive practices.

This is a process by which the abrasive practices are embedded on to the surfaces of the laps which are comparatively softer than the component being lapped.

For charging the cast iron lap apply a thin coating of the abrasive compound over the surface of the lapping plate.

Use a finished hard steel block and press the cutting particles into the lap. While doing so, rubbing should be kept to the minimum. When the entire surface of the lapping plate is charged, the surface will have a uniform grey appearance. If the surface is not fully charged, bright spots will be visible here and there.

**Excessive application of the abrasive compound will result in the rolling action of the abrasive between the work and the plate developing in accuracies.**

The surface of the flat lap should be finished true by scraping before charging. After charging the plate, wash of all the loose abrasives using kerosene.

Then place the workpiece on the plate and move along and across, covering the entire surface areas of the plate. When carrying out fine lapping, the surface should be kept moist with the help of kerosene.

**Wet and dry lapping:** Lapping can be carried out either wet or dry.

In wet lapping there is surplus oil and abrasives on the surface of the lap. As the workpiece which is being lapped is moved on the lap, there is movement of the abrasive particles also.

In the dry method the lap is first charged by rubbing the abrasives on the surface of the lap. The surplus oil and abrasives are then washed off. The abrasives embedded on the surface of the lap will only be remaining. The embedded abrasives act like a fine oilstone when metal pins to be lapped are moved over the surface with light pressure.

However, while lapping, the surface being lapped is kept moistened with kerosene or petrol. Surfaces finished by the dry method will have better finish and appearance. Some prefer to do rough lapping by wet method and finish by dry lapping.

# Lap materials and lapping compounds

**Objectives:** At the end of this lesson you shall be able to
- **state the qualities of different lap materials**
- **name the different types of lap materials**
- **name the different types of abrasive materials used for lapping**
- **distinguished between the application of different lapping abrasives**
- **state the function of lapping vehicles**
- **name the solvents used in lapping.**

The material used for making laps should be softer than the workpiece being lapped. This helps to charge the abrasives on the lap. If the lap is harder than the workpiece, the workpiece will get charged with the abrasives and cut the lap instead of the workpiece being lapped. Laps are usually made of

- close grained iron
- copper
- brass or lead.

The best material used for making lap is cast iron, but this cannot be used for all applications.

When there is excessive lapping allowance, copper and brass laps are preferred as they can be charged more easily and cut more rapidly than cast iron.

Lead is an in expensive form of lap commonly used for holes. Lead is cast to the required size on steel arbar. These laps can be expanded when they are worn out. Charging the lap is much quicker.

**Lapping abrasives and their applications:** Abrasives of different types are used for lapping. The commonly used abrasives are:

- silicon carbide
- aluminium oxide
- boron carbide and
- diamond.

**Silicon carbide:** This is an extremely hand abrasive. Its grit is sharp and brittle. While lapping the sharp cutting edges continuously break down exposing new cutting edges. Due to this reason this is considered as very ideal for lapping hardened steel and cast iron, particularly where heavy stock removal is required.

**Aluminium oxide**: Aluminium oxide is sharp but tougher than silicon carbide. Aluminium oxide is used in un-fused and fused forms.

Un-fused alumina(aluminium oxide) removes stock effectively and is capable of obtaining high quality finish.

Fused alumina is used for lapping soft steels and nonferrous metals.

**Boron Carbide:** This is an expensive abrasive material which is next to diamond in harness. While it has excellent cutting properties, it is used because of the high cost only in special application like dies and gauges.

**Diamond:** This being the hardest of all materials. It is used for lapping tungsten carbide. Rotary diamond laps are also prepared for accurately finishing very small holes which cannot be ground.

**Lapping vehicles:** In the preparation of lapping compounds the abrasive particles are suspended in vehicles. This helps to prevent concentration of abrasives on the lapping surfaces and regulates the cutting action and lubricates the surfaces.

The commonly used vehicles are:

- water soluble cutting oils
- vegetable oils
- machine oils
- petroleum jelly or grease
- vehicles with oil or grease base used for lapping ferrous metals.

  Metals like copper and its alloys and other non-ferrous metals are lapped using soluble oil, bentonite etc.

**Solvents used in lapping**

In addition to the base used in making the lapping compound, solvents like water, kerosene, etc are also used at the time of lapping.

**Abrasives of varying grain sizes from 50 to 800 microns are used for lapping, depending on the surface finish required on the component.**

# Introduction to electricity

**Objectives:** At the end of this lesson you shall be able to
- **describe electricity and structure of matter**
- **describe atomic structure**
- **describe the energy shell and electron distribution**
- **describe conductors, insulators and semi conductors.**

**Introduction:** Electricity is one of today's most useful sources of energy. Electricity is of utmost necessity in the modern world of sophisticated equipment and machinery.

Electricity in motion is called electric current. Whereas the electricity that does not move is called static electricity.

**Examples of Electric current**

- Domestic electric supply, industrial electric supply.

**Examples of static electricity:** Shock received from door knobs of a carpeted room. Attraction of paper of the comb.

**Structure of matter**

To understand electricity, one must understand the structure of matter. Electricity is related to some of the most basic building blocks of matter that are atoms (electrons and protons). All matter is made of these electrical building blocks, and, therefore, all matter is said to be 'electrical'.

Matter is defined as anything that has mass and occupies space. A matter is made of tiny, invisible particles called molecules. A molecule is the smallest particle of a substance that has the properties of the substance. Each molecule can be divided into simpler parts by chemical means. The simplest parts of a molecule are called atoms.

**Atomic Structure:** Basically, an atom contains three types of sub-atomic particles that are of relevance to electricity. They are the electrons, protons and neutrons. The protons and neutrons are located in the centre, or nucleus, of the atom, and the electrons travel around the nucleus in orbits.

**The Nucleus**

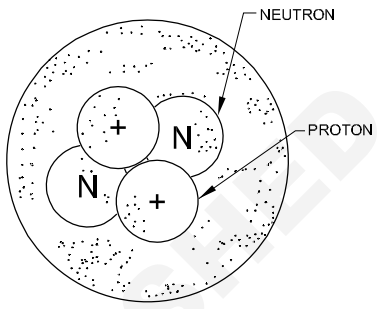
The nucleus is the central part of the atom. It contains the protons and neutrons of an atom as shown in Fig 1

**Protons**

The proton has a positive electrical charge. (Fig 1) It is almost 1840 times heavier than the electron and it is the permanent part of the nucleus; protons do not take an active part in the flow or transfer of electrical energy.

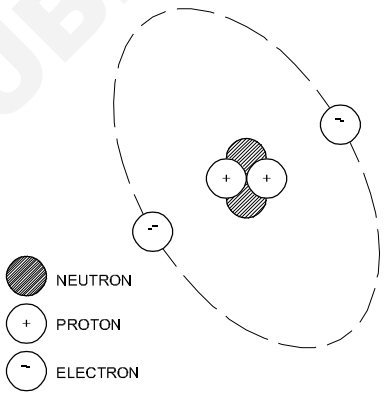
**Electron:** It is a small particle revolving round the nucleus of an atom as shown in Fig 2. It has a negative electric charge. The electron is three times larger in diameter than the proton. In an atom the number of protons is equal to the number of electrons.

Fig 1




NUCLEUS OF AN ATOM

Fig 2




**Neutron**

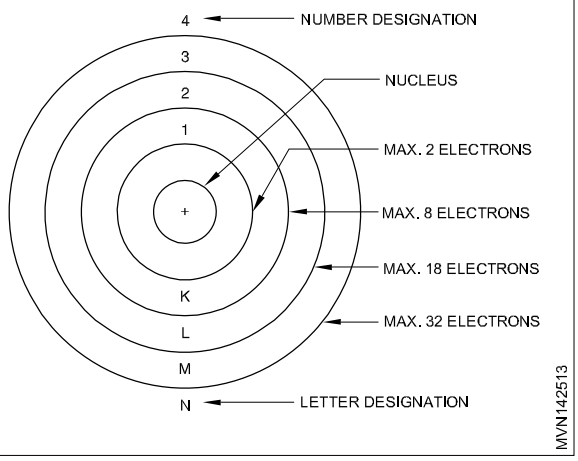
A neutron is actually a particle by itself, and is electrically neutral. Since neutrons are electrically neutral, they are not too important to the electrical nature of atoms.

**Energy Shells**

In an atom, electrons are arranged in shells around the nucleus. A shell is an orbiting layer or energy level of one or more electrons. The major steel layers are identified by numbers of by letters starting with 'K' nearest the nucleus and continuing alphabetically outwards. There is a maximum number of electrons that can be contained in each steel. Fig 3 illustrates the relationship between the energy shell level and the maximum number of electrons it can contain.

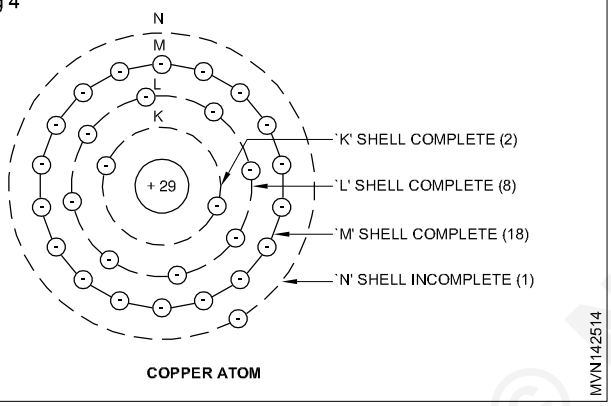
If the total number of electrons for a given atom is known, the placement of electrons in each shell can be easily determined. Each shell layer, beginning with the first, is filled with the maximum number of electrons in sequence.

Fig 3



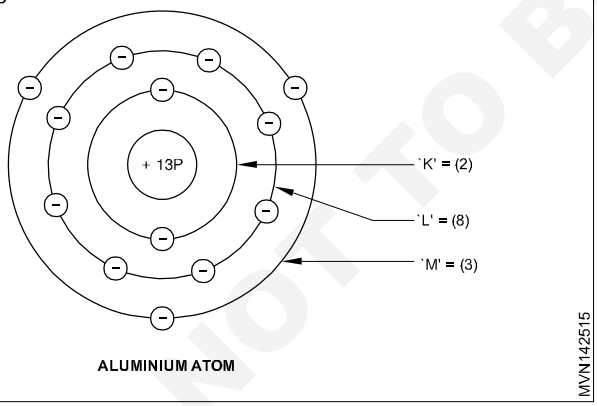

For example, a copper atom which has 29 electrons would have four sheels with a number of electrons in each shell as shown in Fig 4.

Fig 4




Similarly an aluminium atom which has 13 electrons has 3 shell as shown in Fig 5.

Fig 5




## Electron distribution

The chemical and electrical behaviour of atoms depends on how completely the various shell and sub-shells are filled.

Atoms that are chemically active have one electron more or one less than a completely filled shell. Atoms that have the outer shell exactly filled are chemically inactive. They are called inert elements. All inert elements are gases and do not combine chemically with other elements.

**Metals possess the following characteristics**

- They are good electric conductors.
- Electrons in the outer shell and sub-shells can move more easily from one atom to another.
- They carry charge through the material.

The outer shell of the atom is called the valence shell and its electrons are called valence electrons. Because of their greater distance from the nucleus, and because of the partial blocking of the electric field by electrons in the inner shells, the attracting force exerted by nuclues on the valence electrons is less. Therefore, valence electrons can be set free most easily. Whenever a valence electron is removed from its orbit it becomes a free electron. Electricity is commonly defined as the flow of these free electrons through a conductor. Though electrons flow from negative terminal to positive terminal, the conventional current flow is assumed as from positive to negative.

**Conductors Insulators and Semiconductors**

**Conductors**

A conductor is a material that has many free electrons permitting electrons to move through it easily. Generally, conductors have incomplete valence shells of one, two or three electrons. Most metals are good conductors.

Some common good conductors are Copper, Aluminium, Zinc, Lead, Tin, Eureka, Nichrome, Silver and Gold.

**Insulators**

An insulator is a material that has few, if any, free electrons and resists the flow of electrons. Generally, insulators have full valence shells of five, six or seven electrons. Some common insulators are air, glass, rubber, plastic, paper, porcelain, PVC, fibre, mica etc.

**Semiconductors**

A semiconductor is a material that has some of the characteristics of both the conductor and insulator. Semiconductor have valence shells containing four electrons.

Common examples of pure semiconductor materials are silicon and germanium. Specially treated semiconductors are used to produce modern electronic components such as diodes, transistors and integrated circuit chips.

# Ground connections

**Objectives :** At the end of this lesson you shall be able to
- **describe the necessity of earthing**
- **explain the reasons for system and equipment earthing**
- **describe the shielding.**

**Necessity of earthing**

While working in electrical circuits, the most important consideration for an Electrician is the safety factor - safety not only for himself but also for the consumer who uses the electricity.

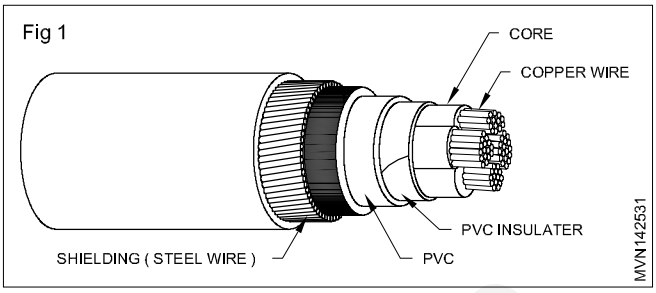
Reasons for earthing

An electric shock is dangerous only when the current through the body exceeds beyond certain milliampere value. In general any current flowing through the body beyond 5 milliamperes is considered dangerous.

**Shielding**

Shielding is the (Fig.1) protective device layer over the insulated cable. Shielded cable or screened cable is an electrical cable one or more insulated conductors enclosed by a common conductive layer. The shield may be composed of braided strands of copper (or other metal - braided spiral winding of copper tape, or a layer of conducting polymer.

Fig 1




**Uses**

- It act as earth / ground for the electrical appliances.
- It protect the cables from moisture entering as well as flexible.
- It also act as mechanical strength as well as flexible to the cables.
- It protect the cable from all weather condition like water, oil, gases and heat.

# Ohm's Law

**Objectives:** At the end of this lesson you shall be able to
- **define EMF, PD, Current and resistance and state their units**
- **state the units of each term**
- **name the instruments used for measurement**
- **define ohm's law**
- **explain close circuit, open circuit and short circuit**
- **distinguish of AC and DC meters**
- **explain pire wheel.**

Scan the QR Code to view the video for these exercise

**Electrical terms and definitions EMF and Pd**

The force tending to make electrons to move along a conductor is called the potential difference (pd) in the conductor and is expressed in volts. This is also called the electric pressure or the voltage.

The voltage developed by a source such as a battery of a generator is called its electromotive force. (emf)

When one ampere current flows through one ohm resistance the p.d. across the resistance is said to be one "Volt". Voltmeter is used to measure the voltage of a supply and is connected in parallel to the supply. EMF/Pd is denoted by letter "V".

**Current**

The flow of electrons is called current. Its unit is ampere. When one volt is applied across a resistance of one ohm the amount of current passess through the resistance is said to be one "Ampere". It is denoted by "A". Smaller units are milliampere and microampere. Ammeter should be connected in series with the load.

**Resistance:** It is the property of a substance which opposes the flow of electricity. Its unit is ohm. The resistance of a conductor, in which a current of one ampere flows when potential difference of one volt is applied across its terminals, is said to be one ohm.

An ohmmeter is used to measure the resistance of an electric circuit. It is denoted by "Ω" Bigger units are Kilo ohms and Mega ohms.

1 K $\Omega = 10^3$ ohms

1 Mega $\Omega = 10^6$ ohms

Ohmmeter should be connected in parallel with the load and should not be connected when there is a supply.

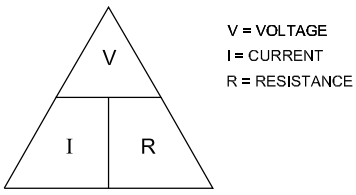
There is a definite relationship between the three electrical quantities of Voltage, Current and Resistance.

**Ohm's Law states**

`The current is directly proportional to the voltage and inversely proportional to the resistance' when the temperature remains constant.

An aid to remember the Ohm's law relationship is shown in the divided triangle. (Fig 1)

Fig 1




Written as a mathematical expression, Ohm's Law is -

$$\text{Current (I)} = \frac{\text{Voltage (V)}}{\text{Current (I)}}$$

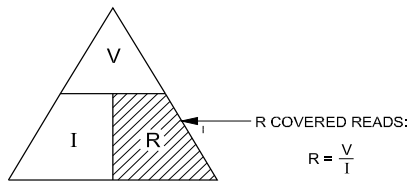
$$\text{or } I = \frac{V}{R}$$

Of course, the above equation can be rearranged as:

$$\text{Resistance (R)} = \frac{\text{Voltage (V)}}{\text{Current (I)}}$$

$$\text{or } R = \frac{V}{I} \qquad \text{(Refer Fig 2)}$$

Fig 2




**Example**

How much current(I) flows in the circuit shown in Fig 3?

Given:

Voltage(V) = 1.5 volts

Resistance(R) = 1 k ohm

= 1000 ohms.

Find:

Current(I)

Formula

$$I = \frac{V}{R}$$

Solution:

$$I = \frac{1.5\ V}{1000\ \text{ohms}} = 0.0015\ \text{amp}$$

*Answer:*

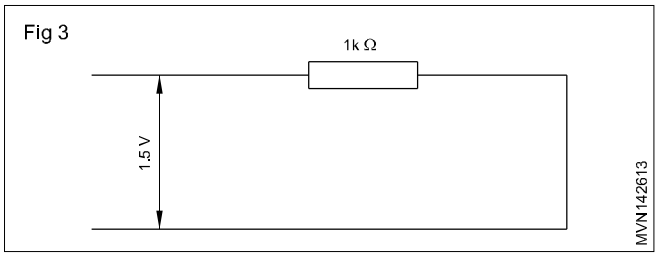
The current in the circuit is 0.0015 A

or

the current in the circuit is 1.5 milliampere (mA).

(1000 milliamps = 1 ampere)

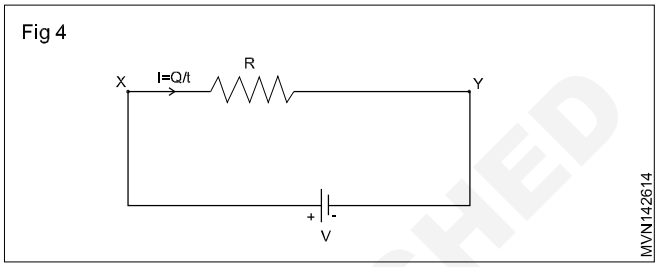
Fig 3




**Electric Circuit (closed circuit, open circuit and short circuit)**

An electric circuit is the path in which the electric current flows. Fig. 4 shows a simple circuit.

Fig 4




B is the source of electric energy (a cell) L is the lamp, the load or appliance to use the electric energy, S is the switch to control the circuit, i.e. to make the circuit on or off, F is the fuse to protect the circuit from faults, B, S and F have terminals marked 1, 2, 3, ... Connecting wires connect them systematically. Electric current starts from terminal 1, goes to terminal 2 through the connecting wire. When S 'ON' it passes to 3 and through F and L it returns to the terminal 8 of the source. Thus the current's path is completed. A circuit like this is called a closed circuit. If the switch is off or the connecting wires are cut or disconnected, it becomes an open circuit. Current cannot pass in an open circuit. If an extra wire connects terminals 5 and 7, the current will find an easier path. This forms a short circuit. In this case, the current does not pass through the load. The current may be very high. The fuse protects the circuit in such cases.

**Identification of A C and D C Meters**

AC and DC meters can be identified as follows;

1 By the symbol available on the dial / scale.

  a Direct current

  b Alternating current

2 By seeing the graduation on the dial / scale

  a If the graduation of dial is uniform throughout, it is a D C meter.

  b If the graduation of dial is cramped at the beginning and at the end, it is an A.C. meter

3 By seeing the terminals

  a In the d C meter the terminals are marked with + and– The positive (+) terminal is Red in colour and the negative (–) terminal is Black in colour.

  b In the A.C meter there is no marking on the terminals and no difference in colour.

**Pire wheel**

(i) current:

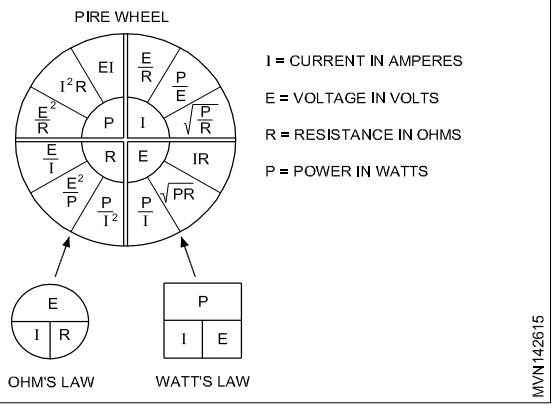
$I = V / R$

$= P / V$

$= \sqrt{P / R}$

The formulae (or equations) to solve for unknown voltage, current, resistance or power can be obtained by combining Ohm's law and Power law. This is shown in Fig 5.

Fig 5




## Electrical measuring instruments and electrical circuits

**Objectives:** At the end of this lesson you shall be able to

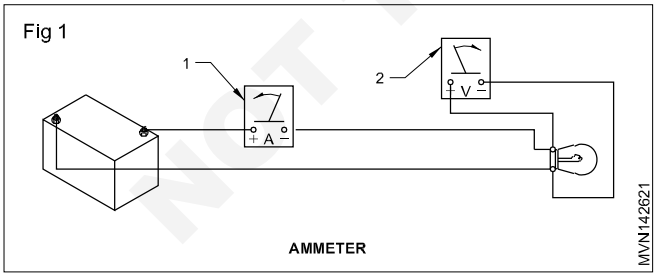
- **explain the connection of an ammeter in the circuit**
- **state the use of an ammeter**
- **explain the care to be taken of an ammeter**
- **explain the connection of a voltmeter**
- **explain the use of a voltmeter**
- **explain the care to be taken of voltmeters**
- **explain the connection of an ohmmeter**
- **state the use of an ohmmeter**
- **explain the care to be taken of ohmmeters**
- **explain the maintenance of meters**
- **state simple electric circuit**
- **state open electric circuit**
- **state short electric circuit**
- **state series circuits & parallel circuits**
- **list the types of resistance**
- **explain resistance symbols used in wiring diagram.**

There are three basic types of meters used to test the electric circuit and accessories. The following meters are used in Automotives.

– Ammeter
– Voltmeter
– Ohmmeter

**Ammeter** (Fig 1)

Fig 1




The ammeter (1) is fitted on the vehicle panel board/ dashboard.

It is connected in series in the circuit as shown in the fig.1.

**Uses of ammeter**

An ammeter is used to measure the amount of current flowing in the circuit.

This is connected in series with the load.

It is used to indicate the rate at which the battery is being charged or discharged.

**Care**

Do not connect an ammeter in parallel in the circuit.

Take care of "+" and "-" mark on terminals.

Use DC meter for Automotive charging system.

Select and use an ammeter as per the required range.

**Voltmeter**

A voltmeter (2) is used to measure electrical voltage. It is not fitted permanently on the vehicle but used separately whenever required. It is connected in parallel with the circuit. Use DC voltmeter for Automotives.

**Uses of a voltmeter**

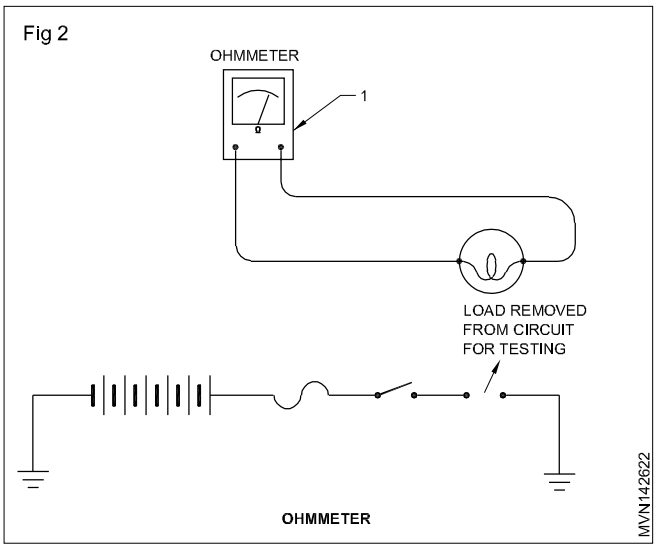
To measure the voltage at any point of circuit.
To measure the voltage drop in the circuit.
To check the condition of the battery.

**Care**

Select the voltmeter as per the required range.

Do not connect the voltmeter in series in the circuit.

**Ohmmeter (Fig 2)**




An ohmmeter (1) is also known as resistance meter.

It is not fitted permanently on the vehicle but is used separately whenever required.

It has its own built-in power source. Hence the device/ circuit being checked with the ohmmeter should be disconnected from the power supply as shown in the figure, to prevent damage to the ohmmeter.

The unit of resistance is an ohm.

**Uses of ohmmeter**

An ohmmeter is used:

– to measure the resistance of any conductor

– to measure the resistance of any load

– to check the continuity of the field coils.

**Care**

Do not connect an ohmmeter to any part of a live circuit.

Do not connect an ohmmeter across the terminals of a battery.

**Maintenance of meters**

Handle the meters with care.

Keep the connections tight while the meters are in use.

Use the meters within specified loads.

After use, keep the meters in a separate place.

**Electrical circuits**

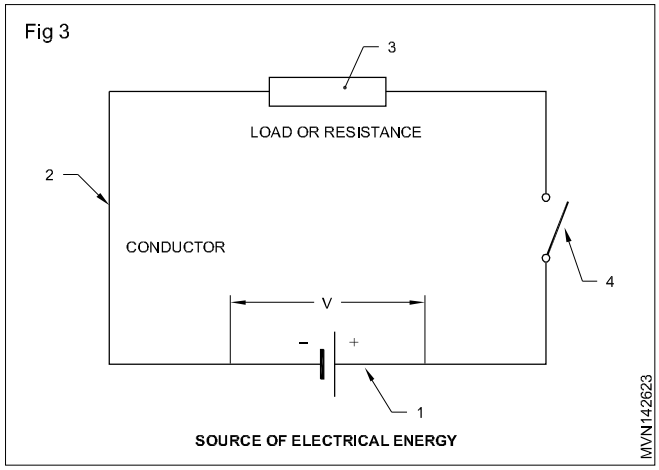
**Simple electrical circuit (Fig 3)**
A simple electric circuit is a complete pathway of the current flow from the battery via the switch and load and back to the battery. An electric circuit consists of :

– a voltage source (1)

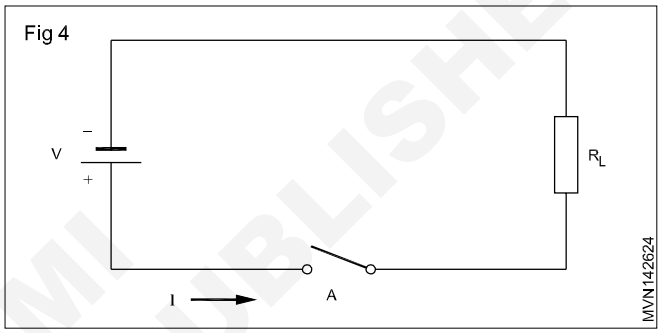
– connecting wires (conductors) (2)

– a load (lamp or motor) (3)

– switch (4).

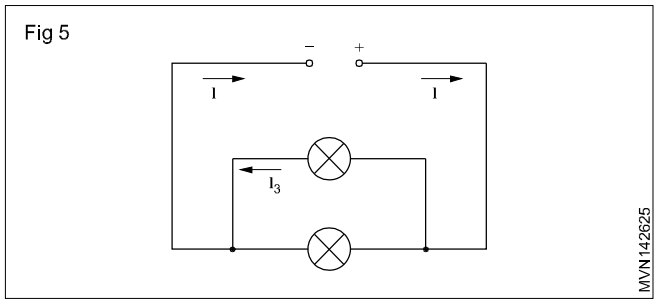



**Open circuit (Fig 4):** In an open circuit, an infinite resistance is provided, most of the time by the open switch (A). Therefore no current can flow.




**Short circuit :** A short circuit will occur when two terminals of the same circuit touch each other. A short circuit may also occur if the insulation between the two cores of the cable are defective. This results in a lower resistance. This causes a large current to flow which can become a hazard.

**Parallel circuit (Fig 5):** In this circuit two or more loads are connected. Each load is provided with its own path to the source of supply.




**Example**

A pair of head lights is connected in parallel circuit. When wired in parallel the failure of one bulb will not effect the operation of the other bulb. Each load receives full system voltage.

The formula to calculate resistance in a parallel circuit is:

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

where

I = current

R = resultant resistance

$R_1, R_2, R_3$ = resistance of each load.

**Series circuit :** This circuit consists of only one load and one source of supply. It has one continuous path for the flow of current. Hence the current flows through all the load in a sequence in circuit. If any of the parts fails the circuit breaks and the current stops flowing. If three resistances $R_1, R_2, R_3$ are connected in series then the total resistance R is given by the formula $R = R_1 + R_2 + R_3$.

$$\text{Resistance(R)} = \frac{\text{Voltage(V)}}{\text{Current(I)}}$$

$$\text{Current(I)} = \frac{\text{Voltage(V)}}{\text{Resistance (R)}}$$

Voltage = Current (I) x Resistance (R)

**Types of resistance**

Based on the ohmic value of resistance it is grouped as low, medium and high resistance.

**Low resistance**

Range : 1 Ohm and below.

Uses : Armature winding, ammeter.

**Medium resistance**

Range : Above 1 Ohm up to 1,00,000 Ohm.

Uses : Bulbs, heaters, relay starters.

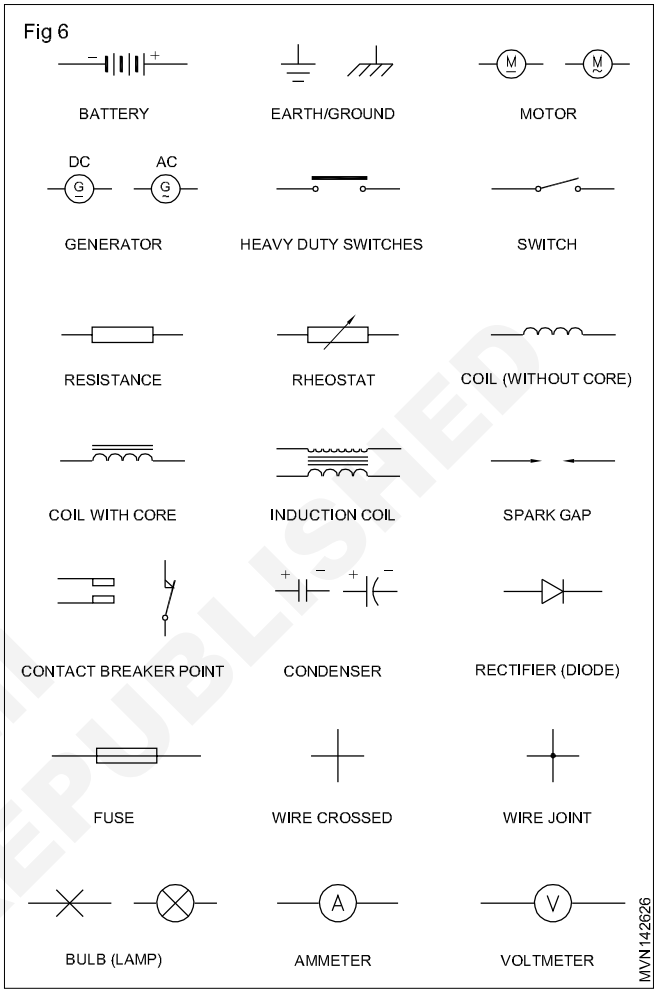
**High resistance**

Range : Above 1,00,000 Ohm (100 k.Ohms).

Use : Lamps.

**Electrical symbols used in a wiring diagram (Fig 6):** Automotive circuits are generally shown by wiring diagrams. The parts in those diagrams are represented by symbols. Symbols are codes or signs that have been adopted by various Automotive manufacturers as a convention.

Fig 6




## Multimeter

**Objectives:** At the end of this lesson you shall be able to

- **state the function of multimeter controls**
- **explain about the dial (scale) of the multimeter**
- **explain about zero adjustment during ohmmeter function**
- **state the function of digital multimeter**
- **state the application of the multimeter**
- **state the precautions to be followed while using a multimeter.**

A multimeter is an instrument in which the functions of an ammeter, voltmeter and ohmmeter are incorporated for measurement of current, voltage and resistance respectively. Some manufacturers call this a VOM meter as this meter is used as volt, ohm and milli ammeter, Multimeters use the basic d'Arsonval (PMMC) movement for all these measurements. This meter has facilities through various switches to change the internal circuit to convert the meter as voltmeter, ammeter or ohmmeter.

There are two major types of multimeters

i Ordinary multimeters having passive components.

ii Electronic multimeters having active and passive components. An electronic multimeter may be of the analog type or digital type.

Most of the ordinary multimeters will have a sensitivity of 20k ohms per volt in the voltmeter mode whereas electronic multimeters have internal resistances to the tune of 5 to 10 megohms, irrespective of the selected voltage range.

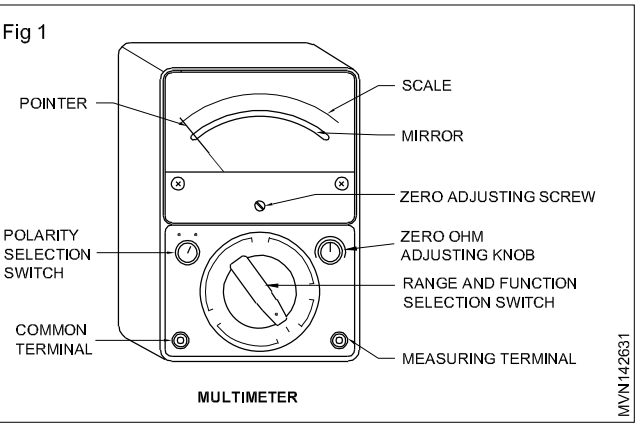
There are several types of multimeters available in the market, manufactured by various manufactures. Each model differs from the others by the extra facilities available. It is a versatile tool for all Automotive. With proper usage and care, it could give service for many years.

Rectifiers are provided inside the meter to convert AC to DC in the AC measurement circuit.

**Parts of a multimeter**

A standard multimeter consists of these main parts and controls as shown in Fig 1.

Fig 1



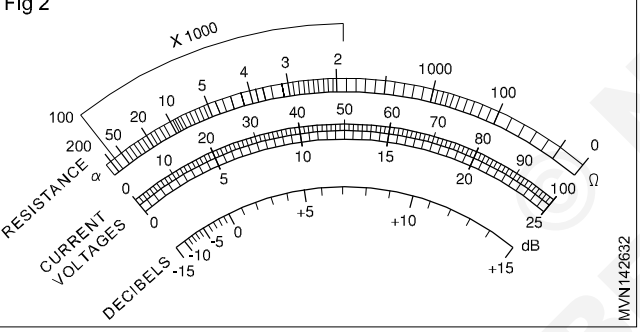

MULTIMETER

**Scale of multimeter**: Separate scales are provided for:

- resistance
- voltage and current.

The scale of current and voltage are uniformly graduated (Fig 2)

Fig 2




The scale for resistance measurement is non-linear. That is, the divisions between zero and infinity (∞) are not equally spaced. As you move from zero to the left across the scale, the division become closer together.

The scale is usually 'backward', with zero at the right.

**Zero adjustment**

When the selector switch is in the resistance range and the leads are open, the pointer is at left side of scale, indicating infinite ($\alpha$) resistance (open circuit). When the leads are shorted, the pointer is at right side of the scale, indicating zero resistance.

The purpose of the zero ohm adjusting knob is to vary the variable resistor and adjust the current so that the pointer is at exactly aero when the leads are shorted. It is used to compensate for changes in the internal battery voltage due to aging.

**Multiple range**

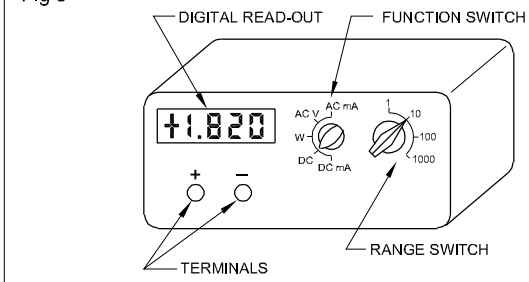
Shunt (parallel) resistors are used to provide multiple ranges so that the meter can measure resistance values from very small to very large values. For each range, a different value of shunt resistance is switched on. The shunt resistance increases for the higher ohm ranges and is always equal to the centre scale reading on any range. These range settings are interpreted differently from those of the ammeter or voltmeter. The reading on the ohmmeter scale is multiplied by the factor indicated by the range setting.

**Digital multimeter (DMM)**

In a digital multimeter the meter movements is replaced by a digital read - out. (Fig 3) this read-out is similar to that used in electronic calculators. The internal circuitry of the digital multimeter is made up of digital integrated circuits. Like the analog-type multimeter, the digital multimeter has also a front panel switching arrangement. The quantity measured is displayed in the form of a four digit number with a properly placed decimal point. When d quantities are measured, the polarity is identified be means of a + or - sign displayed to the left of the number.

**Remember, when a multimeter is set for the ohmmeter function, the multimeter must not be connected to the circuit with the circuit's power is on.**

Fig 3




DIGITAL MULTIMETER

# Resistors

**Objectives:** At the end of this lesson you shall be able to
- **name the types of resistors, construction and power rating**
- **state the meaning of tolerance in resistor**
- **find the value of a resistor using colour code**
- **state the application and types of resistor leads.**

### Fixed value resistors

Its ohmic value is fixed. This value cannot be changed by the user. Resistors of standard fixed values are manufactured for use in majority of applications.

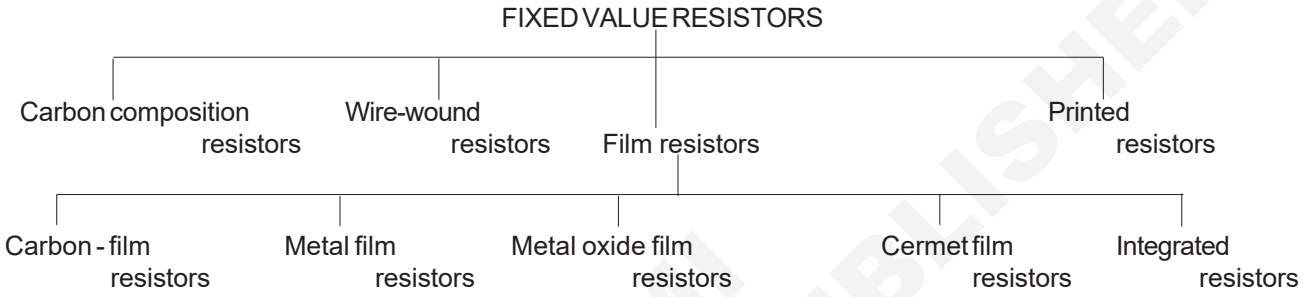
Fixed resistors are manufactured using different materials and by different methods. Based on the material used and their manufacturing method/process, resistors carry different names.

Fixed value resistors can be classified based on the type of material used and the process.

### Carbon composition resistors

### Construction

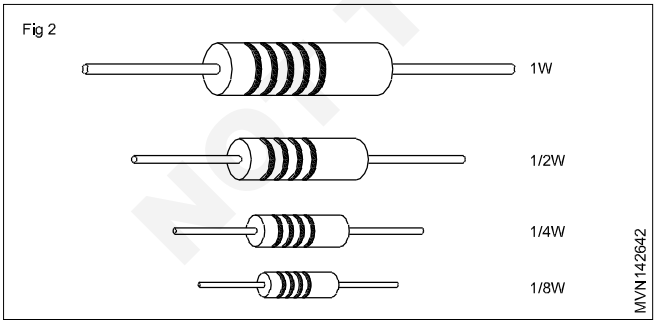
These are the simplest and most economical of all other types. Brief constructional detail of the simplest type of carbon composition resistors commonly called carbon resistor.



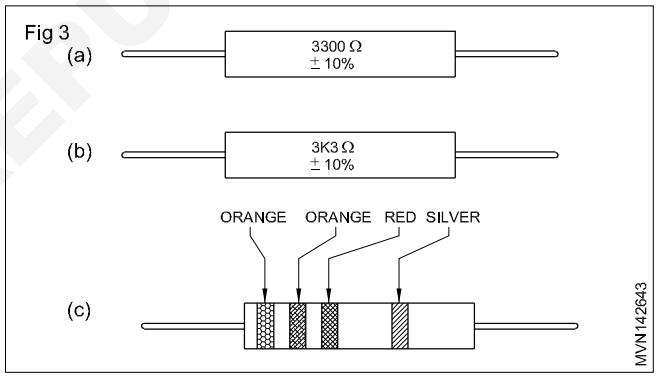

A mixture of finely powdered carbon or graphite(A), filler and binder is made into rods or extruded into desired shapes. Leads(B) made of tinned copper are then attached to the body either by soldering or embedding(C) in the body. A protective layer/tube(D) of phenolic or Bakelite is moulded around the assembly. Finally its resistance value is marked on the body.

### Resistor values - coding schemes (Fig 1)

For using resistors in circuits, depending upon the type of circuit in which it is to be used, a particular type, value and wattage of resistor is to be chosen. Hence before using a resistor in any circuit, it is absolutely necessary to identify the resistor's type, value and power rating.




Selection of a particular type of resistor is possible based on its physical appearance. Table 1 at the end of this lesson illustrates the physical appearance of most commonly used fixed value resistors. The resistance value of a resistor will generally be printed on the body of the resistor either directly in ohms as shown in Fig 2a or using a typographic code as shown in Fig 2b or using a colour code as shown in Fig 2c.




### Colour band coding of resistors

Colour band coding as shown in Fig 2c is most commonly used for carbon composition resistors. This is because the physical size of carbon composition resistor is generally small, and hence, printing resistance values directly on the resistor body is difficult. Refer Table 1.

### Tolerance

In bulk production/ manufacturing of resistors, it is difficult and expensive to manufacture resistors of particular exact values. Hence the manufacturer indicates a possible variation from the standard value for which it is manufactured. This variation will be specified in percentage tolerance. Tolerance is the range(max -to- min) within which the resistance value of the resistor will exist.

### Applications

Carbon composition, fixed value resistors are the most widely used resistors in general purpose electronic circuits such as radio, tape recorder, television etc. More than

50% of the resistors used in electronic industry are carbon resistors.

### Types of resistor leads

Resistors are available with different types of lead attachment as shown in Fig 4. This make it easy for the user to mount the resistors in different ways on lug boards, PCBs and other types of circuit boards.

Fig 4

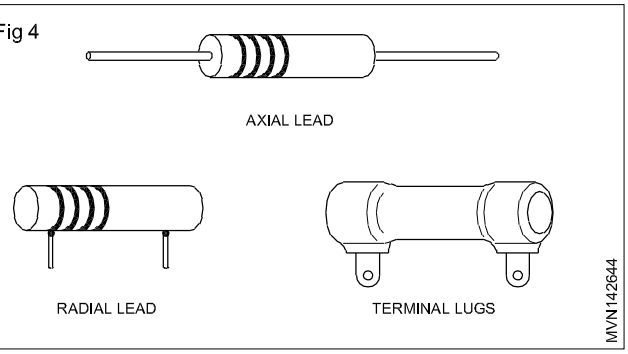



**TABLE 1**

**Resistor Colour Code**

| Colour | Significant figures | Multiplier | Tolerance |
|---|---|---|---|
| Silver | - | $10^{-2}$ | ± 10% |
| Gold | - | $10^{-1}$ | ± 5% |
| Black | 0 | 1 | - |
| Brown | 1 | 10 | ± 1% |
| Red | 2 | $10^{2}$ | ± 2% |
| Orange | 3 | $10^{3}$ | ± 3% |
| Yellow | 4 | $10^{4}$ | ± 4% |
| Green | 5 | $10^{5}$ | ± 0.5% |
| Blue | 6 | $10^{6}$ | - |
| Violet | 7 | - | - |
| Grey | 8 | - | - |
| White | 9 | - | - |
| (None) | - | - | ± 20% |

1, 2 and 3: 1st, 2nd and 3rd significant figures ;

M : Multiplier ; T : Tolerance ; $T_c$ : Temperature co-efficient

## DC series - parallel - series and parallel combination circuits

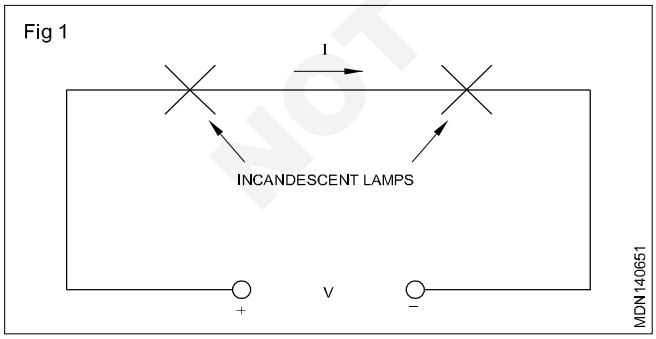
**Objectives:** At the end of this lesson you shall be able to

- **identify the series connection and determine the current in the series circuit**
- **determine the voltage across elements in a series circuit**
- **determine the total voltage in a circuit when the voltage sources are in series**
- **state the uses of a series connection.**

### The series circuit

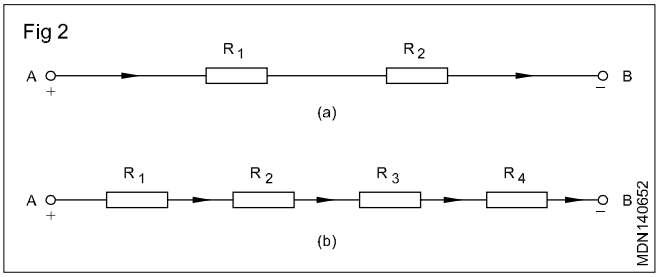
It is possible to connect two incandescent lamps in the way shown in (Fig 1). This connection is called a series connection, in which the same current flows in the two lamps.

Fig 1




The lamps are replaced by resistors in Fig 2. Fig 2 (a) shows two resistors are connected in series between point A and point B. Fig 2(b) shows four resistors are in series. Of course, there can be any number of resistors in a series connection. Such connection provides only one path for the current to flow.

Fig 2




**Identifying series connections:** In an actual circuit diagram, a series connection may not always be as easy to identify as those in the figure. For example, (Fig 3a, 3b, 3c & 3d) shows series resistors drawn in different ways. In all the above circuits we find there is only one path for the current to flow.

### Current in series circuits

The current will be the same at any point of the series circuit. This can be verified by measuring the current in any two points of a given circuit as shown in (Fig 4 a and 4b). The ammeters will show the same reading.

The current relationship in a series circuit is

$I = I_{R1} = I_{R2} = I_{R3}$. (Refer Fig 4)

We can conclude that there is only one path for the current to flow in a series circuit. Hence, the current is the same throughout the circuit.

Fig 3

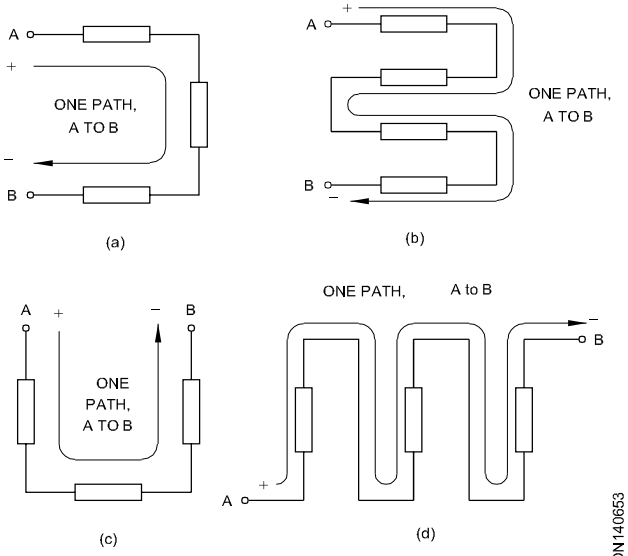
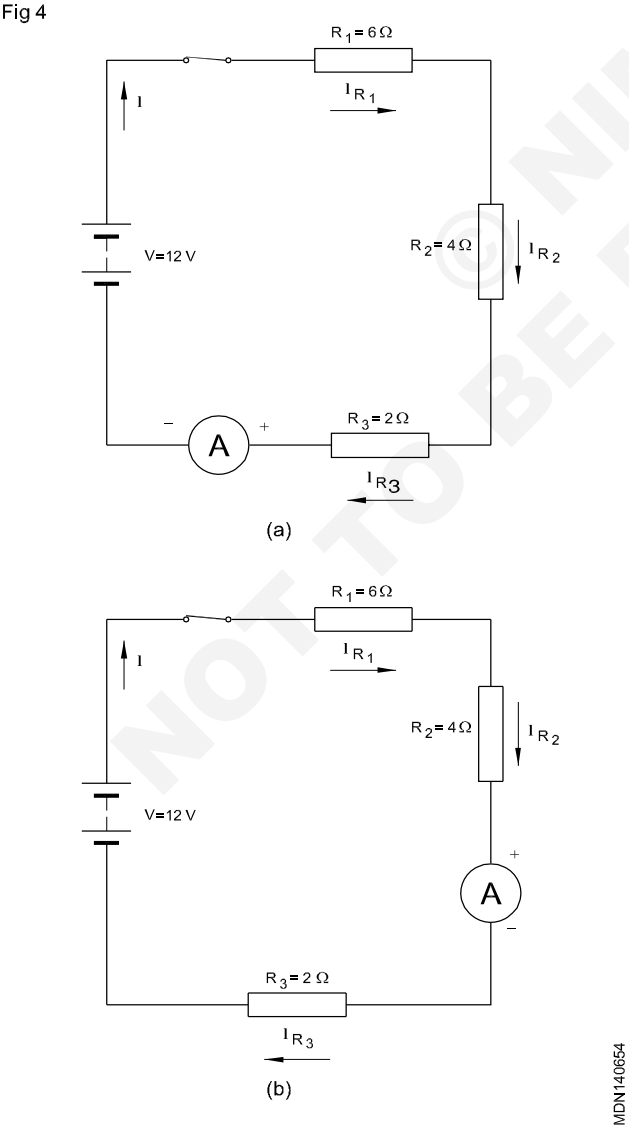



Fig 4




**Total resistance in series circuit**

You know how to calculate the current in a circuit, by Ohm's law, if resistance and voltage are known. In a circuit consisting of two resistors $R_1$ and $R_2$ we know that the resistor $R_1$ offers some opposition to the current flow. As the same current should flow through $R_2$ in series it has to overcome the opposition offered by $R_2$ also.

If there are a number of resistances is series, they all oppose the flow of current through them.

The 2nd characteristic of a DC series circuit could be written as follows.

The total resistance in a series circuit is equal to the sum of the individual resistances around the series circuit. This statement can be written as

$R = R_1 + R_2 + R_3 + .....R_n$

where R is the total resistance

$R_1, R_2, R_3, .....R_n$ are the resistances connected in series.

When a circuit has more than one resistor of the same value in series, the total resistance is $R = r \times N$

where 'r' is the value of each resistor and N is the number of resistors in series.

**Voltage in series circuits**

In DC circuit voltage divides up across the load resistors, depending upon the value of the resistor so that the sum of the individual load voltages equals the source voltage.

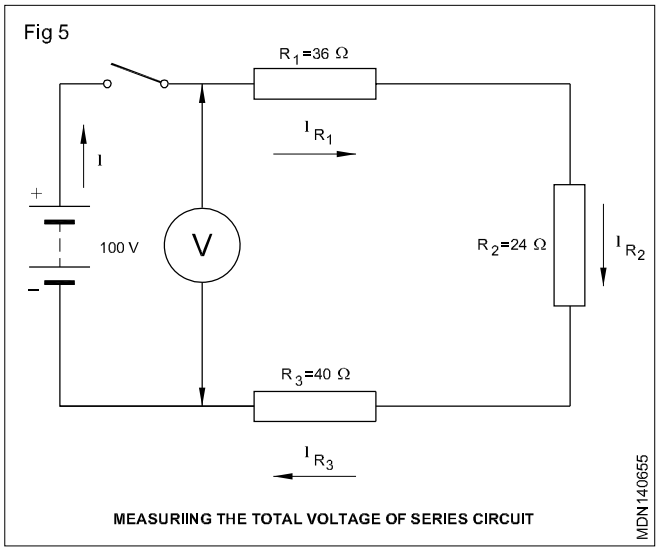
The 3rd characteristic of a DC circuit can be written as follows.

As the source voltage divides/drops across the series resistance depending upon the value of the resistances

$V = V_{R1} + V_{R2} + V_{R3} + .....$

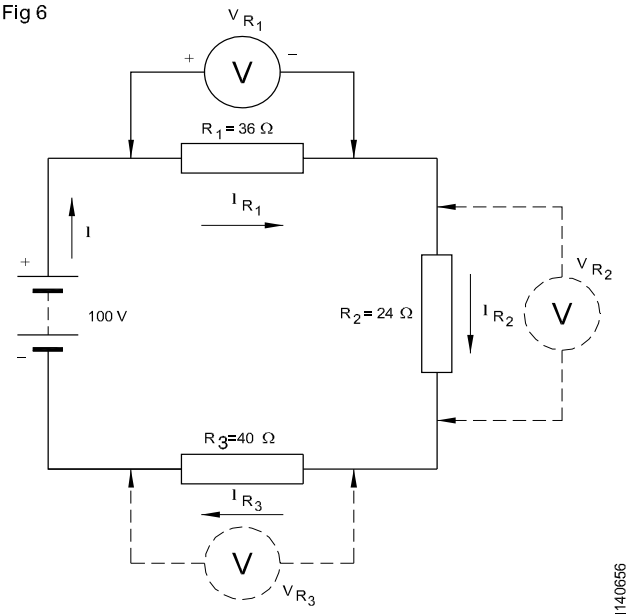
the total voltage of a series circuit must be measured across the voltage source, as shown in (Fig 5).

Fig 5




Voltages across the series resistors could be measured using one voltmeter at different positions as illustrated in (Fig 6).

Fig 6




VOLTAGE DROP IN A SERIES CIRCUIT

When Ohm's law is applied to the complete circuit having an applied voltage V, and total resistance R, we have the current in the circuit as

I = V/R

**Application of Ohm's law to DC series circuits**

Applying to Ohm's law to the series circuit, the relation between various currents could be stated as below.

## Potential difference and polarity of I.R voltage drops

**Objectives:** At the end of this lesson you shall be able to

- **state the relation between the emf, potential difference and terminal voltage**
- **define I.R drop (voltage drop) in a DC series circuit**
- **identify polarity of voltage drops**
- **identify positive and negative grounds**
- **mark the polarity of the voltage drop with respect to ground to determine the terminals of the voltmeter.**

**Definitions**

**Electromotive force (emf)**

We have seen in Related Theory of Exercise 1.07, the electromotive force (emf) of a cell is the open circuit voltage, and the potential difference (PD) is the voltage across the cell when it delivers a current. The potential difference is always less than the emf.

Potential difference

PD = emf – voltage drop in the cell

Potential difference can also be called by another term, the terminal voltage, as explained below.

**Terminal voltage**

It is the voltage available at the terminal of the source of supply. Its symbol is $V_T$. Its unit is also the volt. It is given by the emf minus the voltage drop in the source of supply,

i.e. $V_T$ = emf – IR

where I is the current and R the resistance of the source.

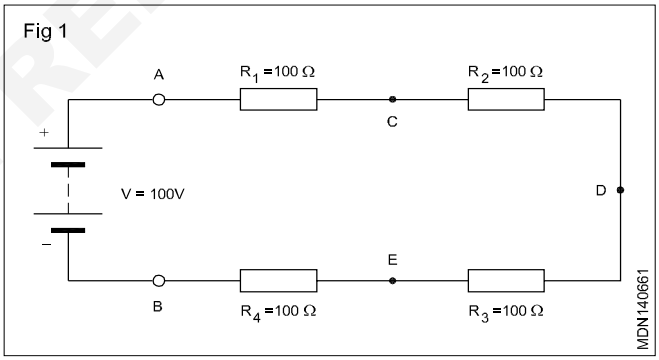
**Voltage drop (IR drop)**

The voltage lost by resistance in a circuit is called the Voltage drop or IR drop.

**Example 1**

The resistances and applied voltage are known. (Fig 1)

Fig 1




What are the voltage drops across the resistors

The total resistance of the circuit in (Fig 1) would be equal to $R_T$ = 100 + 100 + 100 + 100 = 400 ohms.

The current flowing through the circuit would be

I = (100/400) = 0.25 amps.

But point A has a potential of 100 volts and point B has zero. Somewhere along the circuit between A and B, the 100 volts have been lost.

To find the voltage drop for each resistor is easy. First find the current, which we have calculated as 0.25 amps, then

$V_{R1}$ = 0.25 x 100 = 25 V

$V_{R2}$ = 0.25 x 100 = 25 V

$V_{R3}$ = 0.25 x 100 = 25 V

$V_{R4}$ = 0.25 x 100 = 25 V.

Add up all the voltage drops and they will total 100 volts which is the applied voltage of the circuit.

25 + 25 + 25 + 25 = 100 volts.

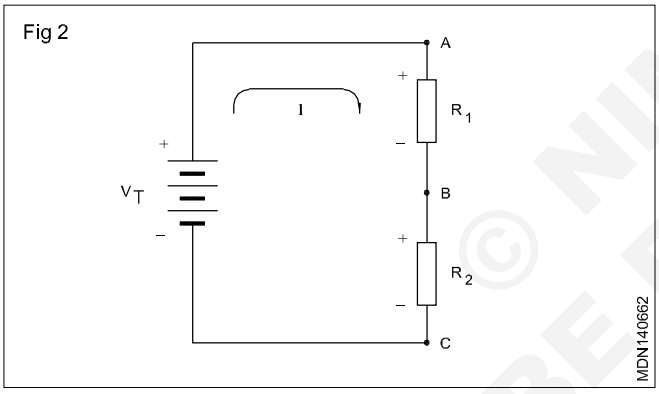
The sum of the voltage drops in a circuit must be equal to the applied voltage.

$V_{Total} = V_{R1} + V_{R2} + V_{R3} + V_{R4}$.

**Polarity of voltage drops**

When there is a voltage drop across a resistance, one end must be more positive or more negative than the other end. The polarity of the voltage drop is determined by the direction of conventional current. In (Fig 2), the current direction is through $R_1$ from point A to B.

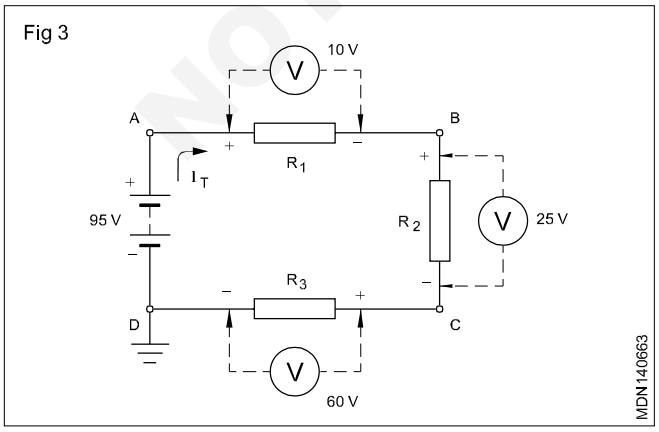
Therefore, the terminal of $R_1$ connected to point A has a more positive potential than point B. We say that the voltage across $R_1$ is such that point A is more positive than point B. Similarly the voltage of point B is more positive than point C. Another way to look at polarity between any two points is that the one nearer to the positive terminal of the voltage source is more positive; also, the point nearer to the negative terminal of the applied voltage is more negative. Therefore, point A is more positive than B, while C is more negative than B. (Fig 2)




**Example 2**

Find the voltage at the points A,B, C and D with respect to ground.

Mark the polarity of voltage drops in the circuit (Fig 3) and find the voltage values at points A, B, C and D with respect to ground.




Trace the complete circuit in the direction of current from the + terminal of the battery to A, A to B, B to C, C to D, and D to the negative terminal. Mark plus (+) where the current enters each resistor and minus (–) where the current leaves each resistor.

The voltage drops indicate (Fig 3) Point A is the nearest point to the positive side of the terminal; so voltage at A with respect to ground is

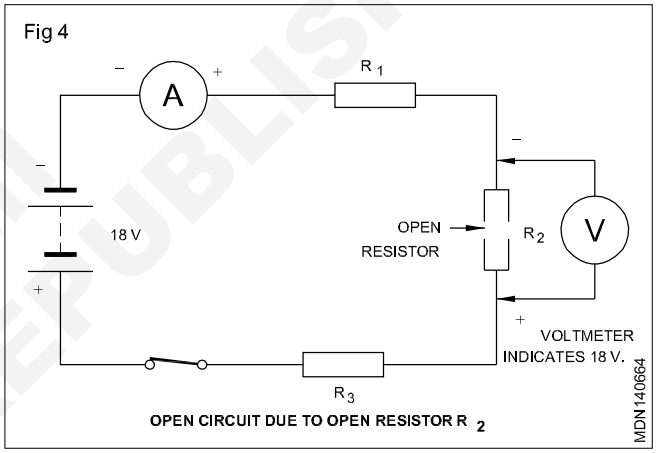
$V_A$ = +95 V.

There is a voltage drop of 10 V across $R_1$; so voltage at B is

$V_B$ = +85 V.

An open circuit results whenever a circuit is broken or is incomplete, and there is no continuity in the circuit.

In a series circuit, open circuit means that there is no path for the current, and no current flows through the circuit. Any ammeter in the circuit will indicate no current as shown in (Fig 4).




**Causes for open circuit in series circuit**

Open circuits, normally, happen due to improper contacts of switches, burnt out fuses, breakage in connection wires and burnt out resistors etc.

**Effect of open in series circuit**

a No current flows in the circuit.

b No device in the circuit will function.

c Total supply voltage/ source voltage appear across the open.

**How can we determine where a break in the circuit has occurred?**

Use a voltmeter on a range that can accommodate the supply voltage; connect it across each connecting wire in turn. If one of the wire is open as shown in (Fig 4), the full supply voltage is indicated on the voltmeter. In the absence of a current, there is no voltage drop across any of the resistors. Therefore, the voltmeter must be reading full supply voltage across the open. That is

Voltmeter reading

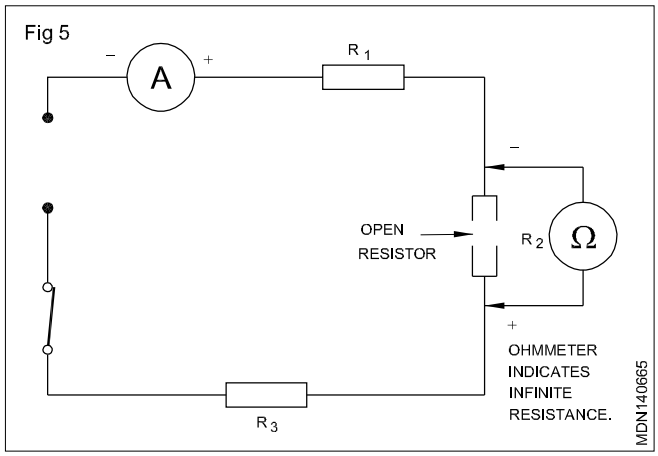
= 18 V – $V_{R1}$ – $V_{R2}$ – $V_{R3}$

= 18 V – O V – O V – O V = 18 V.

If the circuit was open due to a defective resistor, as shown in (Fig 5) (resistors usually open when they burn out), the voltmeter would indicate 18 V when connected across this resistor, $R_2$.

Alternatively, the open circuit may be found using an ohmmeter. With the voltage removed, the ohmmeter will show no continuity (infinite resistance), when connected across the broken wire or open resistor. (Fig 5)

Fig 5




**Practical application**

With the knowledge gained from this lesson:

- locate open and short circuit faults in a series circuit
- repair series-connected decoration bulb sets.

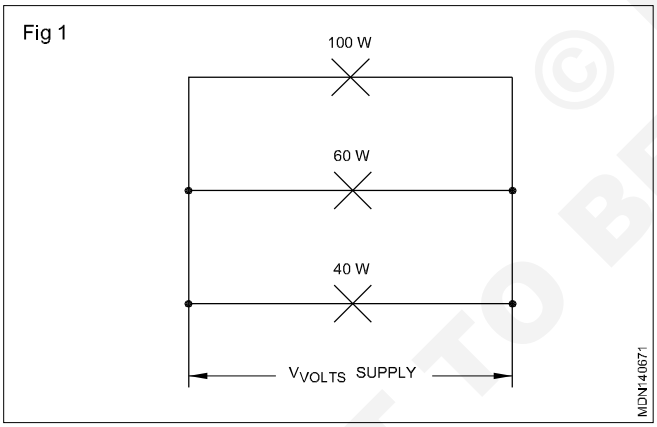
## Parallel circuit

**Objectives:** At the end of this lesson you shall be able to
- **explain a parallel connection**
- **determine the voltage in a parallel circuit**
- **determine the current in a parallel circuit**
- **determine the total resistance in a parallel circuit**
- **state the application of a parallel circuit.**

**Parallel circuit**

It is possible to connect three incandescent lamps as shown in (Fig 1). This connection is called parallel connection in which, the same source voltage is applied across all the three lamps.

Fig 1




**Voltage in parallel circuit**

The lamps in (Fig 1) are replaced by resistors in (Fig 2). Again the voltage applied across the resistors is the same and also equal to the supply voltage.

We can conclude that the voltage across the parallel circuit is the same as the supply voltage.

(Fig 2) could also be drawn as shown in (Fig 3).

Mathematically it could be expressed as $V = V_1 = V_2 = V_3$.

**Current in parallel circuit**

Again referring to (Fig 2) and applying Ohm's law, the individual branch currents in the parallel circuit could be determined.

Current in resistor $R_1 = I_1 =$ =

Current in resistor $R_2 = I_2 =$ =

Current in resistor $R_3 = I_3 =$ =

as $V_1 = V_2 = V_3$.

Refer to (Fig 4) in which the branch currents $I_1$, $I_2$ and $I_3$ are shown to flow into resistance branches $R_1$, $R_2$ and $R_3$ respectively.

The total current I in the parallel circuit is the sum of the individual branch currents.

Mathematically it could be expressed as $I = I_1 + I_2 + I_3 + .... I_n$.

**Resistance in parallel circuit (Fig 4)**

In a parallel circuit, individual branch resistances offer opposition to the current flow though the voltage across the branches will be same.

Fig 2

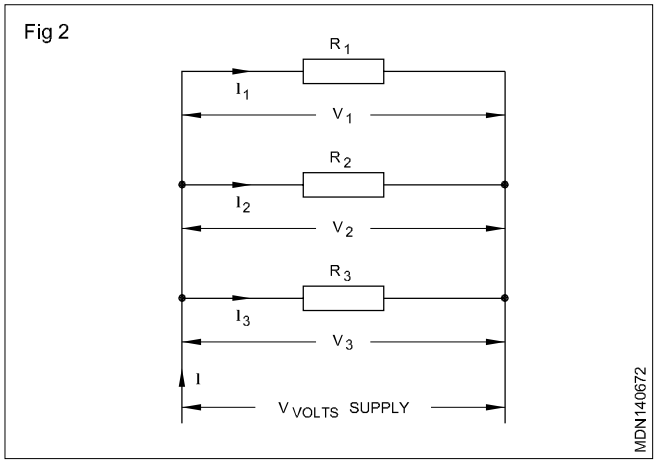


Fig 3

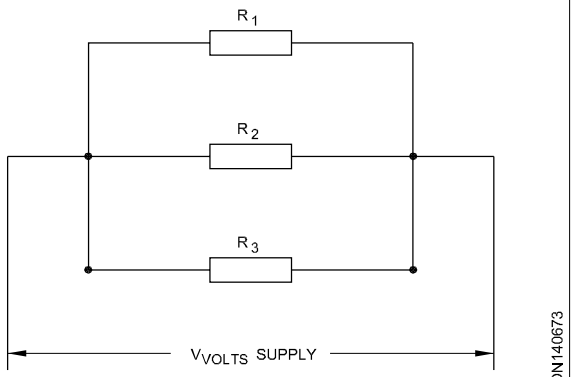
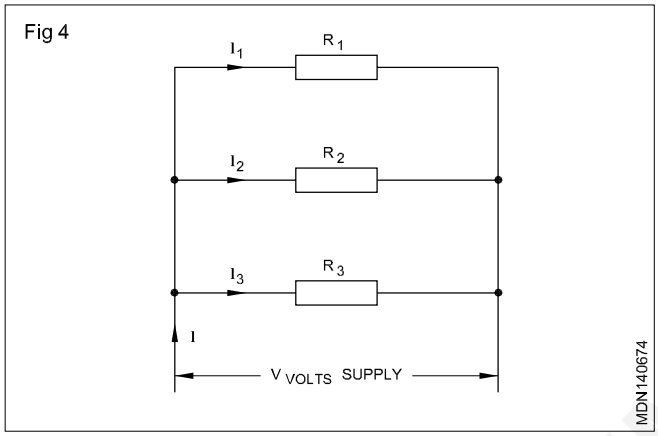



Fig 4




Let the total resistance in the parallel circuit be R ohms.

By the application of Ohm's law

we can write

$$R = \frac{V}{I} \text{ ohms or } I = \frac{V}{R} \text{ amps}$$

where

R is the total resistance of the parallel circuit in ohms

V is the applied source voltage in volts, and

I is the total current in the parallel circuit in amperes.

We have also seen

$$I = I_1 + I_2 + I_3$$

or $$R = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_2}$$

As V is the same throughout the equation and dividing the above equation by V, we can write

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_2}$$

The above equation reveals that in a parallel circuit, the reciprocal of the total resistance is equal to the sum of the reciprocals of the individual branch resistances.

**Special case: Equal resistances in parallel**

Total resistance R, of equal resistors in parallel (Fig 5) is equal to the resistance of one resistor, r divided by the number of resistors, N.

$$R = \frac{r}{N}$$

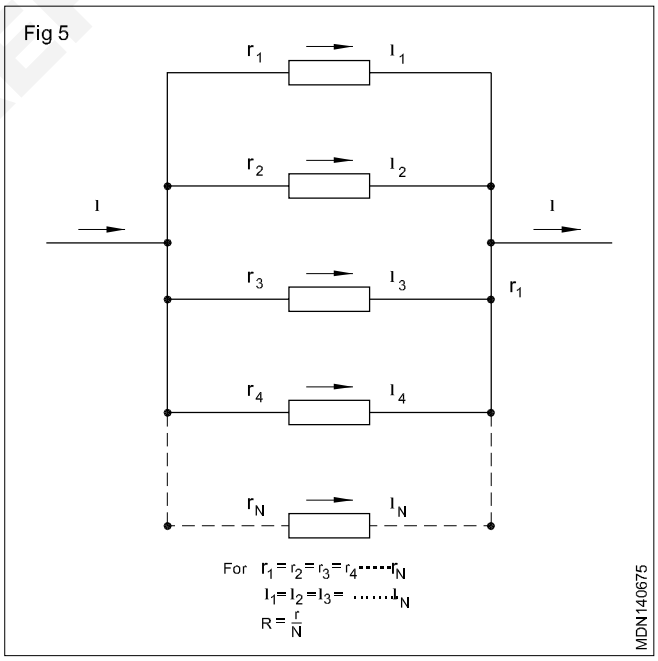
**Applications of parallel circuits**

An electric system in which section can fail and other sections continue to operate in parallel circuits. As previously mentioned, the electric system used in homes consists of many parallel circuits.

An automobile electric system uses parallel circuits for lights, horn, motor, radio etc. Each of these devices operates independently.

Individual television circuits are quite complex. However, the complex circuits are connected in parallel to the main power source. That is why the audio section of television receivers can still work when the video (picture) is inoperative.

Fig 5



# Series parallel combination

**Objectives:** At the end of this lesson you shall be able to
- **compare the characteristics of series and parallel circuits**
- **solve the series-parallel circuit problems**
- **calculate the current in series-parallel circuits.**

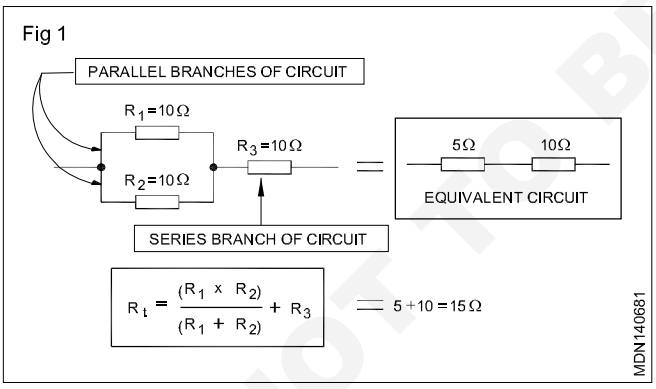
**Comparison of characteristics of DC series and parallel circuits**

| Series circuit | Parallel circuit |
|---|---|
| 1 The sum of voltage drops across the individual resistances equals the applied voltage. | The applied voltage is the same across each branch. |
| 2 The total resistance is equal to the sum of the individual resistances that make up the circuit. $R_t = R_1+R_2+R_3+...$ etc | The reciprocal of the total resistance equals the sum of the reciprocal of the resistances. The resultant resistance is less than the smallest resistance of the parallel combination. |
| 3 Current is the same in all parts of the circuit. | The current divides in each branch according to the resistance of each branch. |
| 4 Total power is equal to the sum of the power dissipated by the individual resistances. | (Same as series circuit) Total power is equal to the sum of the power dissipated by the individual resistances. |

### Formation of series parallel circuit

Apart from the series circuit and parallel circuits, the third type of circuit arrangement is the series-parallel circuit. In this circuit, there is at least one resistance connected in series and two connected in parallel. The two basic arrangements of the series-parallel circuit are shown here. In one, resistor $R_1$ and $R_2$ are connected in parallel and this parallel connection, in turn, is connected in series with resistance $R_3$. (Fig 1)

Fig 1

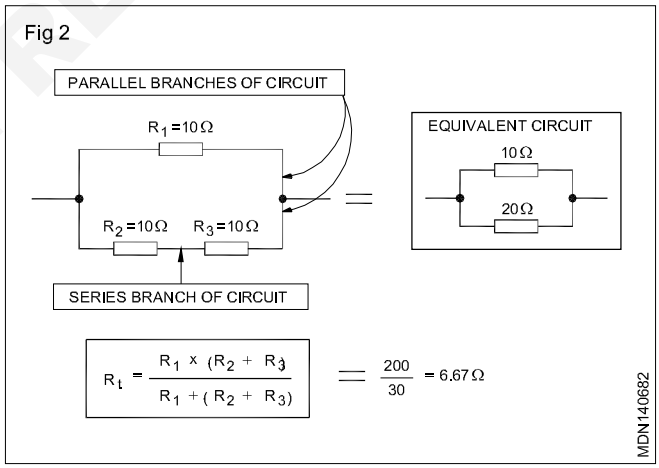



Thus, $R_1$ and $R_2$ form the parallel component, and $R_3$ the series component of a series-parallel circuit. The total resistance of any series-parallel circuit can be found by merely reducing it into a simple series circuit. For example, the parallel portion of $R_1$ and $R_2$ can be reduced to an equivalent 5-ohm resistor(two 10-ohm resistors in parallel).

Then it has an equivalent circuit of a 5-ohm resistor in series with the 10-ohm resistor($R_3$), giving a total resistance of 15 ohms for the series-parallel combination.

A second basic series-parallel arrangement is shown in (Fig 2) where basically it has two branches of a parallel circuit. However, in one of the branches it has two resistances in series $R_2$ and $R_3$. To find the total resistance of this series -parallel circuit, first combine $R_2$ and $R_3$ into an equivalent 20-ohm resistance. The total resistance is then 20 ohms in parallel with 10 ohms, or 6.67 ohms.

Fig 2




### Combination circuits

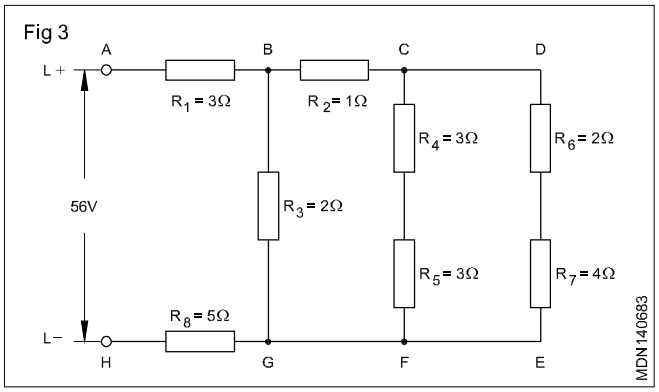
A series-parallel combination appears to be very complex.

However, a simple solution is to break down the circuit into series/or parallel groups, and while solving problems, each may be dealt with individually. Each group may be replaced by one resistance, having the value equal to the sum of all resistances.

Each parallel group may be replaced by one resistance value equivalent to the combined resistance of that group. Equivalent circuits are to be prepared for determining the current, voltage and resistance for each component.

**Example**

Determine the combined resistance of the circuit shown in (Fig 3).




PROCEDURE

1) Combine $R_6$ and $R_7$.

   $R_a = R_6 + R_7$

   $R_a = 2 + 4$

   $R_a = 6$ ohms.

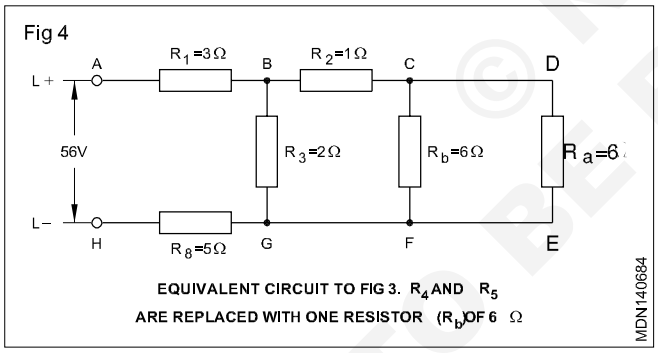
2) Draw an equivalent circuit with resistance Ra. (Fig 4)

3) Combine $R_4$ and $R_5$ of Fig 4.

   $R_b = R_4 + R_5$

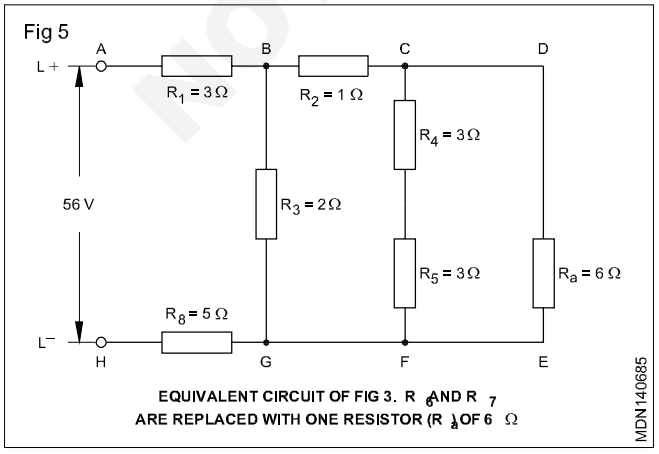
   $R_b = 3 + 3$

   $R_b = 6$ ohms.




4) Draw an equivalent circuit as per Figure 5.

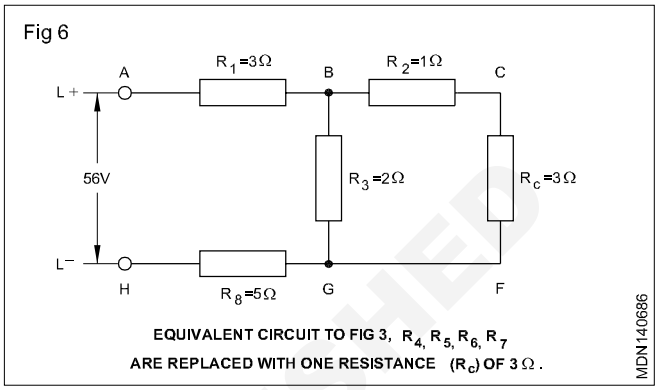
5) Combine $R_a$ and $R_b$ and call the equivalent resistance value as $R_C$. (Fig 5)




$$\frac{36}{12} R_c = \frac{R_a \times R_b}{R_a + R_b} = \frac{6 \times 6}{6 + 6}$$

$$= \frac{36}{12} \text{ 3 ohms.}$$

6) Draw the equivalent circuit. (Fig 6)

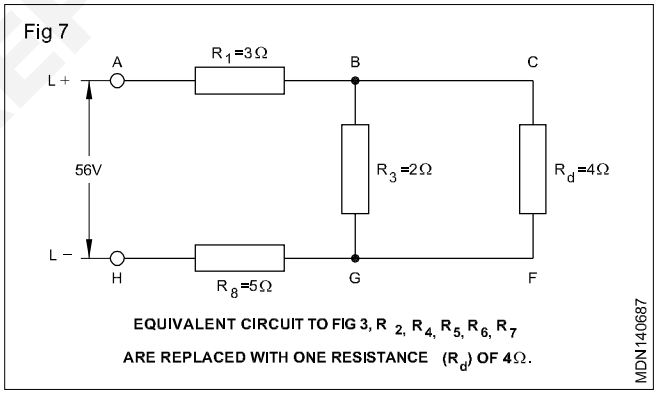



7) Combine $R_2$ and $R_c$ and call the equivalent resistance $R_d$.

   $R_d = R_2 + R_c$

   $R_d = 1 + 3$ $R_d = 4$ ohms.

8) Draw an equivalent circuit. (Fig 7)




9) Now combine $R_3$ and $R_d$ and call it $R_e$

$$R_e = \frac{R_3 \times R_d}{R_3 + R_d} = \frac{2 \times 4}{2 + 4}$$

$$= \frac{8}{6} = \frac{4}{3} = 11/3 \text{ ohms.}$$

10) Draw an equivalent circuit. (Fig 8)

11) Combine $R_1$, $R_e$, and $R_8$.

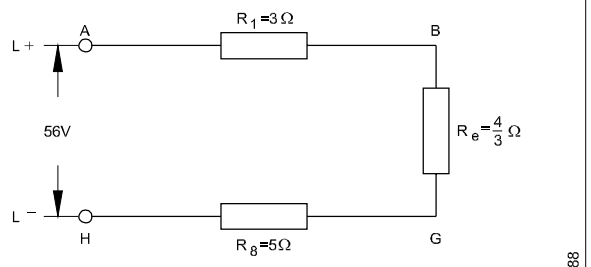
$R_t = R_1 + R_e + R_8$

$$R_t = 1\frac{1}{3} + 5 + 5$$

$$R_t = 9 = \frac{1}{3} \text{ ohms.}$$

The total combined resistance of the circuit is $9\frac{1}{3}$ ohms.

Fig 8




EQUIVALENT CIRCUIT IN FIG 3, $R_2$, $R_3$, $R_4$, $R_5$, $R_6$, AND $R_7$ ARE REPLACED WITH ONE RESISTANCE ($R_e$) EQUAL TO $\frac{4}{3}\Omega$.

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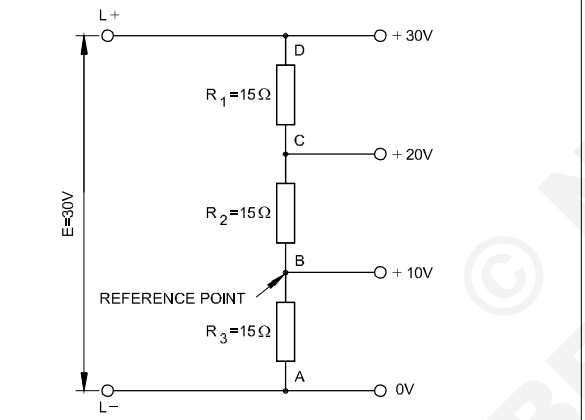
### Application

Series-parallel circuits can be used to form a specific resistance value which is not available in the market and can be used in the voltage divider circuits (Fig 9).

Fig 9




VOLTAGE VALUES ARE GIVEN FOR VOLTAGE DROP TESTS TAKEN ACROSS RESISTORS FROM A TO B ( 10V), B TO C (+10V) AND B TO D (+20V). NOTE THAT THE CIRCUIT IS GROUNDED AT REFERENCE POINT B.

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### Voltage divider

To have different voltages for different parts of a circuit, construct a voltage divider. In effect, a voltage divider is nothing more than a series-parallel circuit.

A good voltage divider cannot be designed without first looking at the load resistance. Note in (Fig 9) that a voltage divider is made with three 15 ohm resistors to get 10 volts drop across each one.

However, as soon as another resistor (load) is added as in (Fig 10), there is a further change. The load resistor serves to drop the total resistance of the lower part of the voltage divider. Use this formula for finding the equivalent resistance ($R_{eq}$) of resistors of equal value in a parallel circuit:

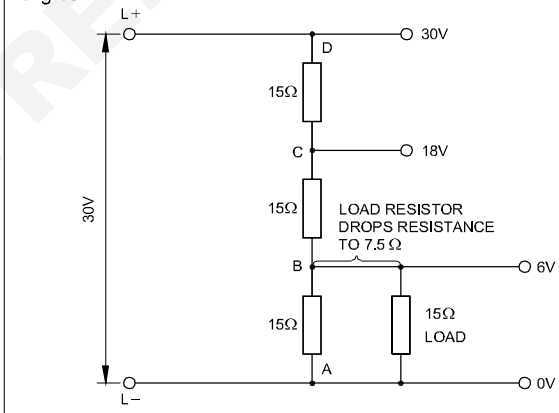
$$R_{eq} = \frac{r}{N}$$

$$R_{eq} = \frac{15}{2} = 7.5 \text{ohms,}$$

The equivalent resistance of these two 15 ohm resistors in the lower part of the voltage divider is 7.5 ohms. What will happen to the current and voltage in the circuit as a result of this resistance change.

Remember that, as resistance goes down, current goes up. Therefore, with the addition of the load resistor, the circuit will now carry higher amperage but the voltage between points A and B as well as A and C changes. It is important, then, when constructing a voltage divider circuit, to watch the resistance values which change both voltage and current values. Study Fig 10 carefully to make sure you understand how a voltage divider works.

Fig 10




THREE 15 OHMS RESISTORS AND ONE 15 OHM LOAD RESISTOR SERVE AS A VOLTAGE DIVIDER THAT ROUTES DIFFERENT VOLTAGES TO DIFFERENT PARTS OF THE CIRCUIT.

MDN14068A

## Fuse

**Objectives:** At the end of this lesson you shall be able to
- **state the need of a fuse in the circuit**
- **explain the construction of a fuse**
- **list out the types of fuses**
- **explain the working of fuses**
- **explain the circuit with and without a fuse**
- **explain circuit breakers.**

### Introduction

A fuse is a protective device. It is a weakest portion in the electrical circuit.

An electric current heats the wire when the current passes through it. The amount of heat depends upon the current and resistance in the wire.

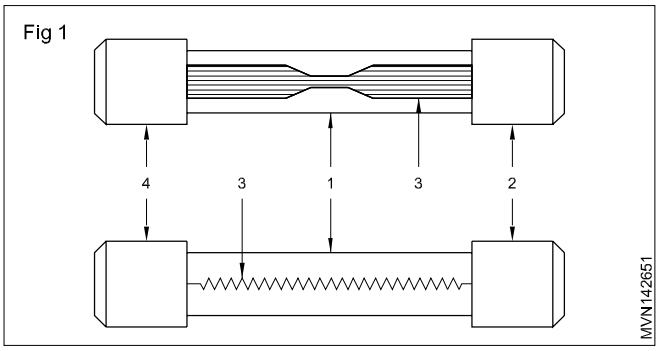
In Automotives, this heating effect is utilized in heaters, bulbs and gauges etc.

The heating effect in the circuit is limited by the fuse. If this limit is not controlled, the circuit an accessories will be overloaded causing severe damage to them.

**Purpose of fuse (Fig 1)**

A fuse opens the circuit by blowing out when current (overload) flows in the circuit to prevent severe damage to the accessories.

The flow of excess current in a circuit may be caused by a short circuit.




**Construction**

Fuse elements are of lead-tin or tin-copper alloy wire in strip of correct amperage for each circuit.

The fuse is assembled in a fuse carrier of glass or ceramic material.

Nowadays fuse elements assembled in glass tubes, called cartridges, are widely used in Automotives.

It consists of a glass tube (1) with metal end caps (2) & (4).

A soft fine wire or strip (3) carries the current from one cap to another (4).

The conductor (3) is designed to carry a specific maximum current.

**Working:** The current flows through the conductor (3) between two metal caps (2) & (4) and then to the equipment.

If the current value exceeds the limit prescribed on the fuse, the fuse element (3) melts and opens the circuit and prevents the equipment from damage.

Identification of blown fuse

If you look at the burnt fuse and if the element is broken the fuse is burnt due to overloading.

The glass is foggy white or black the fuse is blown out due to short circuit.

**Circuits protected with fuse**

- Headlight circuit
- Tall - light circuit
- Number-plate circuit
- Panel lamp circuit
- Interior lamp circuit
- Side indicator circuit
- Horn circuit
- Wiper circuit
- Dashboard / panel instruments circuit
- Header and air conditioner
- Charging circuit
- Radio
- Cigarette lighter
- Reverselamp

**Circuits without fuse**

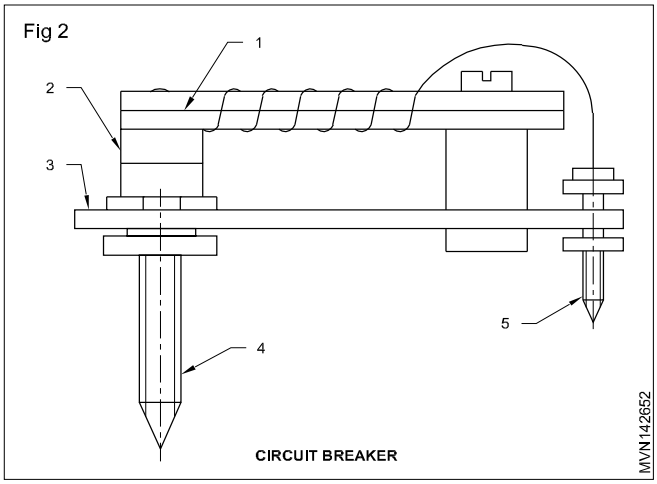
- Starting circuit
- Ignition circuit
- Fuel pump
- Stop - light circuit
- Oil pressure lamp circuit
- Ignition warning lamp circuit.

**Fuse rating and colour**

| Rating | Colour |
|---|---|
| 3 Amp | Violet |
| 5 Amp | Tan |
| 10 Amp | Red |
| 20 Amp | Yellow |
| 25 Amp | White |
| 30 Amp | Light green |

**Circuit Breaker:** Circuit Breaker (Fig.2): These units are regarded as a non- replaceable type of fuses. Generally fitted in the headlight circuit, it consists of a bimetallic strip (1) with moving contact (2). A fixed contact (3) is provided with the terminals (4) & (5). The strip (1) bends as soon as the current exceeds the maximum permissible value for the electrical component concerned. This way it opens the points to break the circuit. When this type of device is used in the lighting circuit, the lamp willl light and then go out. Thus giving an indication of a faulty circuit. The circuit breakers are made in ratings up to 50 amps.

Rectifiers are provided inside the meter to convert AC to DC in the AC measurement circuit.



# Capacitors

**Objectives:** At the end of this lesson you shall be able to
- **describe a capacitor**
- **brief construction and function of a capacitor**
- **brief how does a capacitor store energy**
- **state the units of capacitance**
- **state parallel and serial capacitors.**

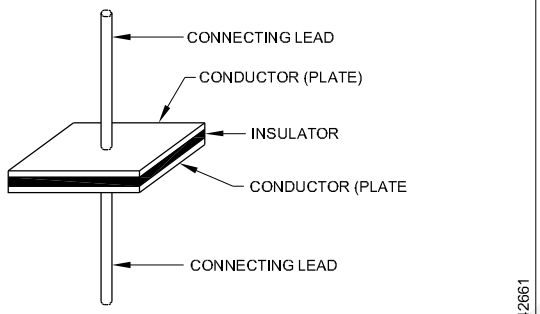
### Capacitors

A device designed to posses capacitance is called a capacitor.

### Construction

A capacitor is an electrical device consisting of two parallel conductive plates, separated by an insulating material called the dielectric. Connecting leads are attached to the parallel plates. (Fig 1)

Fig 1




SIMPLE CAPACITOR. THE PLATES OF A CAPACITOR ARE ALWAYS INSULATED FROM EACH OTHER

### Function

In a capacitor the electric charge is stored in the form of an electrostatic field between the two conductors or plates, due to the ability of dielectric material to distort and store energy while it is charged and keep that charge for a long period or till it is discharged through a resistor or wire. The unit of charge is coulomb and it is denoted by the letter `C'.

### Capacitance

The ability to store energy in the form of electric charge is called capacitance. The symbol used to represent capacitance is C.

### Unit of capacitance

The base unit of capacitance is farad. The abbreviation for farad is F. One farad is that amount of capacitance which stores 1 coulomb of charge when the capacitor is charged to 1 V. In other words, a farad is a coulomb per volt (C/V).

A farad is the unit of capacitance (C), and a coulomb is the unit of charge(Q), and a volt is the unit of voltage(V).

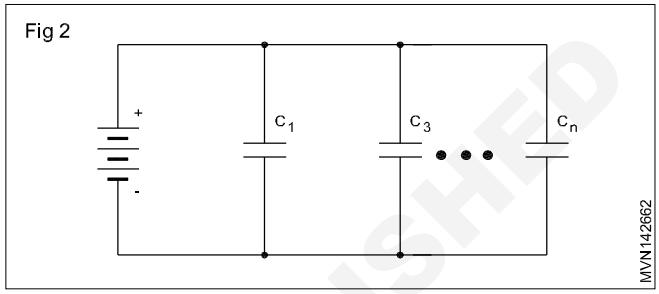
Capacitors are widely used as parts of electrical circuits in many common electrical devices. Ex. Ignition circuit.

### Parallel Capacitors

Capacitors connected in parallel will **add** their capacitance together.

$$C_{total} = C_1 + C_2 + ... + C_n$$

Fig 2




A parallel circuit is the most convenient way to increase the total storage of electric charge.

The total voltage rating does not change. Every capacitor will 'see' the same voltage. They all must be rated for at least the voltage of your power supply. Conversely, you must not apply more voltage than the lowestvoltage rating among the parallel capacitors.

### Series Capacitors

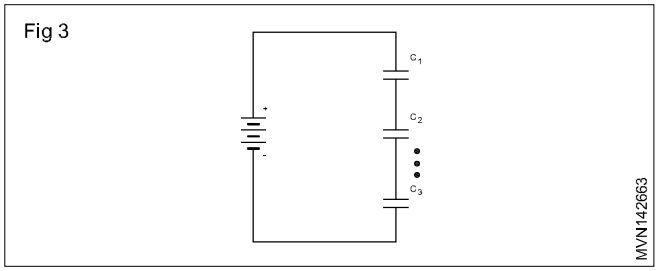
Capacitors connected in series will have a lower total capacitance than any single one in the circuit.

$$C_{total} = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + ... + \frac{1}{C_n}}$$

**This series circuit offers a higher total voltage rating. The voltage drop across each capacitor adds up to the total applied voltage.**

**Series capacitors are generally avoided in power circuits.**

Fig 3



# Battery

**Objectives:** At the end of this lesson you shall be able to
- **state classification of cells**
- **explain the construction of a lead acid battery**
- **explain the chemical action during discharging**
- **explain the chemical action during charging**
- **explain maintenance of a battery**
- **explain testing of a battery**
- **explain battery selection and rating**
- **explain battery charging method**
- **explain advantages of maintenance free battery.**

A cell is an electrochemical device consisting of two electrodes and an electrolyte. The chemical reaction between the electrodes and the electrolyte produces a voltage. Cells are classified as:

– Dry cells – Wet cells

**Dry cells :** A dry cell has paste or gel electrolyte. It is semi-sealed and could be used in any position.

**Wet cells :** It consists of two plates and a liquid electrolyte. These cells have vent holes to allow the gases to escape during charging and discharging. The most common wet cell is the lead acid cell; wet cells can be recharged for reuse.

**Primary cells :** Primary cells are those cells which are not rechargeable. Chemical reaction that occurs during discharge is not reversible. The following types of primary cells are used.

– Voltaic cell – Carbon zinc cell

– Alkaline cell – Mercury cell

– Silver oxide cell – Lithium cell.

**Secondary cell (Lead acid battery) :** These cells can be recharged by supplying electric current in the reverse direction to that of a discharged battery.

**Lead acid battery (Fig 1&2):** This battery is an electrochemical device for converting electrical energy into chemical energy and vice versa. The main purpose of the battery is to store electrical energy in the form of chemical energy.

Fig 1

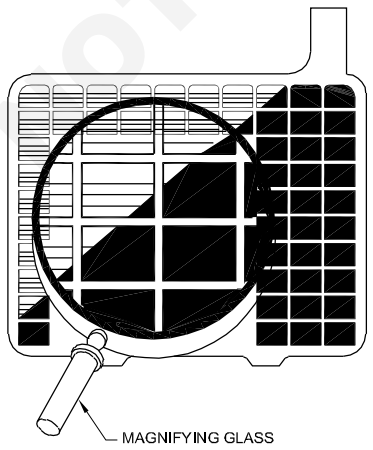
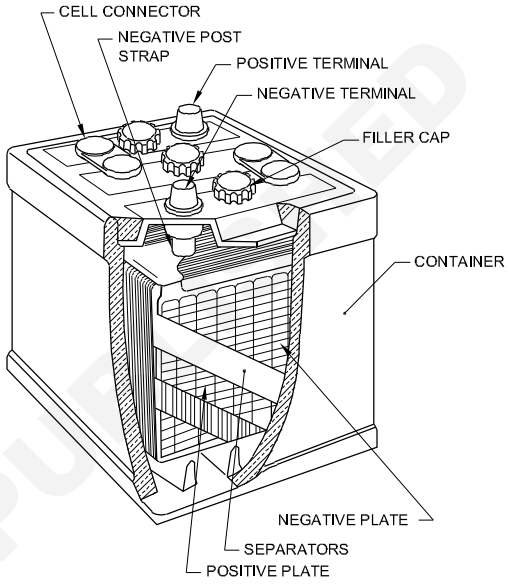



Fig 2




It provides supply of current for operating various electrical accessories, when the engine is not running. When the engine is running it gets electric supply from the dynamo/ alternator. It is also known as accumulator and storage battery.

**Construction:** The Automotive battery's plates are rectangular. They are made of lead. Antimony alloy is used to provide them strength.

The group of plates, which are connected to the positive terminal of the cell, consists of grids filled with a paste of lead peroxide. This lead is brown in colour.

The group of plates, which are connected to the negative terminal of the cell, consists of grids filled with metalic lead which is spongy in nature. This lead is dull grey in colour.

Each a group of plates is held together by a post strap, to which individual plates are welded. The post strap is extended up to the cell cover to provide battery terminals. The positive and negative plates are arranged alterna-tively, and in between the plates, separators are used to prevent contact of the positive and negative plates.

Separators are made of specially treated wood, hard rubber, resin, integrated fibre or in combination with rubber or mats of glass fibres. The container in which the plates are placed is made of hard rubber which is not affected by the electrolyte.

A solution of sulphuric acid and distilled water is added until the level of the liquid in the container is about 1/4" to 3/8" above the top of the plates. A filler cap with air vents is provided to allow gases to escape out.

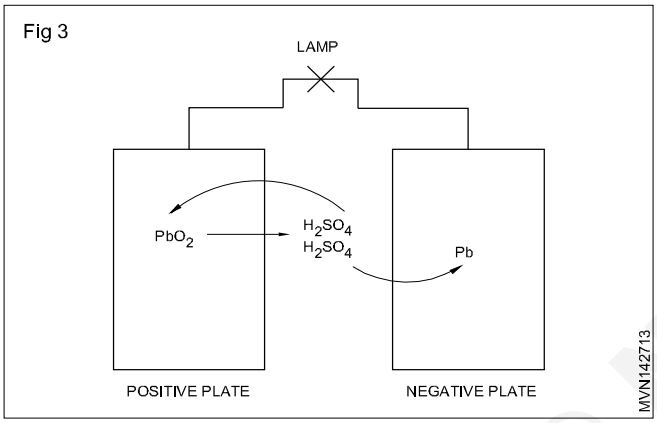
**Chemical Reactions**

**Discharging (Fig 3):** During discharging, the sulphuric acid is broken into two parts, hydrogen ($H_2$) and sulphate ($SO_4$). The hydrogen is liberated at the lead peroxide plates ($PbO_2$) reducing them to lead oxide (PbO) which combines with parts of the sulphuric acid to form lead sulphate ($PbSO_4$) and water ($H_2O$). The $SO_4$ is liberated at the spongy lead plate (Pb) and combines with them to form lead sulphate ($PbSO_4$). During this process the electrolyte becomes less concentrated due to absorption of the sulphate by the lead plates.

$$PbO_2 + 2H_2SO_4 + Pb \rightleftharpoons PbSO_4 + 2H_2O + PbsO_4$$

(+ve) (electrolyte) (-ve) (+ve) (water) (-ve)

Fig 3



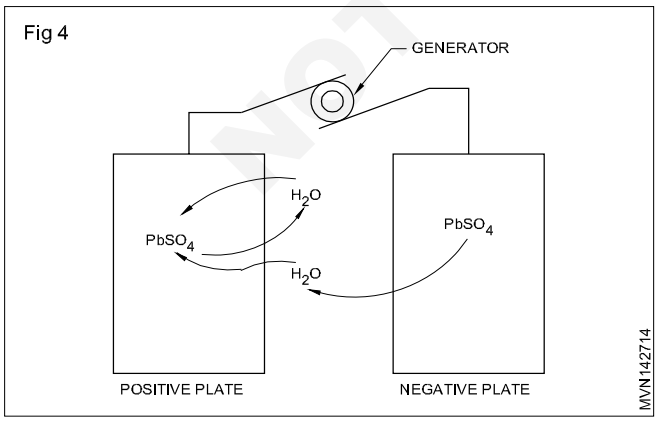

**Charging (Fig 4)**

When the battery is charged by passing current through a dynamo or charger in the opposite direction, the reverse chemical reaction takes place. The lead sulphate on one plate becomes lead peroxide (+ve plate). The lead sulphate on the other plate (-ve plate) becomes spongy lead and the electrolyte becomes more concentrated because of the increased amount of sulphuric acid.

$$PbSO_4 + 2H_2O + PbSO_4 \rightleftharpoons PbO_2 + 2H_2SO4 + Pb$$

(+ve) (water) (-ve) (+ve) (Electrolyte) (-ve)

Fig 4




**Maintenance of battery:** Batteries are expensive items to replace. They should be serviced regularly as recommended by the manufacturer. If maintained properly. They can be used for longer periods. The following aspects are to be checked to maintain the battery in good condition.

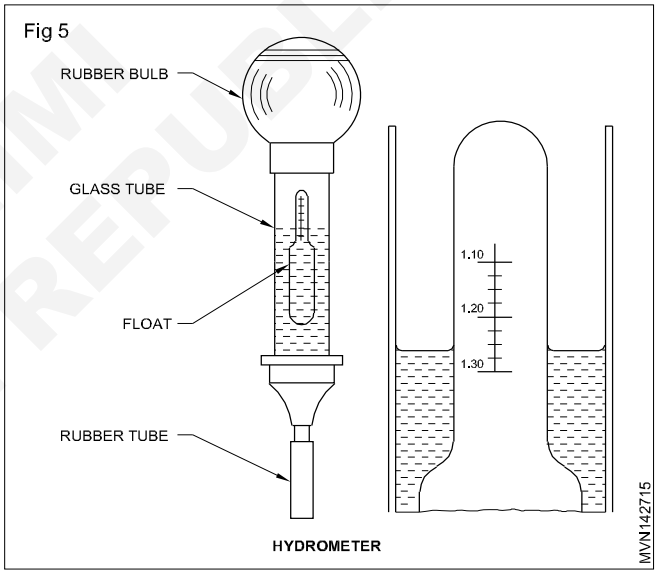
Check and top up electrolyte level every week. Electrolyte should be 10 mm to 15 mm above the plates.

Check the specific gravity of the battery with a hydrometer. (Fig 5) If the specific gravity falls below 1.180 then add a few drops of sulphuric acid.

Sp. gravity readings and the state of charge of the battery are as follows.

| Sl.No. | Specific | State of charge of the battery |
|---|---|---|
| 1 | 1.260 - 1.280 | Fully charged |
| 2 | 1.230 - 1.260 | 3/4 charged |
| 3 | 1.200 - 1.230 | 1/2 charged |
| 4 | 1.170 - 1.200 | 1/4 charged |
| 5 | 1.140 - 1.170 | About run down |
| 6 | 1.110 - 1.140 | Discharged |

Fig 5




Check the voltage across the cell terminals of each cell by using a cell tester. Cell voltage is 2 to 2.3 volts per cell for fully charged condition.

If the voltage of each cell is less than specified, then the battery should be recharged.

While charging do not overcharge the battery.

Keep the battery terminals always tight and clean.

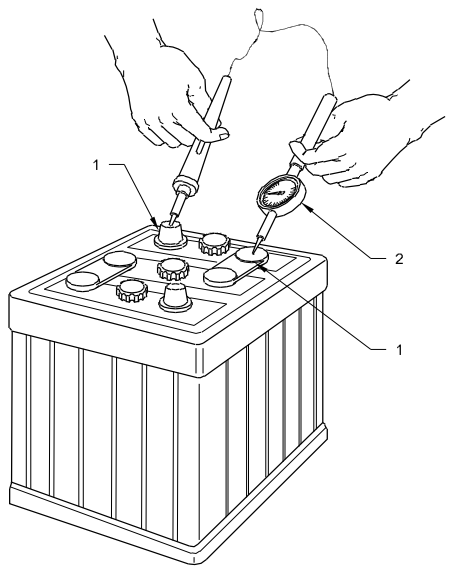
To prevent formation of corrosion on the terminals smear petroleum jelly on it.

**Voltage check of battery:** With the help of a voltmeter the voltage of battery is tested. This will commonly vary from 12-13V

**Battery selection (Fig 6):** Most cars in current production are equipped with a 12V battery. When a manufacturer installs a battery in a new car that battery is chosen to meet the requirements of that particular car. Prime importance

is the battery's ability to crank and start the engine. The current required to crank on engine can range from 150A to over 500A depending on the size of the engine, the temperature and the viscosity of the oil in the engine. Those factors are all considered in battery selection. The number and type of electrical options installed in the car are also considered.

Fig 6




The lead acid batteries are made for different vehicle application to suit the electrical demands, while the voltage of the battery remains same for all application, the ampere-hour rate changes as per demand.

The following examples reveal the importance of ampere-hour of a battery.

| Vehicle type | Battery applicable |
|---|---|
| 2.5 Amps 12V | Two wheeler without starter |
| 7 Amps 12V | Two wheeler with starter motor |
| 35 Amps 12V | 800CC - 1000 car petrol |
| 40 - 45 Amps 12V | 1300 Diesel vehicles |
| 60 Amps 12V | 2.5 Lit LCV |
| 80 Amps 12V | 4 Lit medium |
| 120 Amps 12V | 6 Lit Diesel HCV |
| 180 Amps 12V | 6 Lit Diesel passenger |

**Battery rating**

**Ampere-hour rating:** The ampere-hour rating provides a measure of how much current a battery at $80^0$F ($27^0$C) will deliver for a fixed period of time without the cell voltage dropping below 1.75V (10.5 total terminal volts). Due to a specified 20 hour time period, this test is sometimes referred to as the "20 hour test". The rating number is determined by multiplying the current delivered by 20. If a battery can deliver 3A for the 20 hour period, it receives a 60 ampere-hour rating. If a battery can deliver 5A for the 20 hour period, it receives a rating of 100 ampere-hour.

**CONVENTIONAL BATTERIES**

| BATTERY CAPACITY (AMPERE HOURS) | DISCHARGE RATE (AMPERES) |
|---|---|
| 36 | 155 |
| 41 | 145 |
| 45 | 190 |
| 53 | 175 |
| 54 | 225 |
| 68 | 220 |
| 77 | 228 |

**MAINTENANCE-FREE BATTERIES**

| BATTERY CAPACITY (AMPERE HOURS) | DISCHARGE RATE (AMPERES) |
|---|---|
| 53 | 200 |
| 63 | 215 |
| 68 | 235 |

**Battery charging:** A discharged battery in good condition can be charged and retuned to service.

Many types of battery in use, but all chargers operate on the same principle. They apply an electrical pressure that forces current through the battery to reverse the electro chemical action in the cells.

**Charging rates:** The amount of charge a battery receives is equal to the rate of charge, in amperes, multiplied by the amount of time, in hours, that the charge is applied. As an example, a battery charged at the rate of 5A for a period of 5 hours would receive a 25 ampere-hour charge. To bring a battery to a fully charged condition.

Initial rate for constant voltage taper rate charger.

To avoid damage, charging rate must be reduced or temporarily halted if:

1 Electrolyte temperature exceeds $125^o$F.

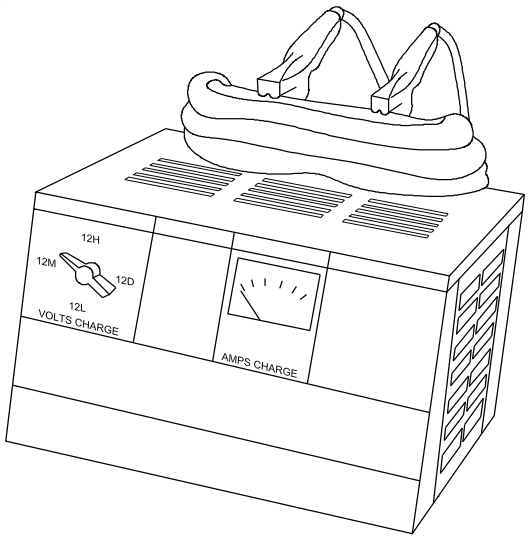
2 Violent gassing or spewing of electrolyte occurs.

Battery is fully charged when over a two hour period at a low charging rate in amperes all cells are gassing freely and no change in specific gravity occurs. For the most satisfactory charging, the lower charging rates in amperes are recommended.

Full charge specific gravity is 1.260 - 1.280 corrected for temperature with electrolyte level at split ring.

**Slow charging (Fig 7):** Slow charging consists of charging a battery at a rate of about 5A for a time sufficient to bring the specific gravity of the electrolyte to its highest reading. Slow charging many require from 12 to 24 hours of time. A battery that is sulphated may require even more time. During the charging period, the electrolyte temperature should not exceed $110^0$F ($43^0$C). If the electrolyte temperature rises above $110^0$F ($43^0$C), the charging rate should be decreased.

Fig 7




A TYPICAL SLOW CHARGER

A conventional battery with vent plugs is considered fully charged when the electrolyte is gassing freely and when no further rise in the specific gravity is noted at intervals of 1 hours. A sealed battery should be slow charged until the green dot appears in the built-in hydrometer. In some instances, a sealed battery must be slightly shaken to allow the green dot to appear.

**Fast charging (Fig 8):** Fast charging will not fully recharge a battery, it will restore the charge sufficiently to allow the battery to be used.

Fast charging consists of charging a battery at a rate from 10 to 50A. The exact charging rate depends on the construction of the battery, the condition of the battery and the time available. The temperature of the electrolyte provides an indication of the current charging rate. If the electrolyte temperature rises above $125^0$F ($65^0$C), the charging rate is too high and should be reduced. Since a high charging rate and the resultant high temperature can damage a battery, a battery should be charged at the lowest possible rate.

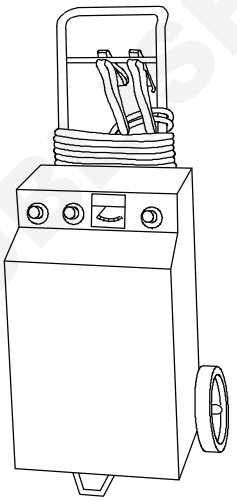
**Features of sealed maintenance free battery**

- No need for checking electrolyte level and tapping through out the life.
- Seal construction ensures no leakage of electrolyte from terminal or casing.

**Benefits**

- Saving of 100 litres of distilled water through out its life time as compared to convention batteries.
- Saving of man power for regular topping up & cleaning corroded terminals as in conventional batteries.
- No damage of flooring by spoilage of batteries acid or water during maintenance.
- No need of separate battery room.

Fig 8




A TYPICAL FAST CHARGER

## Electricity effects

**Objectives:** At the end of this lesson you shall be able to
- **state electro chemical process**
- **state the effect of an electric currents.**
- **state thermo couple**
- **state thermo electric energy**
- **state piezo electric energy.**

**Chemical sources (Electro chemical process) (Fig 1)**

If two electrically conducting materials (metals) are immersed in salt solutions, an electric charge is produced between the two metals (electrodes, poles). Two examples are given below.

Copper and Zinc in salt solution is one combination

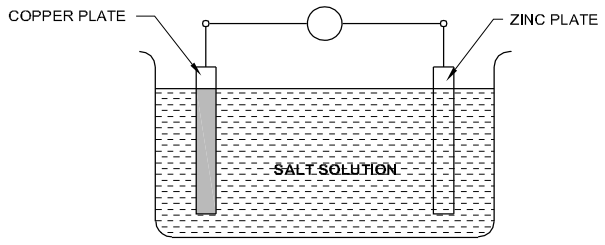
Lead and sulphuric acid is another combination.

This arrangement is known as wet cell and gives direct current. The second combination is used in a Lead Acid Battery for Motor vehicles.

**Dynamic electricity (Fig 2):** The current is produced by A/C or D/C generators, by conversion of mechanical energy into electrical energy. The generation of electric current is based on the fact when a conductor is moved in a magnetic field an E.M.F is set up in the conductor. When a large number of conductors are moved in a powerful magnetic field, high voltages and current are produced. This is the "Principle of Dynamo".

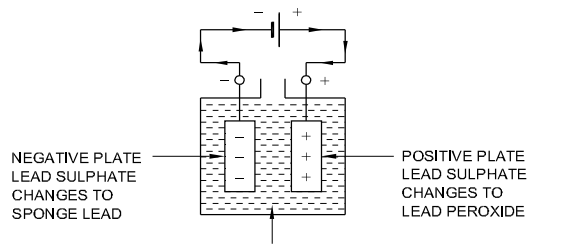
**The effect of an electric current:** Let us now study effects of an electric current. When an electric current flows through a circuit, its presence could be analysed by its effects. They are stated below.

Fig 1




ELECTRICITY GENERATION BY DISSOLVING IN ELECTROLYTES

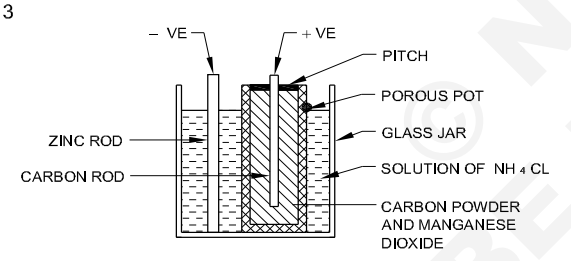
Fig 2




DURING CHARGING PROCESS

**Chemical effect (Fig 3):** When a current is applied to a battery from a battery charger various chemical reactions are produced which enable the electrical energy to be stored in a chemical form. The process is called charging a battery by electrolysis method (using electric current).

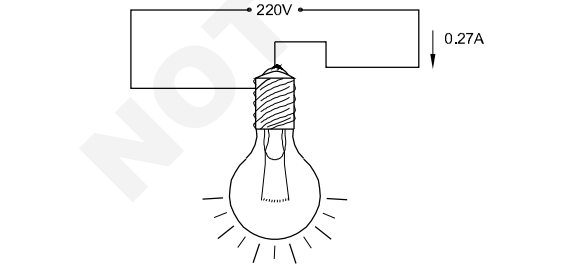
Fig 3




LECLANCHE CELL

**Heating effect (Fig 4):** When a current is applied to a bulb filament (fine wire) it becomes white hot and thus produces light.

Fig 4

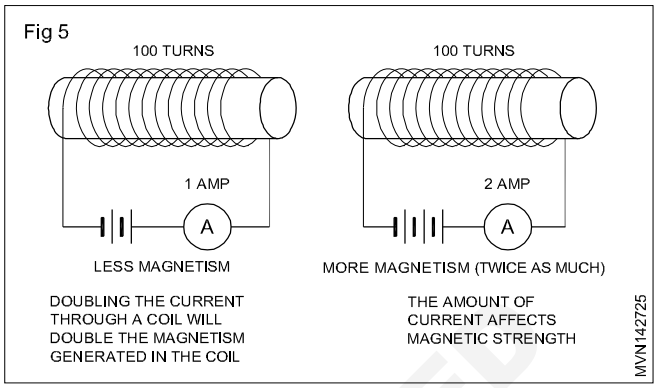



HEATING EFFECT

**Magnetic effect (Fig 5)**

- If a soft iron bar is placed in a coil of wire and a current is passed through the wire, the iron bar becomes magnetised. If the current is withdrawn the bar with retain some magnetism depending on the materials.
- If a bar magnetic is moved in a coil of wire, to and fro then in the coil of wire a current flow, is established. This can be seen by connecting a “Galvanometer”. The current, will flow only when the bar magnet is moving actually. Because, the turns of coil of wire should cut the lines of force.

Fig 5




**Shock effect:** If the current flow through Human body, it may give a severe stock or cause even death of the individuals so everyone must be careful in dealing with electrical current during work.

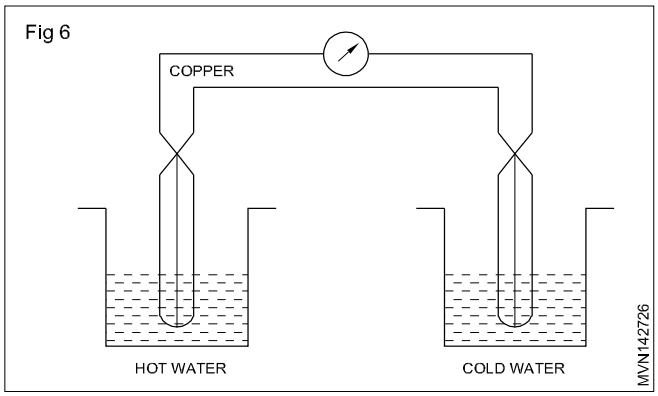
**Note**

In motor vehicle trade application, the following effect electric current are widely used

- Chemical effect-for battery.
- Heating effect-Head lamp bulbs for lighting.
- Magnetic effect-Electro magnets in relays and cuts.

**Thermocouple (Fig 6):** This is such an arrangement where circuit is closed by wires of different metals. One metal wire is kept at low temperature and the other at high temperature. In this way thermo-electro motive force is created which can be seen by galvanometer. This works on the effect of see back.

Fig 6




**Thermo electric energy:** Thermo electric energy is the electrical energy produced by waste heat of an IC engine using seebeck effect.

Thermo electric generated can convert waste heat from an engine coolant or exhaust into electricity.

**Piezo - electric energy:** Piezo electric sensor is a device that uses the piezo electric effect to measure the changes in pressure, acceleration or force, by converting them to an electrical charge.

**Application**

Used to initiate combustion in the IC engine mounted into a holes into the cylinder head. Glow plug is a in-built miniature piezo-electric sensor.

**Photo voltaic energy:** Photo volatile (PV) is a term which covers the conversion of light into electricity by using semiconducting materials that exhibit the photovoltaic effect. This effect is seen in combination of two layers of semi conductor materials, one layer of this combination will have it depleted number of electrons.

When sunlight strikes on this layer, it absorbs the photons of sunlight ray and consequently the electrons are excited and jump to the other layer. This phenomenon creates a charge difference between the layer and resulting to a tiny potential difference between them.

The unit of such combination of two layers of semi conductor materials, for producing electric potential deference in sunlight is called solar cell. Silicon is normally used as solar cell. For building cell, silicon material is cut and very thin wafers. Some of these wafers are doped with impurities. Then both doped and undated wafers are and switched together to build solar cell. A metallic strip is reached to two extreme layers to collect current.

A desired number of solar cell are connected together in both parallel and series to form a solar module for producing desired electricity.

The solar cell can also work in cloudy weather as well is moon light but the rate of production of electricity low as and it depends up on intensity of incident light ray.

(Fig 7) Describes the typical system of solar panels, controller, energy storage, inverter for converting DC into AC and how the system is connected to power grid.

Solar panels installation may be ground, rooftop or wall mounted. The solar panels mount may be fixed a solar tracker to follow the sun across the sky.

Photo voltaic systems have long been used in specialized applications and stand alone and grid-connected PV systems have been in use since the 1990. After hydro and wind powers, PV is the third renewable energy source in term of global capacity. The PV energy covering approximately two percent of global electricity demand. It is an environmentally clean source of energy and it is free and available in adequate quantities in all the parts of world.

**Advantages of solar photo voltaic:** Solar panels once installed. Its operation generates no pollution and no green house gas emissions it is simple salability in respect of power needs and silicon has large availability in earth

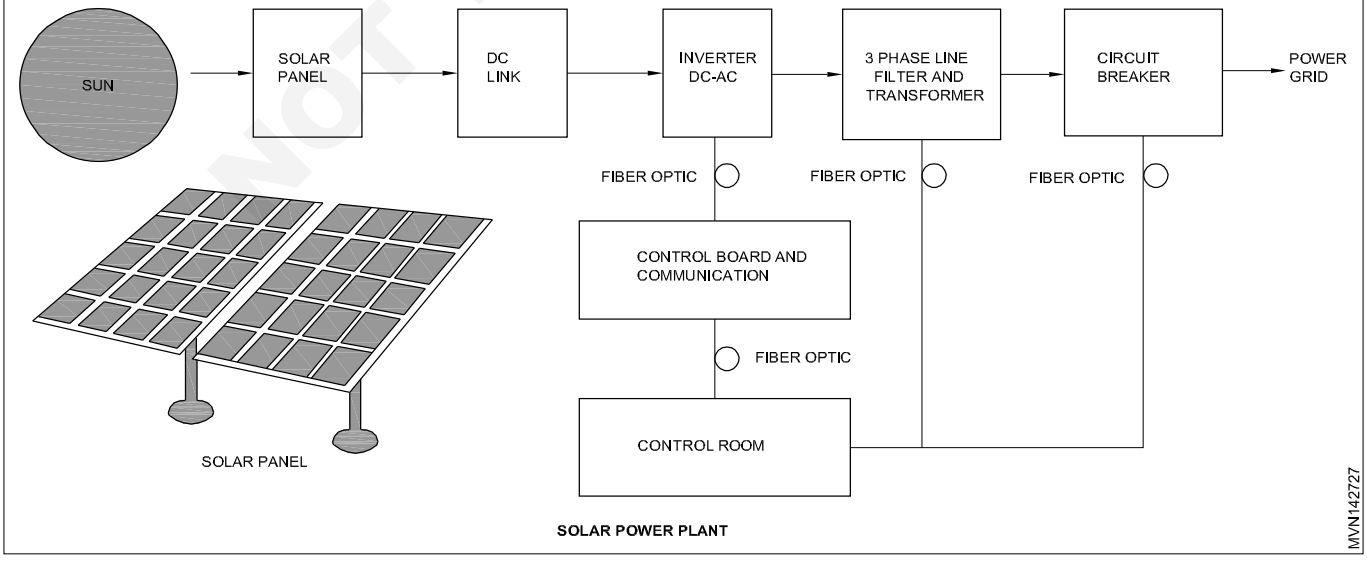
**Disadvantages of solar photovoltaic:** The power output is dependent on direct sunlight. That 10-25% is lost, if a tracking system is not used. Dust, clouds and other obstruction in the atmosphere also diminish the power output. Solar photovoltaic power needs to be stored for later use.

**Electrostatic effects:** It has been known that some materials such as amber attract light weight particles after rubbing. Electrostatic phenomena arise from the force that electric charges exert on each other. Such forces are described by coulomb's law. Electrostatics involves the buildup of charge on the surface of objects due to contact with other surfaces. Although charges exchange happens whenever any two surfaces contact and Separate the effects of charge exchange are usually only noticed when atleast one of the surfaces has a high resistance to electrical flow. This because the charges that transfer are trapped therefore a time long enough for their effects to be observed. These charges than remain on the object until they either bleed off to ground or quickly neutralized by discharge.

**Ballast resistor:** A ballast resistor is a resistor inserted into a circuit to compensate for different changes or a resister that has the property of increasing in resistance as current decreases. This resistor is used in car engines produced with breaker points type ignition primary circuit, between battery and ignition coil.

**Electromagnetic induction:** It is the phenomenon in which the relative motion between a conductor and a magnetic field produces a potential difference (voltage) across the conductor.

Fig 7




SOLAR POWER PLANT

# Solenoid and relay

**Objectives:** At the end of this lesson you shall be able to
- **define a relay**
- **classify relays according to the operating force and function**
- **explain the function of current sensing relay & Voltage sensing relay**
- **state solenoid and its application**
- **describe a solenoid switch and its function.**

**Relay**: A relay is a device which opens or closes an auxiliary circuit under predetermined conditions in the main circuit.

Relays are extensively used in electronics, electrical engineering and many other fields.

There are relays that are sensitive to conditions of voltage, current, temperature, frequency or some combination of these conditions.

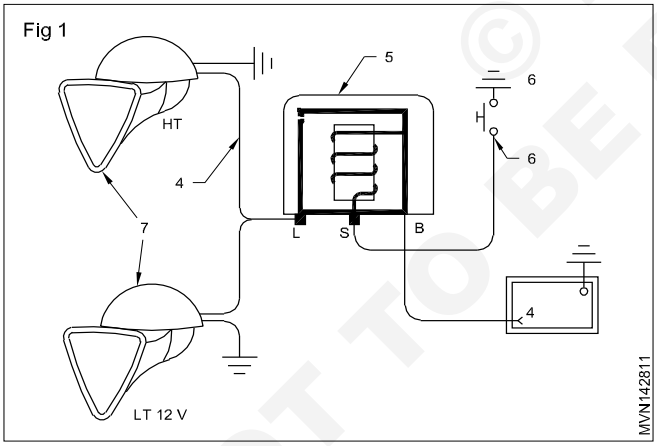
Classification of relays

Relays are also classified according to their main operating force as stated under

- Electromagnetic relays
- Thermal relays

**Electromagnetic relay:** A relay switch assembly is a combination of movable and fixed low - resistance contacts that open or close a circuit. The fixed contacts are mounted on springs or brackets, which have some flexibility. The movable contacts are mounted on a spring or a hinged arm that is moved by the electromagnet in the relay as shown in Fig 1.

Fig 1




The other types of relays coming under this group are as follows.

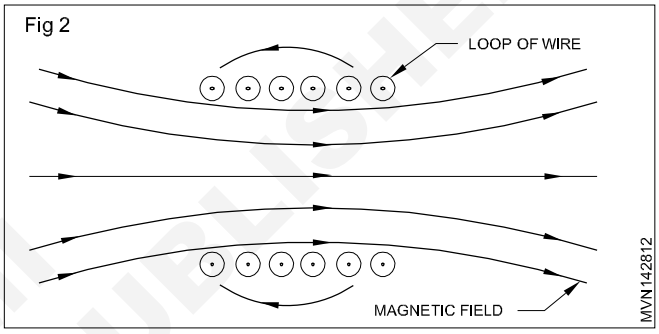
**Current sensing relay:** A current sensing relay functions whenever the current the coil reaches an upper limit. The difference between the current specified for pick up (must operate) and non - pick up (must non operate) is usually closely controlled. The difference in current may also be closely controlled for drop out (must release) and non - drop out (must not release).

**Voltage sensing relay:** A voltage sensing relay is used where a condition of under - voltage or over - voltage may cause a damage to the equipment. For example, these types of relays are used in voltage stabilizers. Either a proportional AC voltage derived from a transformer or a proportional DC derived from a transformer and rectifier is used for this purpose.

**Solenoid**

Solenoid is a coil wound into a tightly packed to a long thin loop of wire, often wrapped around a metalic core, which produces a uniform magnetic field in a volume of space. (Fig. 2)

Fig 2

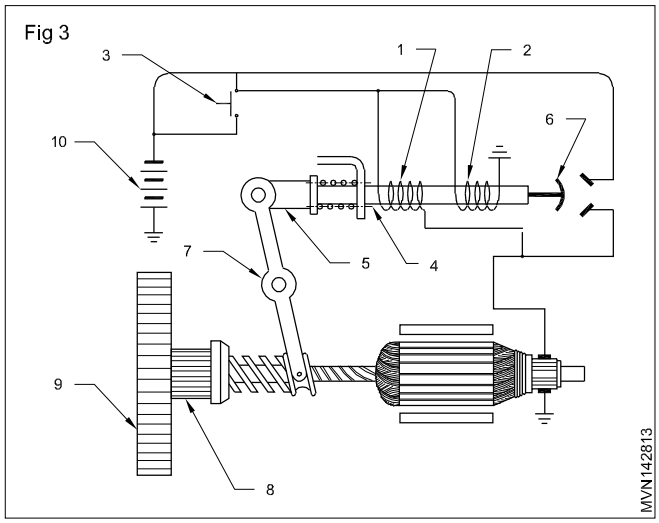



**Application**

**Need for solenoid switch:** The solenoid switch is a strong electromagnetic switch. It is used to operate the over running clutch drive pinion to engage with the fly wheel ring gear. It also acts as a relay to close the contacts between the battery and the staring motor.

**Construction of solenoid switch (Fig 3):** In a solenoid there are two windings, a pull-in winding (1) and a hold - in winding (11). The pull - in winding (10) is wound with thick wires (series winding) and the hold - in winding (11) is of thin wires ( shunt winding). The pull-in winding (10) is connected to the starter switch (3) in the solenoid.

Fig 3



The hold in winding (2) is connected across the switch terminal and ground. The two windings are wound around a hollow core (4). An iron plunger (5) is placed inside the core (4). The other end of the plunger moves a shift lever (7) to engage the pinion (8) with the fly wheel ring gear (9).

**Function of solenoid switch:** When the starter switch (Fig.3) (3) is turned, current flows the battery to the solenoid windings (1) and (2). This energises the windings which pull the plunger (5). The plunger (5) operates the shift lever (7) to engage the pinion (8) on the flywheel ring gear (9). Then it closes the circuit between the battery (10) and the starter motor.

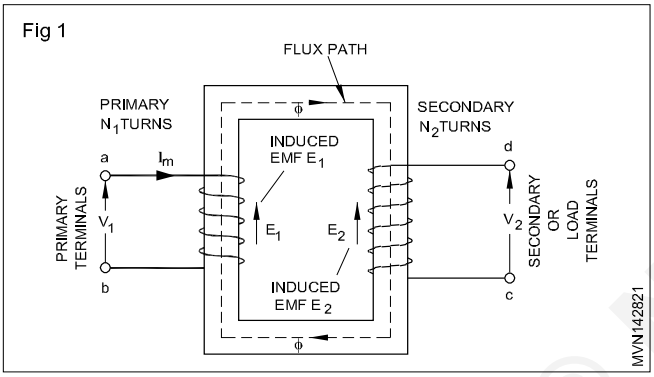
## Transformers and alternators

**Objectives:** At the end of this lesson you shall be able to
- **describe a two winding transformer**
- **explain the ignition coil as a step up transformer**
- **state the function of a transformer**
- **describe a function of a alternator and its parts.**

### Two- winding transformers

A transformer in its simplest form consists of two stationary coils coupled by a mutual magnetic flux (Fig 1). The coils are said to be mutually coupled because they link a common flux.

Fig 1




Laminated steel core transformers are used in power applications. As shown in Fig 1, the current flowing in the coil connected to the AC source is called the primary winding or simply primary. The primary is the input to a transformer. It sets up the flux in the core, which varies periodically both in magnitude and direction. The flux links the second coil, called the secondary winding or simply the secondary.

The flux is changing; therefore, it induces a voltage in the secondary by electromagnetic induction. Thus the primary receives its power from the source while the secondary supplies this power to the load. This action is known as transformer action. There is no electrical connection between these two coils.

Transformers are efficient and reliable devices used mainly to change voltage levels. Transformers are efficient because the rotational losses are absent; so little power is lost when transforming power from one voltage level to another. Typical efficiencies are in the range of 92 to 99%. The higher values apply to the large power transformers. There is no change in frequency of voltage.

### Transformer

A transformer is an electrical device that transforms the AC voltage between two circuit through an electromagnetic induction.

A transformer may be used as a safe and efficient voltage convertor to change the AC/DC voltage and its to a higher / lower voltage its output without changing the frequency and power.

### Types

1 Step up transformer

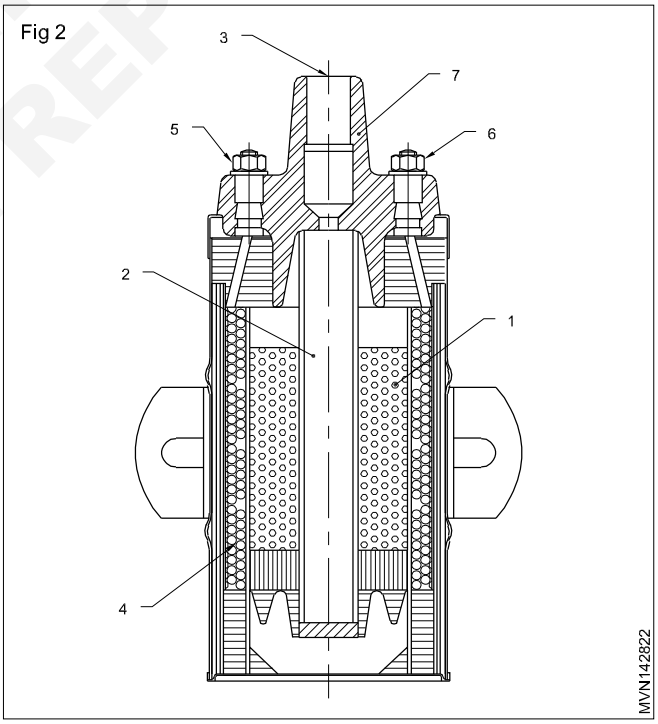
2 Step down transformer

### Application

Transformer is used in (1) ignition coil in petrol engine ignition system.

### Ignition coil (Fig 2)

Fig 2




It is used to step up low voltage to high voltage to generate sparks. In consists of two windings, one is wound over soft iron core. The secondary winding (1) is wound over the core (2). It consists of about 21,000 turns. One end of the winding is connected to the secondary terminal (3) and the other end to the primary winding (4). The primary winding (4) is wound over the secondary winding (1) and consists of about 200-300 turns. The ends are connected

to the external terminal (5,6) of coil. The bakelite cap (7) insulates the secondary terminal from the container and primary terminals.

**Alternator:** Alternators are used in cars trucks tractors and two wheelers.

**Alternators has two main functions**

1 To charge the battery.

2 To supply current to the vehicle while it is running.

**Description:** The alternator is a 3 phase machine of the revolving field and stationary armature type. Its output from the stator windings is rectified by means of built in silicon diodes in heat sinks mounted within the slip diodes in heat sinks mounted within the slip ring end shield. Output control is effected by varying the rotor excitation.

The machine is self limiting in terms of output current. Cooling is provided by a radial fan mounted on the drive end of the rotor shaft. The standard machine is insulated return version. The regulator is housed in the alternator itself.

**Terminal arrangement:** The alternator has three terminals i.e. positive terminal, negative terminal and warning lamp terminal 'WL'.

**Rectifier:** The rectifier pack comprises of nine silicon diodes, six main output diodes and three field diodes .

**Rotor** - Forged claw or pressed claw rotors are used. A pair of four fingered claws envelope the field shaft from the 8 pole imbricated rotor. The ends of the windings are brought out an connected to two slip rings at the end of the rotor assembly. The rotor is supported by bearings housed on the two end brackets (Fig 3).

**Stator:** The stator assembly comprises of a pack of laminations housing a three phase winding in the slots. The stator is held in position by the Drive End (DE) and Slip Ring End (SRE) shields (Fig 4).

Fig 3

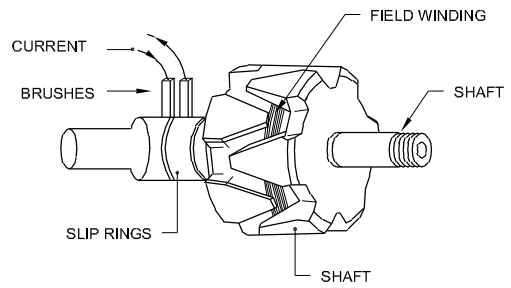
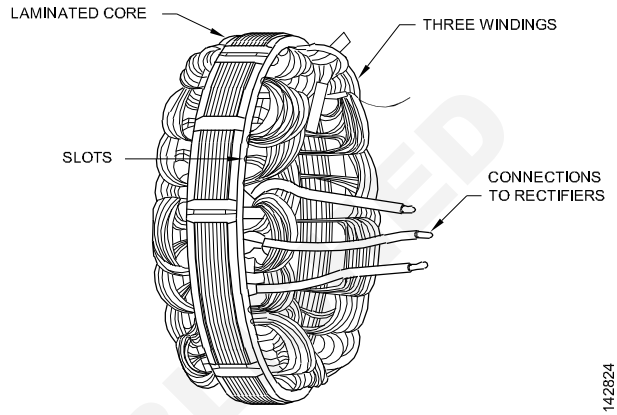



Fig 4




**In-built regulator** - This is a fully transistorised device with no moving parts, requiring no service attention. The transistors, diodes and resistors are fixed on a printed circuit base and then encapsulated. No cutout relay is necessary as the diodes in the alternator prevent reverse currents from the battery flowing through the stator when the machine is stationary or when generating less than the battery voltage. As the alternator is self limiting in current output, the regulator has only to control voltage which it does by regulating the alternator field current.

The regulator is housed in then alternator in between SRE shield and cowl by means of three studs.

## Diodes

**Objectives:** At the end of this lesson you shall be able to
- **state the meaning of semiconductors**
- **state how P and N materials are formed**
- **state the unique property of a PN junction**
- **list the different classifications of diodes**
- **state the polarity**
- **list a few type numbers/code numbers of diodes.**

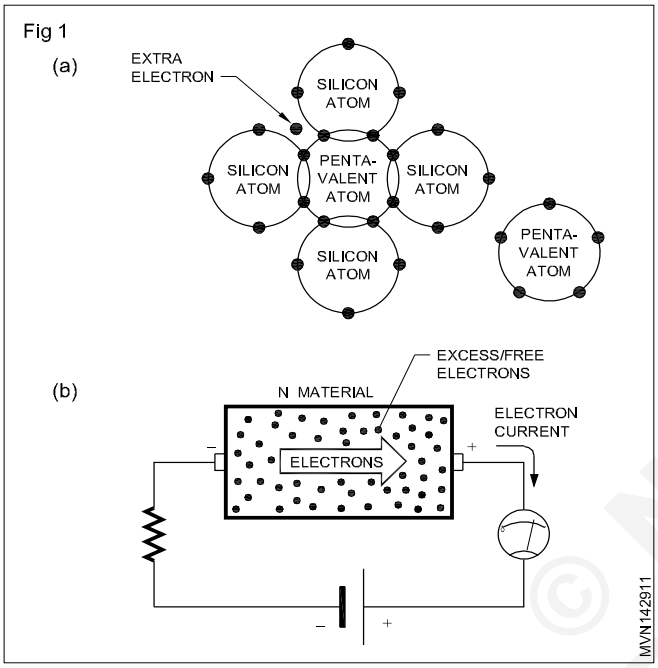
Scan the QR Code to view the video for these exercise

**Semi-conductors:** Semi-conductors are materials whose electrical property lies between that of Conductors and Insulators. Because of this fact, these materials are termed as semiconductors. In conductors the valence electrons are always free. In an insulator the valence electrons are always bound. Whereas in a semiconductor the valence electrons are normally bound but can be set free by supplying a small amount of energy. Several electronic devices are made using semiconductor materials. One such device is known as Diode.

1 **N-type semiconductors:** When a pentavalent material like Arsenic (As) is added to a pure Germanium or pure Silicon crystal, one free electron results per bond as shown in Fig 1a. As every arsenic atom donates one free electron, arsenic is called the donor impurity. Since a free electron is available and since the electron is of a Negative charge, the material so formed by mixing is known as **N type material.**

When a N-type material is connected across a battery, as shown in Fig 1b, current flows due to the availability of free electrons. As this current is due to the flow of free electrons, the current is called electron current.

2 **P-type semiconductors:** When a trivalent material like Gallium(Ga) is added to a pure Germanium or pure Silicon crystal, one vacancy or deficit of electron results per bond as shown in Fig 2a. As every gallium atom creates one deficit of electron or hole, the material is ready to accept electrons when supplied. Hence gallium is called acceptor impurity. Since vacancy for an electron is available, and as this vacancy is a hole which is of Positive charge, the material so formed is known as **P-type material**.



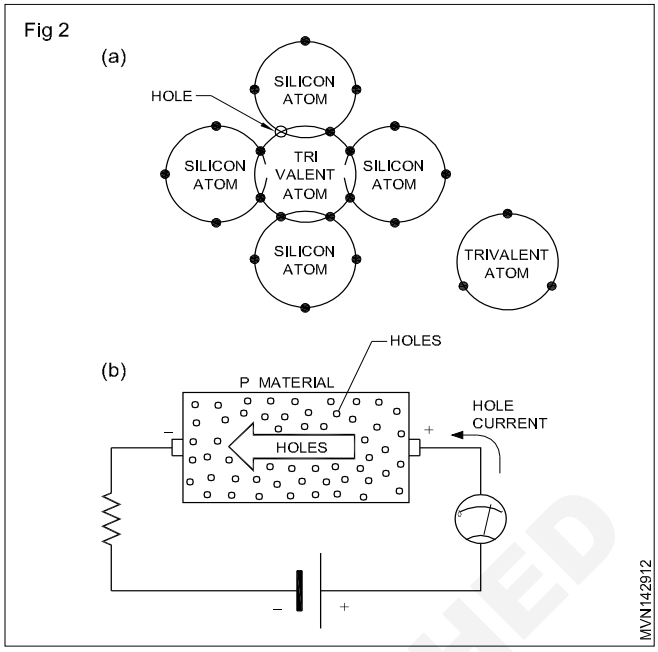

When a P-type material is connected across a battery as shown in Fig 2b, current flows due to the availability of free holes. As this current is due to flow of holes, the current is called hole current.

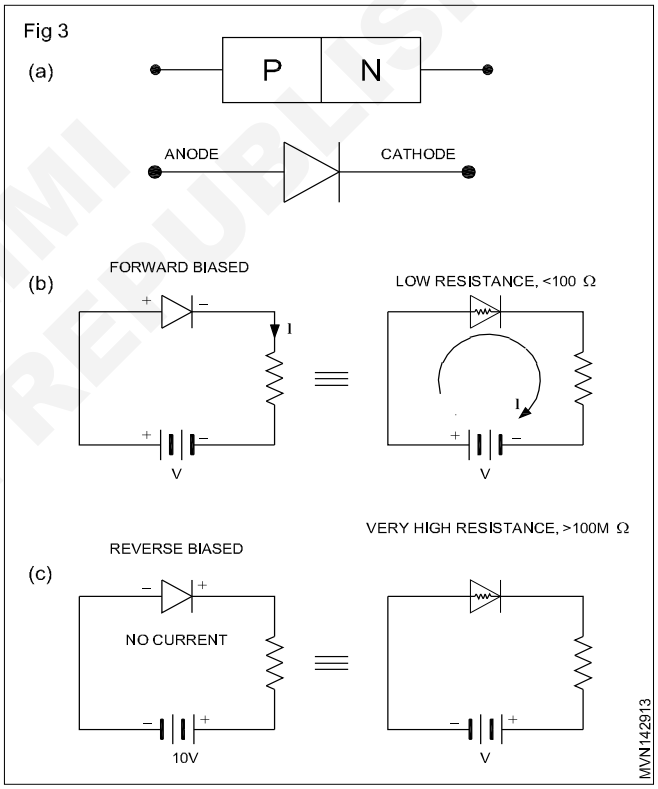
### P-N junction

When a P-type and a N-type semiconductors are joined, a contact surface between the two materials called PN-junction is formed. This junction has a unique characteristic. This junction, has the ability to pass current in one direction and stop current flow in the other direction. To make use of this unique property of the PN junction, two terminals one on the P side and the other on the N side are attached. Such a PN junction with terminals attached is called a **Diode.** The typical symbol of a PN-junction diode is shown in Fig 3a.

### Types of diodes

The PN junction diodes discussed so far are commonly referred to as *rectifier diodes.* This is because these diodes are used mostly in the application of rectifying AC to DC.




### Classification of Diodes

1 **Based on their current carrying capacity/power handling capacity, diodes can be classified as**

– **low power diodes**

can handle power of the order of several milliwatts only

– **medium power diodes**

can handle power of the order of several watts only

– **high power diodes**

can handle power of the order of several 100's of watts.

**2 Based on their principal application, diodes can be classified as,**

– **Signal diodes**

low power diodes used in communication circuits such as radio receivers etc. for signal detection and mixing

– **Switching diodes**

low power diodes used in switching circuits such as digital electronics etc. for fast switching ON/ OFF of circuits

– **Rectifier diodes**

medium to high power used in power supplies for electronic circuits for converting AC voltage to DC.

**Polarity marking on the diodes:** The cathode end of a diode is usually marked by a circular band or by a dot or by plus (+) sign. In some diodes the symbol of the diode, which itself indicates the polarities, is printed on the body of the diode.

**Type number or diode code number:** Unlike resistors, capacitors or inductors, the diodes do not have any value that can be printed or coded on its body. The other reason for this is, there are almost innumerable types of diodes with varied current handling and other specifications. Hence, instead of printing its specifications on its body, all diodes will have a type number printed on their body. This type number carries a set of specifications which can be found out by referring to a diode data manual. Diode data manuals give data of several thousands of diodes from different manufacturers. Some of the popular type numbers of diodes are

| | | |
|---|---|---|
| OAxx, | xx - from 70 to 95. | examples: OA79, OA85 etc., |
| BYxxx, | xxx- from 100 onwards, | examples: BY127, BY128 etc. |
| DRxxx, | xxx- from 25 onwards. | examples: DR25, DR150 etc., |
| 1Nxxxx | examples: 1N917 | 1N4001, 1N4007 etc. |

## Transistors and classification

**Objectives:** At the end of this lesson you shall be able to
- **state the two main uses of transistors**
- **list the advantages of transistors over vacuum tubes**
- **list the important classifications of transistors**
- **state the use of a transistor data book**
- **state about thyristor and characteristics of SCR**
- **explain working of SCR**
- **describe a thermistor and its usage.**

Scan the QR Code to view the video for these exercise



### Introduction to Transistors

Transistors are the semiconductor devices having three or four leads/terminals. Fig 1a shows some typical transistors. Fig 1b shows the symbols used for different types of transistors.

Transistors are mainly used for enlarging or amplifying small electric/electronic signals as shown in Fig 2. The circuit which uses transistors for amplifying is known as a transistor amplifier.

Other important application of transistors is its use as a solid state switch. A solid state switch is nothing but a switch which does not involve any physical ON/OFF contacts for switching.

Fig 1

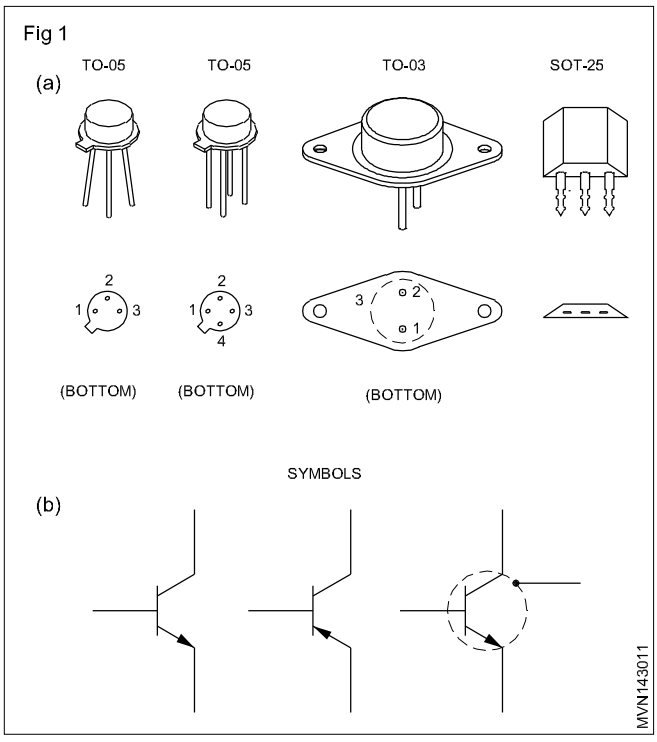
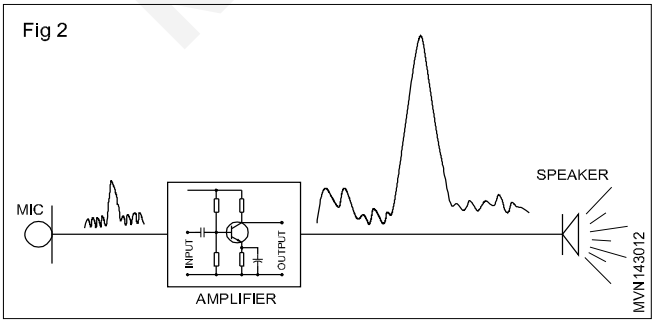
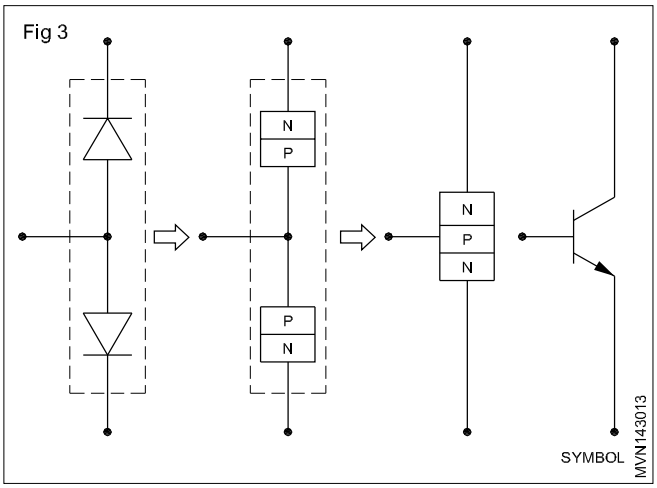


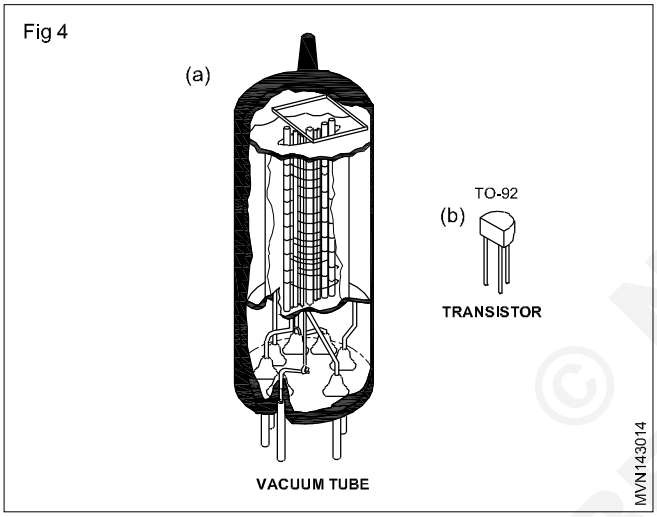

Fig 2



Transistors can be thought of as two PN junction diodes connected back to back as shown in Fig 3.




Before the transistors were invented (1947), there was vacuum tubes which were used in amplifiers. A typical vacuum tube is shown in Fig 4a.




Compared with the present day transistors the vacuum tubes were big in size , consumed more power, generated lot of unwanted heat and were fragile. Hence vacuum tubes became obsolete as soon as transistors came to market.

Transistors were invented by Walter H. Brazil and John Barlow of Bell Telephone Laboratories on 23rd Dec. 1947. Compared to vacuum tubes (also known as valves), transistors have several advantages. Some important advantages are listed below;

– Very small in size (Fig 4)
– Light in weight
– Minimum or no power loss in the form of heat
– Low operating voltage
– Rugged in construction.

To satisfy the requirements of different applications, several types of transistors in different types of packaging are available. As in diodes, depending upon the characteristics, transistors are given a type number such as BC 107, 2N 6004 etc., The characteristics data corresponding to these type numbers are given in Transistor data books.

**Classification of Transistors**

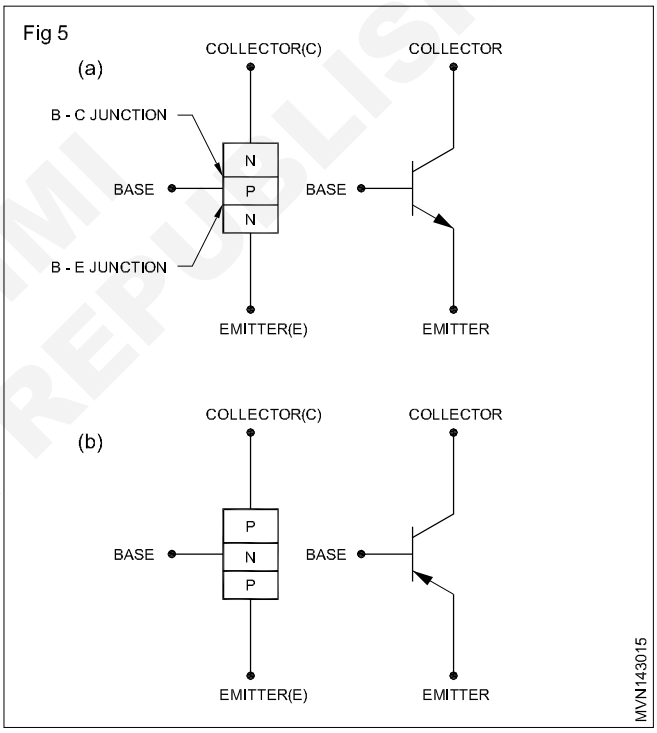
**1 Based on the semiconductor used.**

– Germanium transistors
– Silicon transistors

Like in diodes, transistors can be made, using any one of the above two important semiconductors. However, most of the transistors are made using silicon. This is because, silicon transistors work better over a wide temperature range (higher thermal stability) compared to germanium transistors.

Transistor data books give information about the semiconductor used in any particular transistor.

**2 Based on the way the P and N junctions are organized as shown in Fig 5**

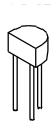
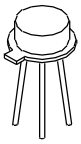
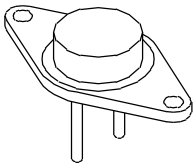



– NPN transistors
– PNP transistors

Both NPN and PNP transistors are equally useful in electronic circuits. However, NPN transistors are preferred for the reason that NPN has higher switching speed compared to PNP.

Whether a transistor is PNP or NPN can be found with the help of transistor data book.

**3 Based on the power handling capacity of transistors as shown in Table below (Fig 6)**

| Low power transistors (less than 2 watts) | Medium power transistors (2 to 10 watts) | High power transistors (more than 10 watts) |
|---|---|---|
| Fig 6  |  |  |

Low power transistors, also known as small signal amplifiers, are generally used at the first stage of amplification in which the strength of the signal to be amplified is low. For example, to amplify signals from a microphone, tape head, transducers etc.,

Medium power and high power transistors, also known as large signal amplifiers are used for achieving medium to high power amplification. For example, signals to be given to loudspeakers etc. High power transistors are usually mounted on metal chassis or on a physically large piece of metal known as heat sink. The function of heat sink is to, take away the heat from the transistor and pass it to air.

Transistor data books give information about the power handling capacity of different transistors.

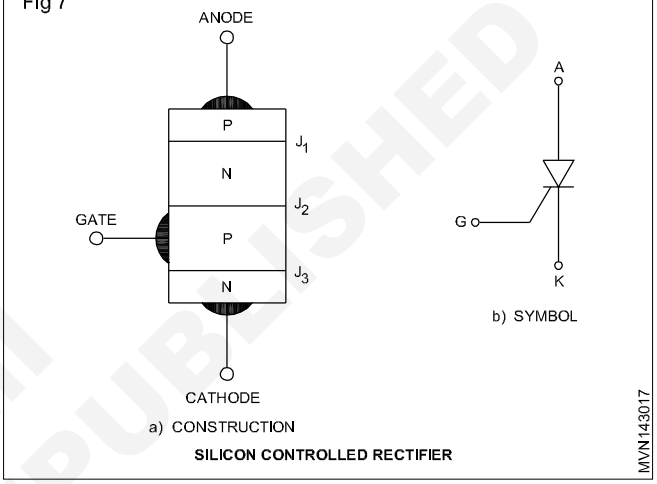
**Thyristor and the characteristics of SCR**

**Introduction:** Thyristors are four layer device which can be switched 'on' or 'off' electronically to control relatively large amounts of current for motors and other electrical equipments. The Silicon Controlled Rectifier (SCR) and the triac are examples of thyristor. Almost all electronic controls used in modern industries consist of electronic circuits with thyristors.

**Working of SCR:** The SCR is a four-layer device with three terminals, namely, the anode, the cathode, and the gate. When the anode is made positive with respect to the cathode (Fig 7), junction $J_2$ is reverse-biased and only the leakage current will flow through the device. The SCR is then said to be in the forward blocking state or off-state. When the anode-to-cathode voltage is increased, the reverse-biased junction $J_2$ will break down due to the large voltage gradient across the depletion layers. This is the avalanche breakdown. Since the other junctions $J_1$ and $J_3$ are forward-biased, there will be free carrier movement across all the three junctions, resulting in a large anode-to-cathode forward current $I_F$. The voltage drop $V_F$ across the device will be the ohmic drop in the four layers, and the device is then said to be in the conduction state or on-state.

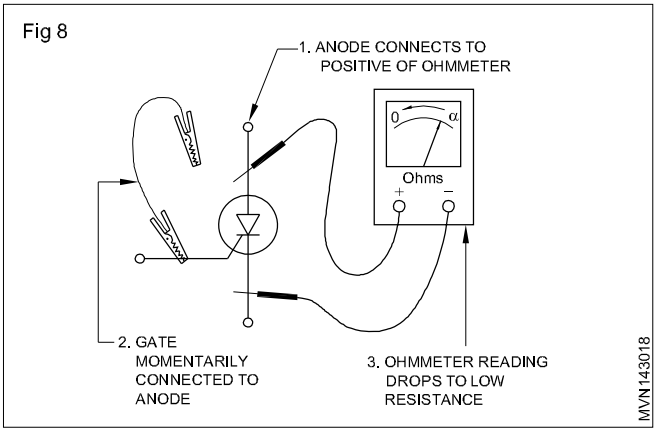
In the on-state, the current is limited by the external impedance. If the anode-to cathode voltage is now reduced, since the original depletion layer and the reverse-biased junction $J_2$ no longer exist due to the free movement of the carriers, the device will continue to stay on. When the forward current falls below the level of the holding current $I_h$, the depletion region will begin to develop around $J_2$ due to the reduced number of carriers, and the device will go to the blocking state. Similarly, when the SCR is switched on, the resulting forward current has to be more than the latching current $I_L$. This is necessary for maintaining the required amount of carrier flow across the junctions; otherwise, the device will return to the blocking state as soon as the anode-to-cathode voltage is reduced. The holding current is usually lower than, but very close to the latching current; its magnitude is in the order of a few milliampere (mA). When the cathode is made positive with respect to the anode, junctions $J_1$ and $J_3$ are reverse-biased, and a small reverse leakage current will flow through the SCR. This is the reverse blocking state of the device.

Fig 7




Set the multimeter to a low range. Adjust to zero and infinity with the adjustment knob. Connect the SCR as shown in Fig 8. The meter will not indicate any reading. Even the test prods are interchanged because of the junctions. The multimeter shows infinite resistance. Connect the SCR as shown in Fig 8. When the gate is touched momentarily with the anode prods, the meter reads low resistance between 30 and 40 Ohm. When the gate is removed, the meter still continues to read the same value of 30 and 40ohm.

Fig 8




This means that the SCR is in good working condition. If the meter does not show any reading, the SCR is faulty. When the gate is given a small forward bias, the gate switching the SCR and the internal resistance of the junction is low, so the current can flow easily from the cathode to the anode. Once the SCR is conducted, even

if the gate's forward bias is removed, the SCR anode-to-cathode current will flow through the meter, and the multimeter will continue to read a low resistance, ie 30 to 40ohm.

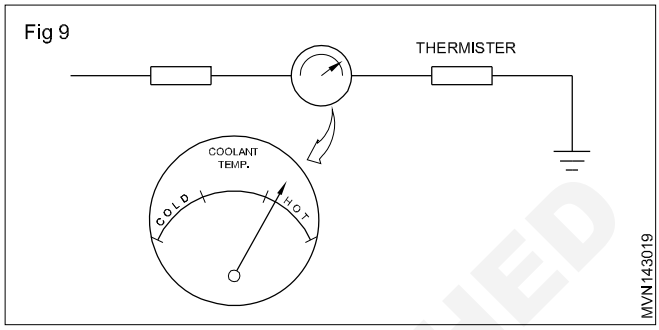
**Thermistor:** It is also semiconductor device used in most vehicles today. They are named because they are actually a temperature sensitive resistor. It is made of powdered nickel, cobalt, copper, iron and manganese which has been fused together at a higher temperature. The electrical resistance of a thermistor changes greatly with temperature.

Thermistors are used to detect various temperatures or changes in temperature. Their most frequent use involves the measurement of engine coolant temperature, or inlet air temperature.

In the most common type of thermistor, the resistance decreases as the temperature increases. This type is called a negative temperature coefficient (NTC) thermistor. Some thermistors are of the positive temperature coefficient (PTC) type. This means that the resistance of the thermistor increases with temperature. NTC type thermistors are used in Automotives as engine coolant temperature sensors as shown in Fig 9.

Thermistors can also be used to detect the temperature of the air. Many of the computer controlled fuel system in use utilize air temperature as an input. These are easily installed and wired into the computers and will have their resistance changes seen as temperature changes.

Fig 9



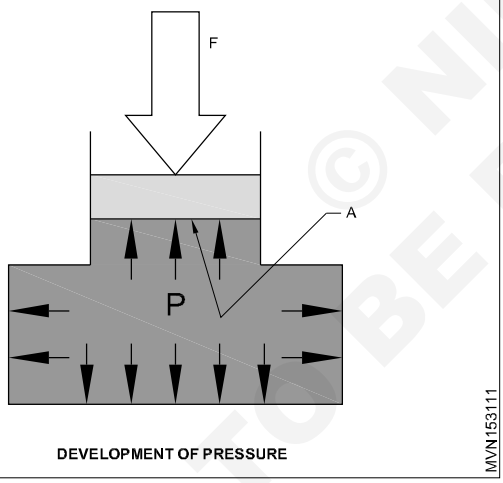
# Pascal's Law - Pressure viscosity

**Objectives:** At the end of this lesson you shall be able to
- **state Pascal's Law**
- **understand the concept of force multiplication**
- **state many functions of hydraulic fluids**
- **define the term viscosity.**

**Pascal's law (Blase Pascal, 1623-1662):** Pascal's law is the central law for the development of a number of machines, such as hydraulic brakes, hydraulic jacks, etc. The law states that 'pressure exerted on a fluid is transmitted equally in all directions, acting with equal force on equal areas'. The following sections explain how a pressure is developed in a hydraulic system with the application of a force through a pump mechanism and how a force is developed with the application of the pressure through an actuator mechanism.

**Hydraulic pressure:** is the result of the resistance offered to compression when an incompressible oil medium is squeezed by the application of a force. This pressure is transmitted equally throughout the medium in all directions, according to the Pascal's law.

Fig 1




DEVELOPMENT OF PRESSURE

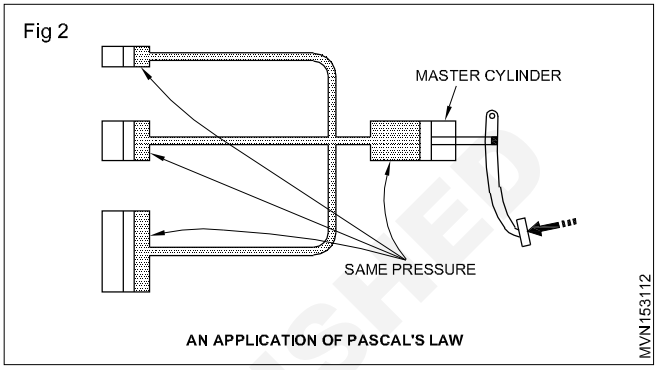
Fig 1 shows a cylinder chamber with a definite volume of oil and a piston. A force (F) is applied to the oil through the piston. When the oil is pushed, its pressure (P) increases in direct proportion to the applied force and inverse proportion to the piston area (A). Pressure can, therefore, be defined as the force acting per unit area. That is,

$$P = \frac{F}{A}$$

### A typical Application of Pascal's Law

A feature of hydraulic theory can be seen in the illustration in Fig 2. which demonstrates the pressure in the master cylinder is transmitted equally to all wheel cylinders as per the Pascal's Law.

Fig 2




AN APPLICATION OF PASCAL'S LAW

**Units of Pressure:** There are many units of pressure, such as Pascal (Pa), bar, pounds per square inch (psi), Kg/ $cm^2$, etc., used in industrial world. Some of the most important units of pressure are highlighted below:

| | |
|---|---|
| 1 Pascal | = 1 $N/m^2$ |
| 1 bar | = 100000 Pa = $10^5$ Pa (100 kPa) |
| 1 bar | = 14.5 psi |
| 1 bar | = 1.02 $kgf/cm^2$ |
| 1 kgf/ $cm^2$ | = 0.981 bar |

### Hydraulic Force

When a pressure (P) is applied onto the area (A) of a cylinder piston, a force (F) is developed. The amount of force developed is equal to the area times the applied pressure. That is,

$$F = P \times A$$

**Example 1:** What will be the pressure required to lift 75000 N using a hydraulic cylinder with an effective area of 0.0103 $m^2$?

| | |
|---|---|
| Force, F | = 75000 N |
| Area, F | = 0.0103 $m^2$ |
| Pressure, P | = F/A |
| | = 75000/0.0103 Pa |
| | = 7281553 Pa = 72.8 bar |

Exercise 1: Calculate the approximate force, a hydraulic cylinder can apply, if it has a diameter of 5.1 cm and is connected to a 200 bar circuit.

**Force multiplication**

Fig 3 shows an arrangement of two cylinders with piston areas $A_1$ and $A_2$ ($A_2 > A_1$) respectively. These two cylinders are interconnected by a pipeline. Oil is enclosed in the cylinder chambers and in the pipeline. When the plunger piston $A_1$ is applied with a force $F_1$, a pressure (say P1) is developed in the oil, which acts equally in all directions through the oil. It means that the same pressure (P1) acts on the ram piston $A_2$. This causes the development of a force (say $F_2$). The governing equations for the forces developed in the cylinders are as follows:

$$F_1 = P \times A_1$$

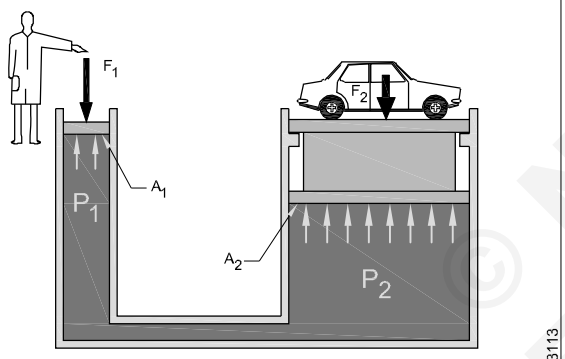
$$F_2 = P \times A_2$$

Therefore,

$$F_2 = F_1 \times (A_2 / A_1)$$

We can see that by controlling the area ratio (A2/ A1) a larger output force can be obtained from a smaller input force. This principle is also used in many hydraulic machines. For example, a hydraulic jack used to lift cars at service stations, brakes in vehicles, etc., use the force multiplier principle for power amplification.

Fig 3




ILLUSTRATING THE CONCEPT OF FORCE MULTIPLICATION

**Example 2**

To understand the idea of force multiplication, consider Fig 1.1, where applied force, F1= 25 N, cross sectional area of plunger, A1 = 10 cm2, ram piston area A2 = 100 cm2. What will be the force F2 required to lift the car placed on the ram platform?

**Solution:**

Pressure $P_1$ $= F_1 / A_1 = 25/10 = 2.5$ n.cm$^2$

$P_1$ $= P_2 = 2.5$ n.cm$^2$

Therefore, $F_2$ $= A_2 P_2$

$= 100 \times 2.5$ N

$= 250$ N

**Exercises 2:** A hydraulic car lift used in a service station has an input pump piston and an output plunger to support a loading platform. The pump piston has a radius of 0.012 m and the loading piston has a radius of 0.15 m. The total weight of the car and the plunger is 25000 N. If the bottom surfaces of the piston and plunger are at the same level, what input force is required to lift the car and output plunger? What pressure produces this force? [Ans: 160 N, 3.536 bar]

**Oil flow**

A hydraulic system, with a pump pushing oil continuously through a pipeline, produces a oil flow between any two points in the pipeline as long as there is a pressure difference between these two points.

**Flow rate**

Flow rate of oil is a measure of the volume of the oil passing a point per unit of time. It is usually measured in m$^3$ per minute or in other units.

**Hydraulic oil**

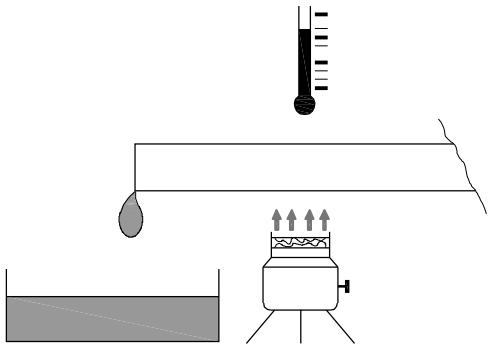
Hydraulic oil is the lifeblood of any hydraulic system. Its primary function is to transmit power from one part of the system to the other part. Apart from this function, it has to lubricate the internal moving parts of system components, seal clearance between the moving parts, and act as a heat transfer medium, as it flows through the system. Oil is usually composed of base stock ad many additives. Mineral-based oils (i.e., petroleum-based oils) are used in a majority of applications. The purpose of using additives in oil is to improve the performance of the oil for a give application. Oil's resistance to flow, expressed in terms of its viscosity, is an important parameter that must be considered.

**Hydraulic oils** are susceptible to the problem of contamination as they are generally used in harsh environments. Presence of particulates, water, air, and their reaction products in hydraulic oil can adversely affect the performance of these systems. Therefore, the most important requirement of any hydraulic system is to maintain its oil medium in a clean state. Hydraulic filters are used to remove solid contaminants in hydraulic oil.

**Viscosity (Fig 4)**

Viscosity is a measure of a liquid's resistance to flow. Thicker oil has more resistance to flow and possesses a higher viscosity. Viscosity is affected by temperature. Oil viscosity decreases as the temperature of oil increases.

Fig 4




ILLUSTRATING THE EFFECT OF TEMPERATURE ON VISCOSITY

A property, that describes the difficulty with which oil moves under the force of gravity, is called kinematic viscosity. It is measured in terms of stokes.

**Stoke (St):** This is the CGS unit of kinematic viscosity, equivalent to square centimeter per second ($cm^2/s$.) The more customary unit of kinematic viscosity is the centistokes (cSt). One cSt is one one-hundredth of a stoke. The relations amongst various units of kinematic viscosity are summarized below:

* 1 stoke = 1 $cm^2/s$
* 1 cSt = 0.01 Stoke
* 1 cSt = 1 $mm^2/s$

## Hydraulic system

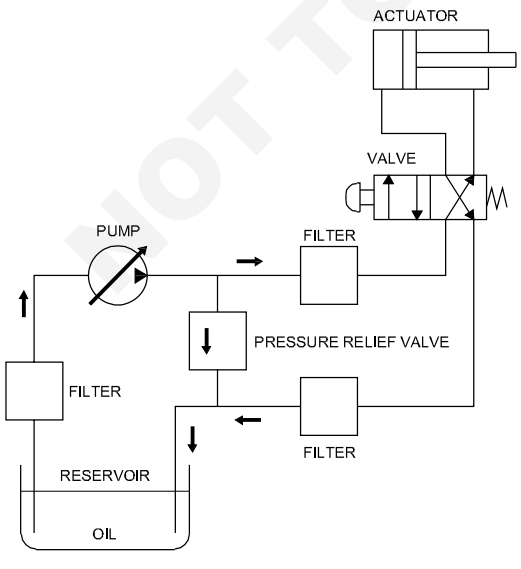
**Objectives:** At the end of this lesson you shall be able to
- **appreciate a typical hydraulic system**
- **understand the components of a hydraulic power pack**
- **explain the working of a hydraulic pump.**

### A typical hydraulic system

A typical hydraulic system is shown in the schematic diagram of Fig 1. The system is a closed system and comprises a power pack, control valves, and actuators. The hydraulic power pack consists of a hydraulic pump coupled to engine, a reservoir filled with oil, and a pressure relief valve (PRV). The pump pushes the oil into the closed system. It develops a high pressure, when the pump flow encounters some opposition. Therefore, the mechanical energy provided by the prime mover of the pump is converted into hydraulic energy. This energy is transmitted to hydraulic actuators through the oil medium. Hydraulic actuators, such as cylinders, are used to convert the hydrostatic energy back to mechanical energy. Hydraulic valves are used to control the direction and the speed of the actuators. The pressure relief valve is used to limit the pressure in the system.

All system components are interconnected through fluid conductors, such as pipes, tubing and/or hoses, for the leak-free transmission of the hydraulic power. The pressurized oil media must be positively confined in the system, through the use of effective seals, for the efficient utilization of the power. Contaminants should not be allowed to accumulate in the system. Filters are used to remove contaminants in the oil medium.

Fig 1

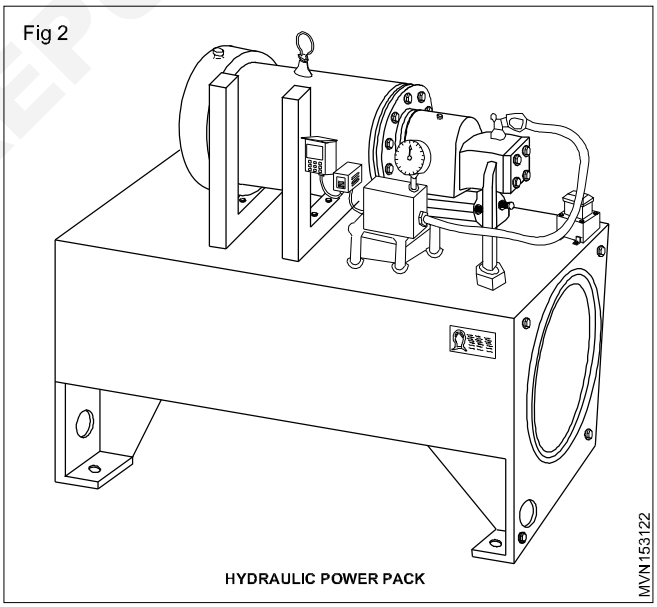



REPRESENTATIONS OF A TYPICAL HYDRAULIC SYSTEM

### Reservoir (Fig 2)

A hydraulic power pack, employed in a hydraulic system, transforms the power conveyed by its prime mover into hydraulic power, at pressures and flow rates as required for all system actuators. It is usually a compact and portable assembly that contains components necessary to store and condition a given quantity of oil, and to push a part of the oil into the system. The essential components are reservoir (tank), pump, relief valve, pressure gauge etc. A reservoir is essentially a container that stores a sufficient quantity of oil required for the system. A well-designed reservoir in a hydraulic system allows most of the foreign matter to drop out of the oil and assists in dissipating heat from the oil.

Fig 2

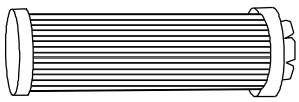



HYDRAULIC POWER PACK

**Oil filter (Fig 3):** Impurities can be introduced into a system as a result of mechanical wear, and external environmental influences. For this reason filters are installed in the hydraulic circuit to remove dirt particles from the hydraulic oil. The reliability of the system also depends on cleanliness of oil.

**Pressure relief valve (Fig 4):** A pressure relief valve (PRV) is used in a hydraulic system to limit the maximum working pressure of the system to a safe value in order to protect operating personnel against injury and system components against any damage.

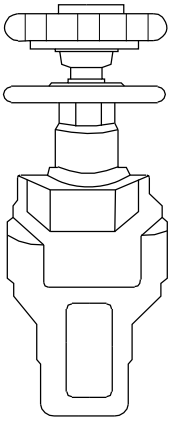
Fig 3



HYDRAULIC FILTER ELEMENT

MVN153123

Fig 4



PRESSURE RELIEF VALVE

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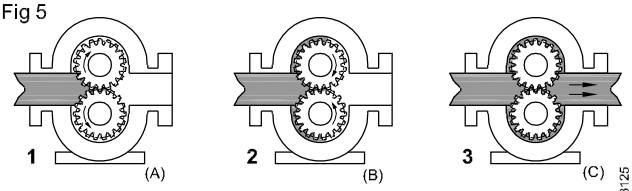
**External gear pump (Fig 5)**

Fig 5 illustrates the operation of an external gear pump with the help of its schematic diagrams in three critical positions. It basically consists of two close-meshing identical gears, enclosed in a close-fitting housing. Oil chambers are formed in the space enclosed by the gear teeth, pump housing, and side plates. Each of the gears is mounted on a shaft supported on bearings in the end covers. One of the gears - called the drive gear - is coupled to a prime mover through its drive shaft. The second gear is driven, as it meshes with the driver gear.

The gears rotate in opposite directions when driven by the prime mover, and mesh at a point in the housing between the inlet and outlet ports. When the gears rotate in the housing, the diverging teeth create an expanding volume at the inlet side of the pump. This creates a partial vacuum at the inlet chamber of the pump, which draws oil into the chamber from the system reservoir (Fig 5A).

Fig 5




SCHEMATIC DIAGRAMS ILLUSTRATING THE OPERATION OF AN EXTERNAL GEAR PUMP

MVN153125

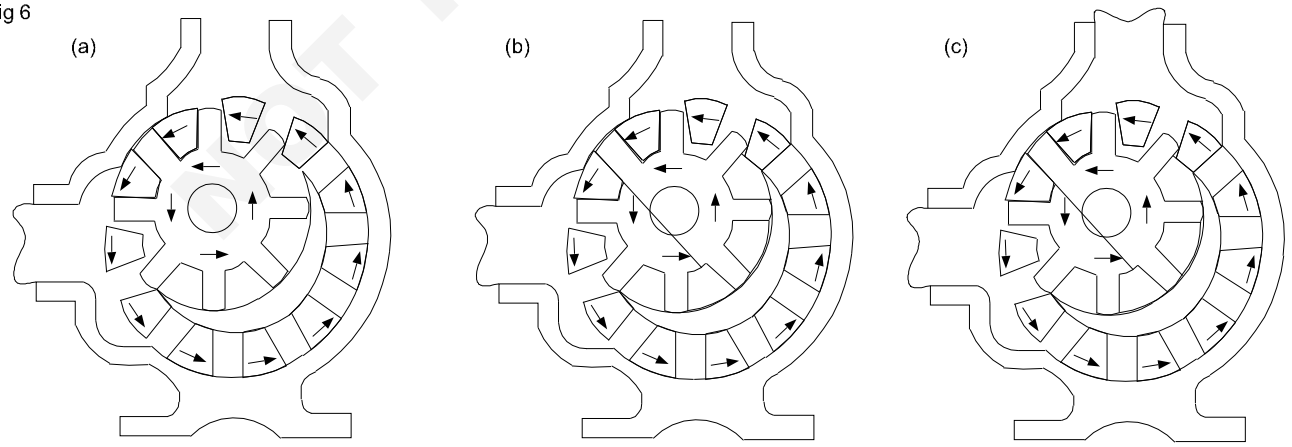
The oil then travels around the periphery of the rotating gears as two streams [Fig 5(b)]. Since the pump has a positive internal seal against leakage, the oil is positively ejected out of its delivery port [Fig 5(c)]. Therefore, when run by the prime mover, the intermeshing gears displace a fixed volume of oil from the suction side to discharge side in one revolution of the drive shaft and crate a flow.

**Internal gear pump**

Fig 6 illustrates the operation of an internal gear pump with the help of its schematic diagrams in three critical positions. This pump consists of an outer rotor gear, an inner spur gear, and a crescent-shaped spacer, all enclosed in a housing. The inner gear with less number of teeth operates inside the rotor gear. The gears are set eccentric to each other. The stationary crescent spacer is machined into the space between these gears and separates them. The spacer divides the oil stream, and acts as a seal between the suction and discharge ports.

Any one of the gears can be driven through a shaft supported on bearings. Both the gears rotate in the same direction, when power is applied to the drive shaft. The rotation of gears causes the teeth to un-mesh near the inlet port and consequently a partial vacuum is created at the inlet chamber of the pump, which draws oil into the chamber from the system reservoir [Fig 6(a)]. Oil trapped between the inner and outer gear teeth on both sides of the spacer is carried from the inlet port to the delivery port, as the gears rotate [Fig 6(b & c)]. Since the pump has a positive internal seal against any leakage, the oil is positively ejected out of the delivery port.

Fig 6




SCHEMATIC DIAGRAM ILLUSTRATING THE OPERATION OF AN INTERNAL GEAR PUMP

MVN153126

# Hydraulic actuators, DC valves, non-return valves and another valves

**Objectives:** At the end of this lesson you shall be able to
- **explain different types of hydraulic actuators**
- **explain the symbol and working of hydraulic DC valves**
- **explain the symbol and working of non-return valve**
- **explain the symbol and working of an adjustable type throttle valve.**

### Hydraulic actuators

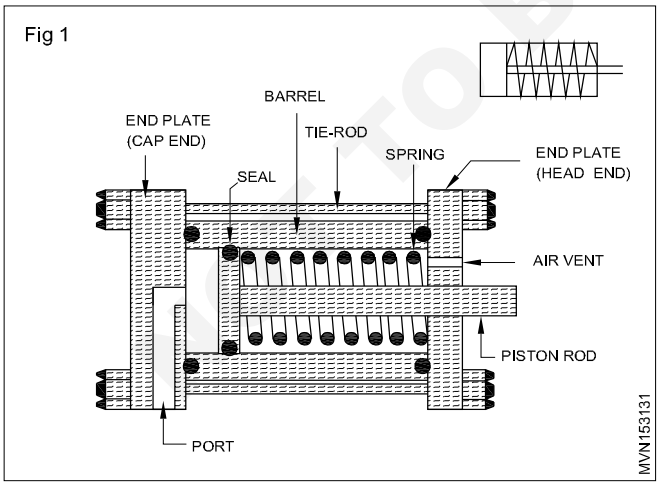
A linear actuator, is used in hydraulic system, it converts hydraulic power into a controllable linear force or motion.

### Single-acting hydraulic cylinders

A single-acting cylinder is designed to exert force hydraulically in one direction - either on its extension stroke or on its retraction stroke. It utilizes some other force to complete the motion in the other direction. It can be seen that the single-acting cylinder is capable of performing work only in one direction of its motion and hence the name single-acting cylinder.

The cross-sectional view of a single-acting cylinder is shown in Fig 1. It consists of a barrel, a piston-and-rod assembly, a spring, end-caps, a set of seals, and a port. Oil chamber is formed in the cylinder with the barrel, piston, and the piston-side end-cap. The piston-and-rod assembly is a tight-fit inside the barrel and is biased by the spring. The port is integrated into its cap-end to permit or to relieve the system oil. Application of a hydraulic pressure through the port moves the piston-and-rod assembly in one direction to provide the working stroke. The piston-and-rod assembly moves in the opposite direction, either by a spring force or by gravity, or even by exerting an external force. In a cylinder with a spring-assisted retraction, the spring is designed not to carry any load, but, to retract the piston-and-rod assembly with sufficient speed. Fig 1 A schematic diagram showing the cross-sectional view of a single-acting cylinder.

Fig 1

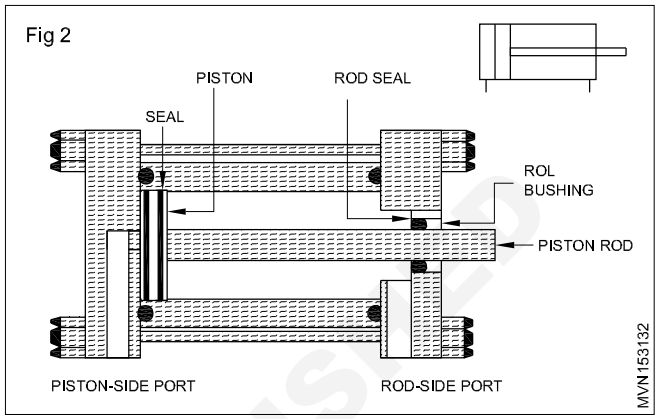



### Double-acting hydraulic cylinders

Double-acting hydraulic cylinders, like single-acting cylinders, are also linear actuators. A double-acting cylinder can perform work in both directions of its motion, and hence the name double-acting cylinder.

### Cross-sectional view of a double-acting cylinder (Fig 2)

Fig 2



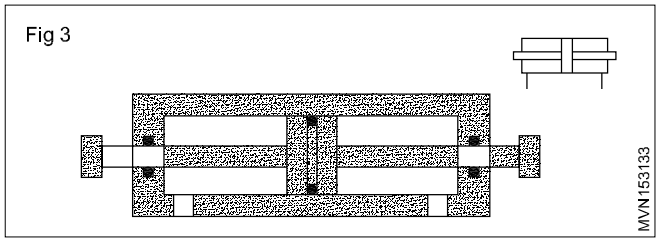

A cross-sectional view of a double-acting hydraulic cylinder is given in Fig 2. It consists of a barrel, a piston-and-rod assembly, end-caps, a set of seals, and two ports. The double-acting cylinder has oil ports on both ends, namely piston-side port and piston-rod-side port. Application of a hydraulic pressure through the piston side port extends the cylinder, provided that the pressure from the piston-rod side is relieved. In the same way, application of a hydraulic pressure through the piston-rod side port retracts the cylinder, provided that the pressure from the piston side is relieved.

### Double rod-end hydraulic cylinders

A double rod-end cylinder has piston-rods extending out of the cylinder at both ends, as shown in Fig 3. It has equal areas on both sides of the piston.

### A double rod-end hydraulic cylinder (Fig 3)

Fig 3




**Non-return hydraulic valve:** A non-return valve (NRV) is the simplest type of directional control valve used in a hydraulic circuit. The valve preferentially permits flow through it in one direction and blocks the flow in the reverse direction. The basic NRV is the so-called check valve. A hydraulic check valve consists of a valve body and a spring-biased ball poppet or cone poppet, apart from inlet/outlet ports. The spring holds the poppet against the valve seat. Cross-sectional views of these two types of hydraulic check valves are shown in Fig 4.

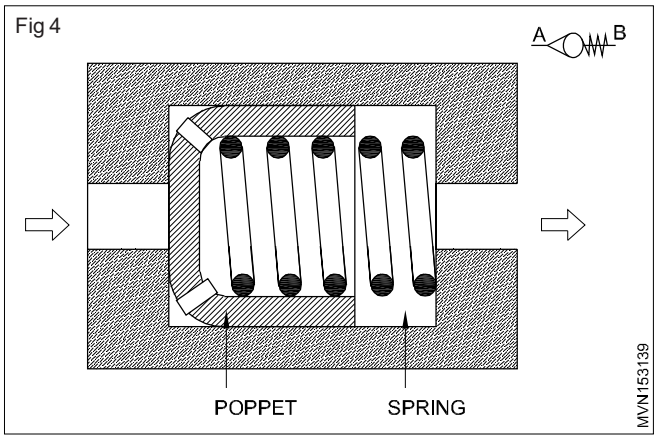



Fig 4: Cross-sectional views of a check valve

When the system pressure at the port A is high enough to overcome the spring force, the poppet is pushed off its seat allowing the system oil to flow freely through the valve from the port A the port B with a low-pressure drop across it. The flow through the valve is blocked when the intended flow direction is from the port B to the part A, by poppet reseating.

**Flow control (throttle) valve**

A throttle valve is a device with a restriction that offers a resistance to the system oil flowing through it. The throttle valve regulates the flow rate of the system oil. According to the type of restriction, throttle valves are of two types. They are: (1) Fixed type and (2) Adjustable type. In a fixed type throttle valve, the restriction is fixed, whereas in an adjustable type throttle valve, the area of the restriction can be varied. These types of throttle valves are further explained in the following sections.

An adjustable throttle valve consists of an orifice whose cross-section can be controlled by an externally adjustable needle-shaped plunger. Oil flow passing through the controlled cross-section can be regulated precisely by the pointed needle. The cross-sectional view of the adjustable throttle valve is given in Fig 5.

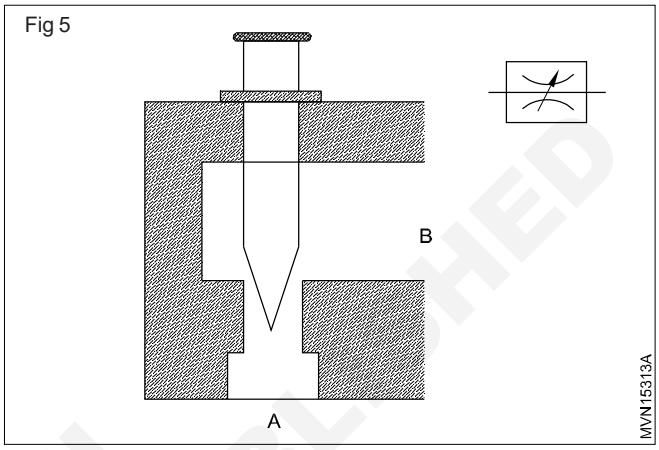



Fig 5: A cross-sectional view of an adjustable type throttle valve

## Pneumatic system

**Objectives:** At the end of this lesson you shall be able to
- **appreciate a typical pneumatic system**
- **understand the working of a reciprocating compressor**
- **explain the functions FRL**
- **explain the working of pneumatic cylinders.**

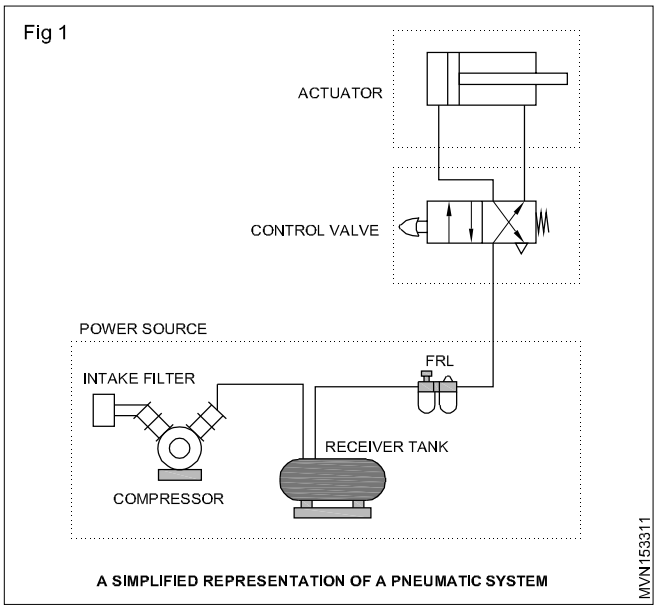
**A typical pneumatic system:** A basic pneumatic system can be thought of consisting of the following three main blocks: (1) Power source, (2) Control valves and (3) Actuators. A typical pneumatic system with a number of components is depicted in Fig 1. The power source includes compressor, receiver tank, FRL etc.

**Air compressors:** The compressor is the most common industrial energy supply unit that converts mechanical energy into pneumatic energy. The vast of pneumatic systems use air as the operating medium. It is designed to take in air at atmospheric pressure and deliver it into a closed system at a higher pressure, as per Boyle's Law.

**Boyle's law:** The relation between pressure and volume of a gas is given by Boyle's law. It states that: "At constant temperature, the volume of a given mass of gas is inversely proportional to the absolute pressure." Let $V_1$ is the volume of a gas at pressure p1. When this gas is compressed to a volume $V_2$ then the pressure will rise to a value of $P_2$. Mathematically,

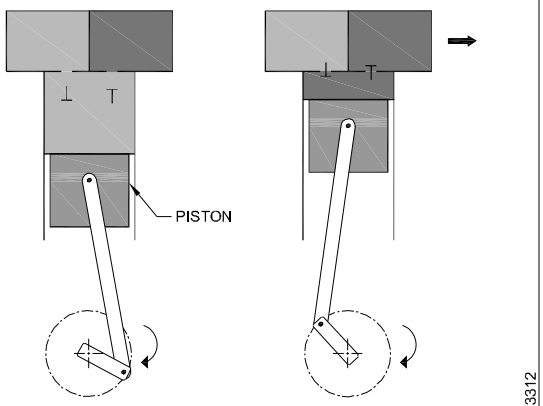
$$P_1V_1 = P_2V_2 \text{ T, Constant}$$

As air is compressed, energy used in this work is dissipated as heat, i.e., the temperature will rise as the air is reduced in volume. This is known as adiabatic compression.



**Reciprocating piston compressor:** Reciprocating piston compressors are very common and provide a wide range of pressures. Piston compressors are employed where high pressures (4-30 bar) are needed. Fig 2 shows the basic single-cylinder reciprocating compressor. As the piston moves down during the inlet stroke, the inlet valve opens and draws air into the cylinder. During the upward motion of the piston air is compressed and discharged through the opened outlet valve.

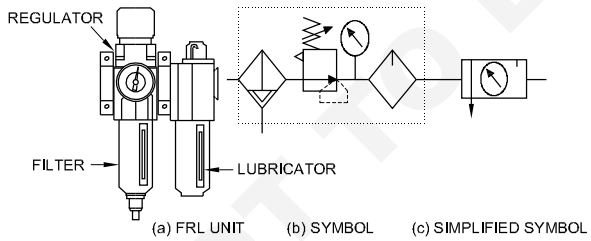
Fig 2




RECIPROCATING COMPRESSOR

**FRL or Air service unit:** Compressed air, which is dry and clean, is the most important requirement for the satisfactory operation of any pneumatic system. As we are aware, compressed air in a pneumatic system is liable to be contaminated to a high degree. It is essential to remove fine dirt particles, to regulate the pressure, and perhaps to introduce a fine mist of oil in the compressed air to aid lubrication. These important functions can be accomplished through auxiliary airline equipment, namely, filter, regulator and lubricator (FRL). A combined FRL unit and detailed and simplified symbols are shown in fig 3.

Fig 3




AIR SERVICE UNIT

**Pneumatic Actuators**

Pneumatic actuators are output devices for conversion of energy contained in compressed air to produce linear or rotary motion or apply a force. Linear actuators convert energy of compressed air into straight-line mechanical energy. Single-acting and double-acting cylinders are the two basic types of pneumatic linear actuators.

**Valves in Fluid Power Systems**

In fluid power systems, power is conveyed and controlled through a fluid under pressure within a circuit. Therefore, pneumatic and hydraulic systems require valves to control or regulate the flow of pressurised fluid from power source to various actuators. According to their function, valves in fluid power systems can be divided into the following groups:

- Directional control valves (way-valves) control the direction of fluid flow.
- Non-return valves allow the fluid flow in only one direction and block the flow in the other direction.
- Pressure control valves regulate or limit the fluid pressure or generate a control signal when a set pressure is reached.
- Flow control valves restrict the fluid flow in order to reduce its flow rate.

**Graphic representation**

A symbol specifies only the function of the valve without indicating the design principle. Apart from that, a symbol also indicates the method of actuation and designations of ports of the concerned valve. Fluid power symbols are standardized and described in ISO 1219. This is a set of basic shapes and rules for the construction of fluid power symbols.

**Port markings**

Ports of pneumatic valves are designated using a number system in accordance with ISO 5599. Letter system for pneumatic valves is no longer used. Port markings of hydraulic valves are, however, designated using a letter system. Both systems of port marking are presented in table below:

# Classification of vehicle

**Objective:** At the end of this lesson you shall be able to
- **state the classification of vehicle.**

**Classification of vehicles**

**Based on central motor vehicle act**

- Motor cycle
- Invalid carriage
- Three wheelers
- Light motor vehicle
- Medium passenger vehicle
- Medium goods vehicle
- Heavy passenger vehicle
- Heavy goods vehicle
- Any other motor vehicle of a specified description

**Based on wheel**

- Two wheeler
- Three wheelers
- Four wheelers
- Six wheelers
- Multi axles

**Based on fuel used**

- Petrol vehicle
- Diesel vehicle
- Gas vehicle (CNG & LPG)
- Electric vehicle

**Based on body**

- Saloon (BMW, AUDI)
- Sedan (Maruti ciaz, ambassador etc)
- Hatch back (Alto, i10, santro, Tata Tiago)
- Convertible (Jeep, maruti gypsy)
- Station wagon (Innova, Ertiga, etc)
- Van ( Omni, Touristor)
- Special purpose (Ambulance, Milk van, etc)

**Based on drive**

- Front engine rear wheel drive (Sumo, Omni, Ambassador, etc.) (Fig 1)
- Rear engine rear wheel drive (Tata Nano, Bajaj auto, Valvo bus etc) (Fig 2)
- Four wheel/ All wheel drive (Jeep, Scorpio, Gypsy etc.) (Fig 3)
- Front engine front wheel drive (Alto, Ertiga, santro, Tiago etc.) (Fig 4)

Fig 1

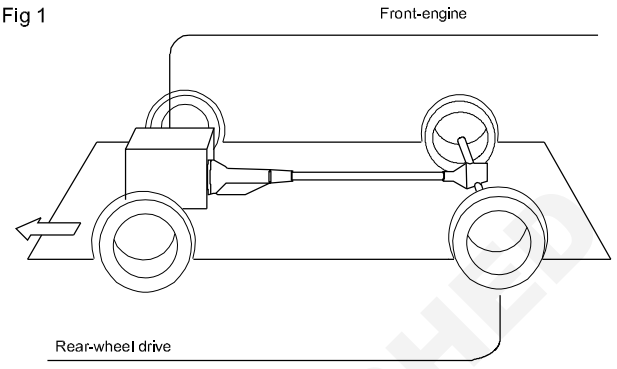



Fig 2

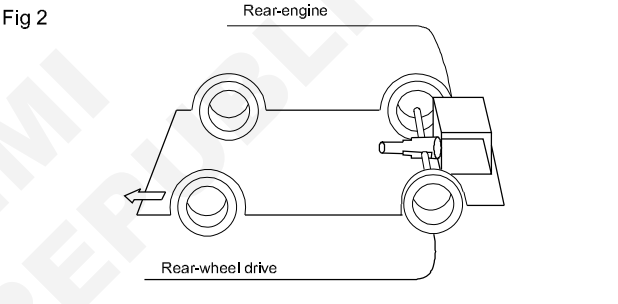



Fig 3

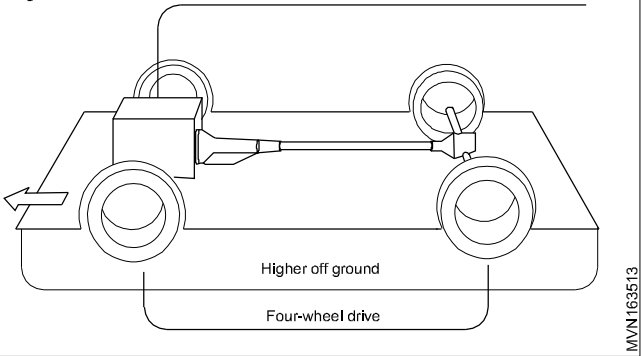
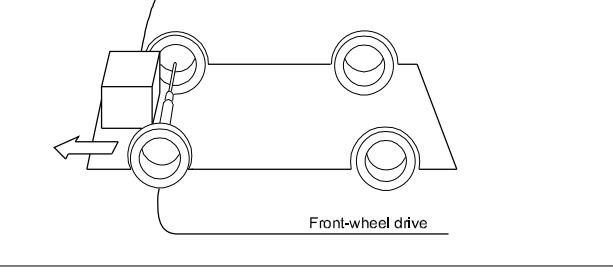



Fig 4



**Based on position of engine**

- Front transverse engine (Example ; Maruti 800)
- Front longitudinal engine (Example ; Maruti Omni)
- Rear Transverse engine (Example ; Volvo bus)

**Based on steering**

- Conventional manual steering
- Power steering hydraulic
- Power steering electric

**Based on transmission**

- Manual transmission
- **Automatic transmission:** This is transmission that uses a torque converter, planetary gears set and clutches or bands to shift a vehicle's forward gears automatically.
- **Automated manual transmission (AMT):** This is an automated manual transmission it employs a mechanical clutch, but the action of the clutch is not controlled by the driver's clutch pedal. Gears shifts done by using automated electronic, pneumatic or hydraulic controls.
- **Continuously Variable Transmission (CVT):** This transmission has a continuously variable drive ratio and uses belts, pulleys and sensors rather than gears to maintain a steady acceleration curve with no pauses for gear changes. Because of this, a CVT can keep the engine in its optimum power range, thereby increasing efficiency and gas mileage.

## Uses of hoists, jacks and stands

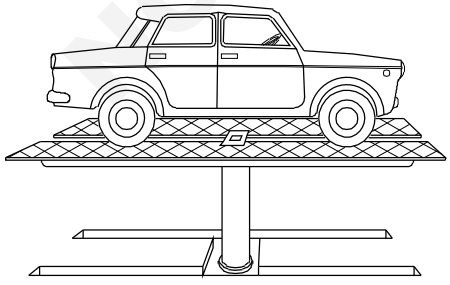
**Objectives:** At the end of this lesson you shall be able to
- **state the function of vehicle hoists**
- **state the function of engine hoists**
- **sate the function of jacks**
- **state the function of axes stand.**

The modern Automotive service stations are used the various types of equipments to lift the vehicles. They are as follows.

- Single post hydraulic car hoist
- Two post car hoist
- Four post car hoist
- Engine hoist
- Jacks
- Stands

**Single post hydraulic car hoist (Fig 1):** It is facilitate the servicing and repair works conveniently. It is constructed for dependable, trouble free performance and ensuring smooth and safe operation. The post is made of high grade steel. The car hoists are specially designed for resistant to wear and damage during water wash. Single post type is suitable for vehicle up to 6 tones.

Fig 1



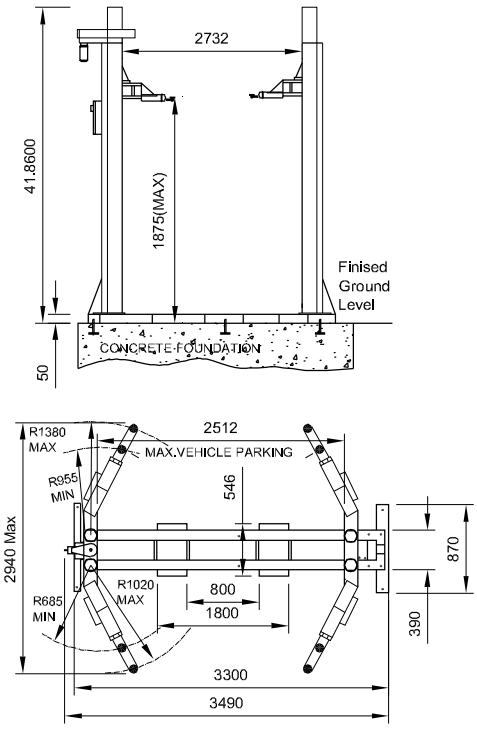
HYDRAULIC CAR HOIST

MVN163611

**Two post hoist (Fig 2):** It is operate by electro -hydraulic system. it is easy to operate and maintain the double post hoist and safety provision also provided to hold the vehicle. Double post type suitable for vehicle upto 4 tones.

**Four post car hoist (Fig 3):** It is operate by electro hydraulically and balancing the lifting vehicle. It is easy to operate and maintain the moving parts. Four post hoists is work as single and double post hoist it is suitable for lift the vehicle light and heavy vehicle.

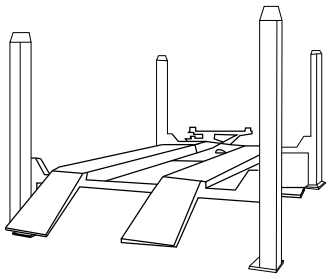
Fig 2




TWO POST HOIST

MVN163612

Fig 3

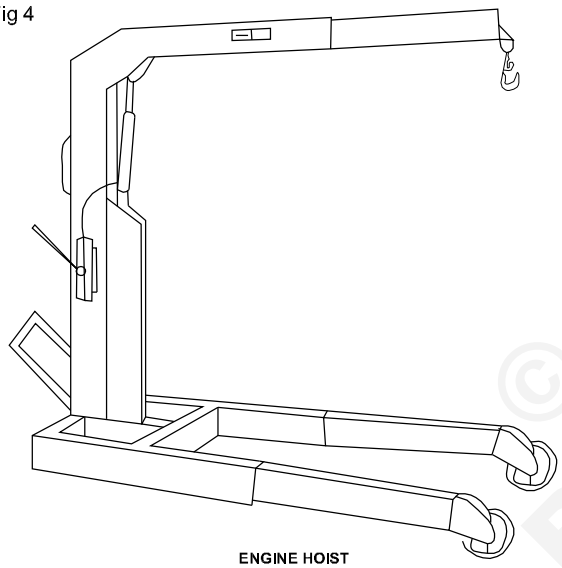


FOUR POST HOIST

MVN163613

**Engine hoist (Fig 4):** The engine hoist helps to lift an engine from a car/truck. The hydraulic pressure converts power to a mechanical advantage and lifts the engine from the car with less effort. When using a block and tackles for lifting an engine, use a lifting plate attached to the intake manifold or use a chain bolted at each end of the block so on. They are operated by moving the handle up and down. The other type of portable floor jack is the pneumatic jack which uses compressed air to lift a car or truck. It is mostly used in production side.

Fig 4



ENGINE HOIST

MVN163614

**Never work under a car without safety stands or jack stands**

On roads mostly mechanical jacks are used to lift the car/vehicle for small jobs. These jacks work under the principle of screw and nut.

**Jacks:** It is used to lift the vehicle, which are operated by mechanically and hydraulically, Jack is designed to lift the vehicle and hold the vehicle load during the repair works. Jack is a standard accessory with many vehicles.

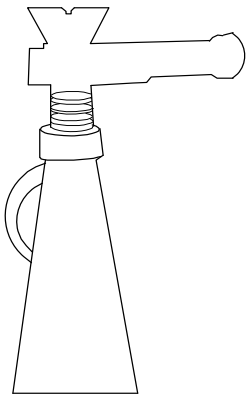
**Types of jacks**

- Light weight screw jack (Fig 5)
- Heavy duty bottle type hydraulic jack (Fig 6)
- Trolley types hydraulic jack (Fig 7)

In raising front vehicle end off the floor by jacking , be sure to apply jack against front jacking bracket(1) (Fig 8).

In raising rear vehicle end off the floor by jacking, be sure to apply jack against the center portion of rear axle (2).

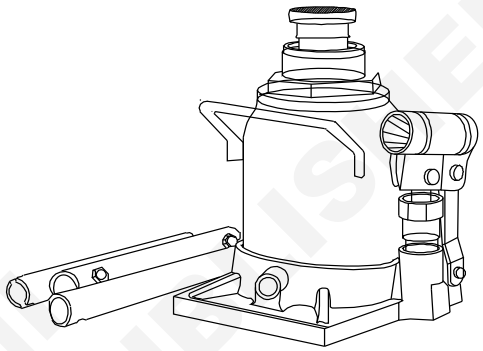
Fig 5



MANUAL TYPE LIFITING JACK

MVN163615

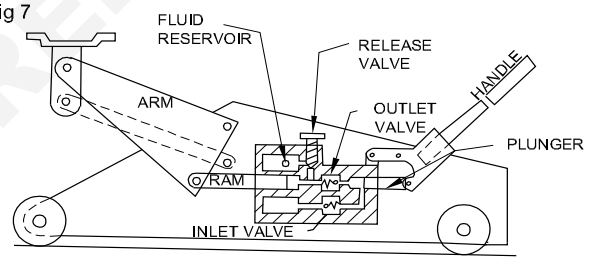
Fig 6



HEAVY DUTY BOTTEL TYPE LIFITING JACK

MVN163616

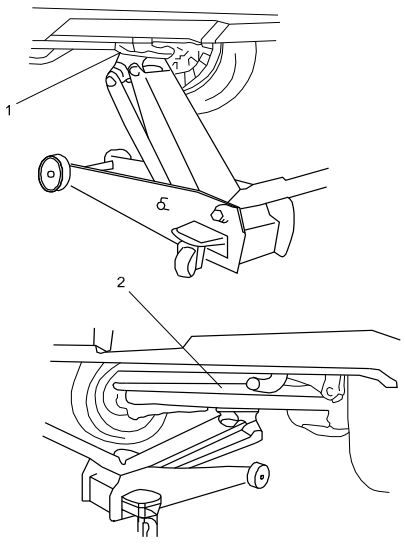
Fig 7




TROLLEY TYPE JACK

MVN163617

Fig 8




FLOOR JACK

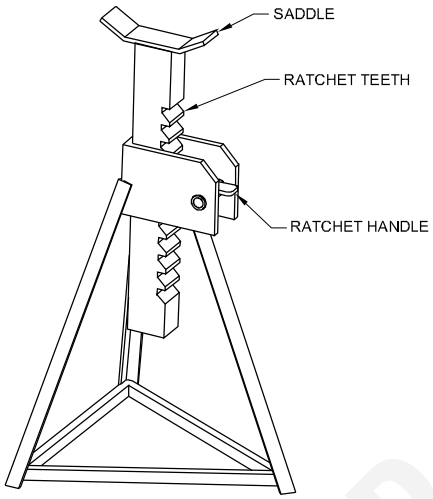
MVN163618

**Caution: Never apply jack against suspension parts (i.e., stabilizer, etc.) front bumper or vehicle floor, Otherwise it may get deformed.**

**Warning: If the vehicle to be jacked up only at the front or rear end, be sure to block the wheels on ground in order to ensure safety.**

**After the vehicle is jacked up , be sure to support it on stands. It is extremely dangerous to do any work on the vehicle raised on jack alone.**

Fig 9




TYPICAL ADJUSTABLE JACK STAND

**Axle stand** (Fig 9)**:** It is always injure safety before starting the work under the lifted vehicle, Jack support is not enough, it could be dangerous. Always use axle stands for safety work. Different size of stands are used depend upon the vehicle load.

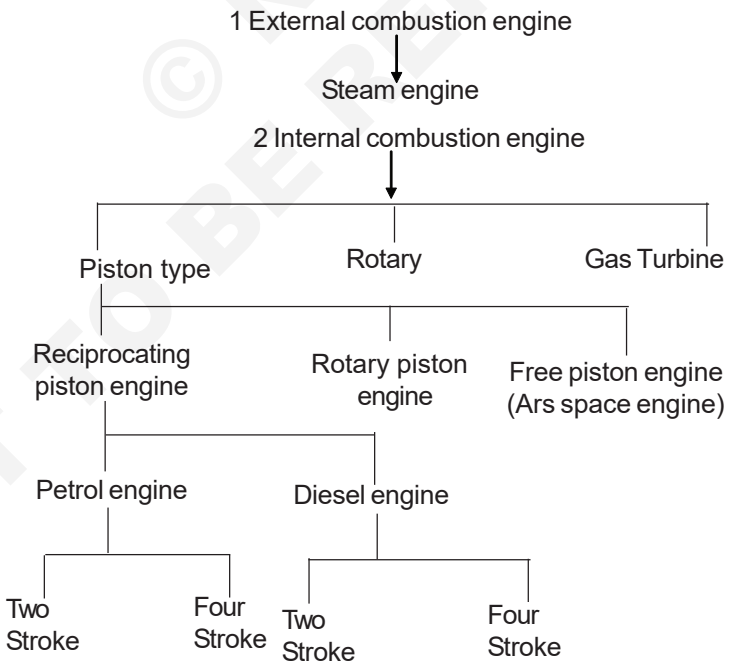
To perform service with either front or rear vehicle end jacked up, be sure to place safety stands (1) under body so that body is securely supported. And the check to ensure that body does not slide on safety stands and the vehicle is held stable for safety.

## Internal and external combustion engine

**Objectives:** At the end of this lesson you shall be able to
- **type of heat engine**
- **state the internal and external combustion engine**
- **difference between an internal and external combustion engine.**



**Types of heat engines**




### Internal combustion engine

Internal combustion engines are those heat engine, that burns their fuel and takes combustion inside the cylinder, this definition including the two stroke and four stroke engine, spark ignition and compression ignition engine, austine and jet engines are also internal combustion engine. Ex: Wankel.

### External combustion engine

The external combustion engines are those heat engine that burn their fuel outside the engine cylinder. The energy developed during the combustion of fuel is transmitted to steam. This steam acts on the piston inside cylinder example - railway steam engine.

**Difference between internal and external combustion engine**

| Sl.No. | Internal combustion engine | External combustion engine |
|---|---|---|
| 1 | Occupies less space. | Occupies more space. |
| 2 | Lighter in weight. | Heavier in weight. |
| 3 | High speed engine. | Slow speed engine. |
| 4 | Combustion of fuel takes place inside the engine. | Combustion of fuel takes place outside the engine. |
| 5 | Liquid or gas cars fuel is used. | Solid or liquid fuels used to form steam. |
| 6 | No loss of fuel when engine is not running. | Fuel has to burn even when the engine is not running for small halts. |
| 7 | Could be started or stopped at will. | Cannot be started unless steam is prepared which takes much time. |
| 8 | Temperature produced inside the cylinder is too high. | Works at comparatively low temperature. |
| 9 | Cooling arrangement necessary. | No cooling of the cylinders required. Rather it is steam jacketed. |
| 10 | Single acting. | Mostly double acting. |
| 11 | Exhaust gas temperature as high as 300°C. | The temperature of exhaust steam is quite low. |
| 12 | Thermal efficiency of diesel engine up to 40%. | Thermal efficiency up to 24% as that of petrol engine. |
| 13 | No needs boiler, furnace or condenser. | Boiler, furnace and condenser are must. |

## Classification of I.C engines

**Objective:** At the end of this lesson you shall be able to
- **state the classification of engines.**

Engines are classified according to the following factors.

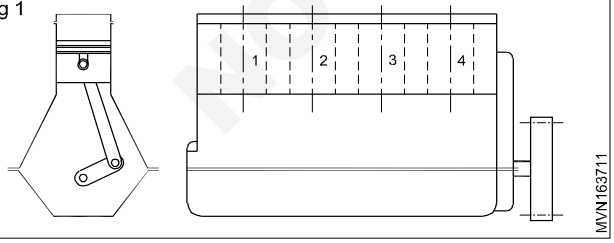
**Number of cylinders**

- Single cylinder
- Multi cylinder

**Arrangements of cylinders**

- In-line engine (Fig 1)
- `V' shape engine (Fig 2)
- Opposed engine (Fig 3)
- Horizontal engine
- Radial engine (Fig 4)
- Vertical engine

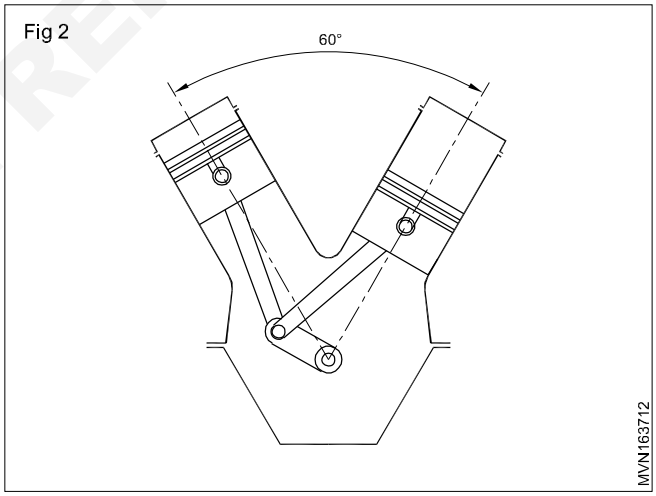
Fig 1




**Types of engines as per cylinder arrangement**

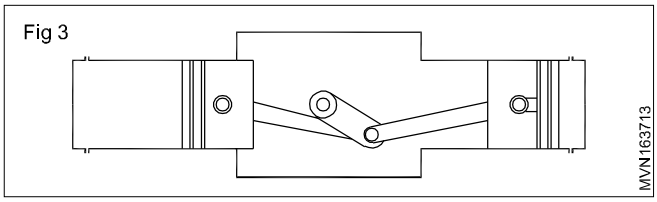
**In-line engines:** In this type, the cylinders are arranged in one line. The length of the crankshaft is longer than that of the other types of engines, and hence a limited number of cylinders are used. Better balancing and more uniform torque is obtained in this type.

Fig 2



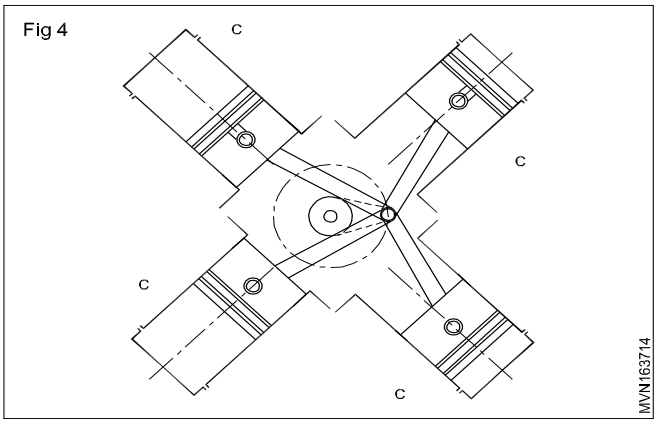

**'V' shape engines:** In this type, the cylinders are arranged in V shape at an angle, of usually 60°. This engine is more economical and compact. For multi-cylinder engines, the length of the crankshaft is much shorter than that of the in-line engine. In this type, the engine height is also lower than it is in the in-line engine.

**Opposed engines:** In this type the cylinders are arranged horizontally opposite to each other. This provides better mechanical balance. This type of engine can run smoothly even at a much higher speed. It also gives higher output. The length of the engine is too much, and therefore engine has to be placed in the transverse direction in the vehicle.




**Radial engines**

In this type, the cylinders are arranged radially. This type of engine is shorter, lighter and more rigid. Since it is rigid, a higher engine speed is possible and a higher combustion pressure can be obtained. This leads to high fuel efficiency. The radial type engines are used mostly in aeroplanes.




**Types of engine as per number of cylinders**

**Single cylinder engines:** An engine which has only one cylinder is called a single cylinder engine. Since it is a single cylinder engine it cannot develop more power. It is normally used only in two wheelers like scooters and motor cycles.

**Multi cylinder engines:** These engines have more than one cylinder. Two-cylinder engines are usually used in tractors. Three or four cylinder engines are used in cars, jeeps and other vehicles. In heavy vehicles six-cylinder engines are used. A greater number of cylinders gives smoother engine operation.

**Types of fuel used**

- Petrol
- Diesel
- Gas

**Types of valve arrangements**

- `I' head engine
- `F' head engine
- `L' head engine
- `H' head engine
- `T' head engine

**Application of engine**

- Constant speed engine
- Variable speed engine

**Engine Cooling system**

- Air cooled engine
- Water cooled engine

**Strokes of engine**

- Four-stroke engine
- Two-stroke engine

## Working of diesel engine (Compression ignition engine)

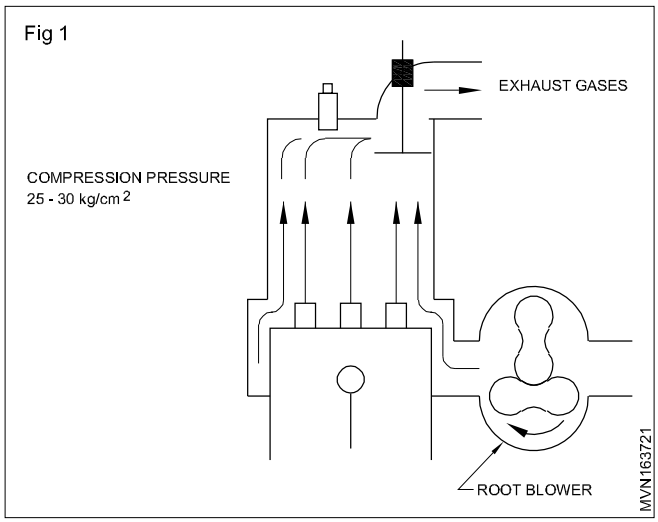
**Objectives:** At the end of this lesson you shall be able to
- **describe the function of a two-stroke diesel engine**
- **describe the function of a four-stroke diesel engine.**

**Two stroke diesel engine:** To produce power in a two stroke engine the following operation take place in the sequence given.

**First stroke:** Piston at BDC to TDC, the scavenging port and outlet valve open (Fig 1). A root blower sucks in pure air and presses it through the scavenging port into the cylinder. The tangential layout of the scavenging port brings the air into a turbulent motion. The cylinder is completely flushed out in the direct current and filled with fresh air. The exhaust gases flow out towards the outlet valve.

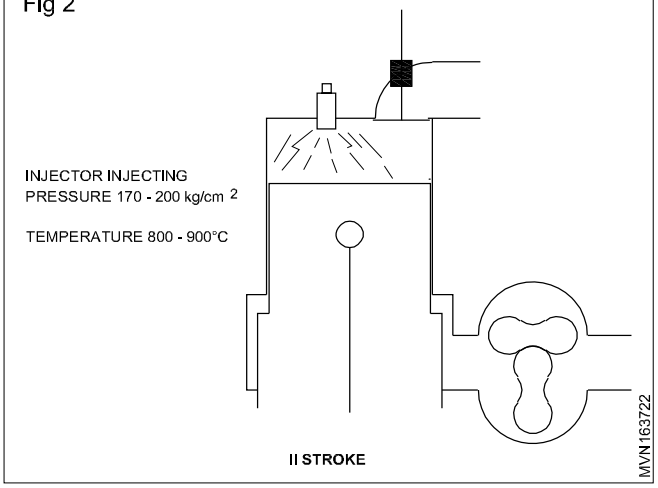
As the piston moves up from BDC to TDC the scavenging port and outlet valve closed. The piston compresses the fresh air to the compression chamber. The air temperature increases intensively.

**Second stroke**: Piston at TDC (Fig 2) scavenging port and outlet valve closed. The fuel is directly injected into the cylinder with the help of a fuel injection pump and an injector fitted in the cylinder head. The fuel gets vaporised into an ignitable fuel air mixture by the hot air. After attaining the ignition temperature the mixture gets automatically ignited and burns. The heat increases the pressure in the combustion chamber.



The gases get expanded and push the piston towards the bottom dead centre.

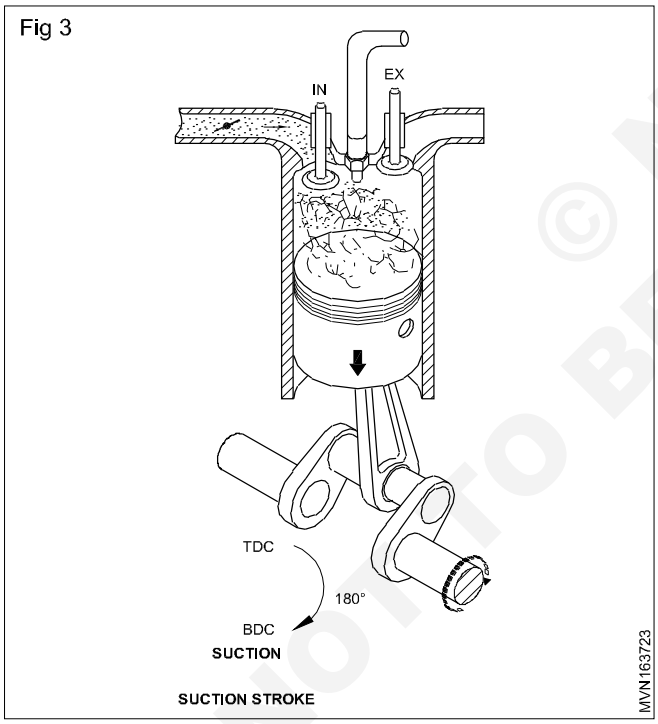
Fig 2




**Four-stroke engine:** To produce power in a four-stroke engine the following operations take place in the sequence given.

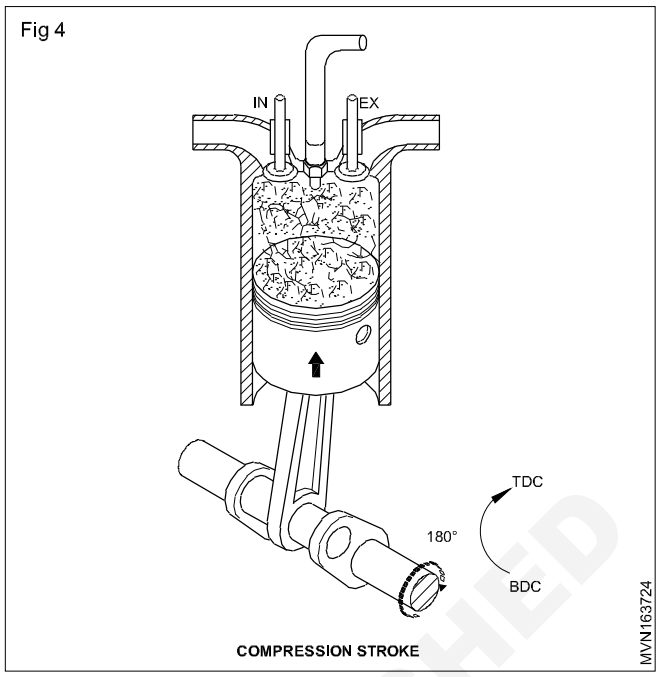
**Suction stroke:** The piston moves from TDC to BDC (Fig 3). A vacuum is created inside the cylinder. The inlet valve opens while the exhaust valve remains closed. The charge air enters into the cylinder.

Fig 3



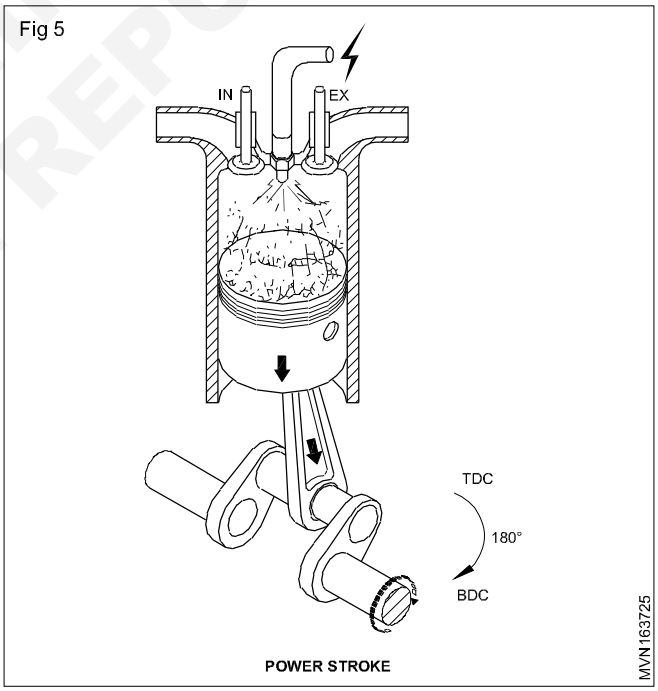

**Compression stroke (Fig 4):** The inlet and exhaust valves are closed. The piston moves from BDC to TDC (Fig.4). The charged air is compressed in the cylinder. The compressed air pressure and temperature is increased upto 800°C.

Fig 4




**Power stroke:** At the end of the compression stroke diesel fuel is injected into the hot compressed air in the combustion chamber; result burning of diesel with an explosion the gas expand and pressure develops inside the cylinder. The piston moves from TDC to BDC (Fig 5). Both the valves remain closed. Power is supplied to the fly wheel.

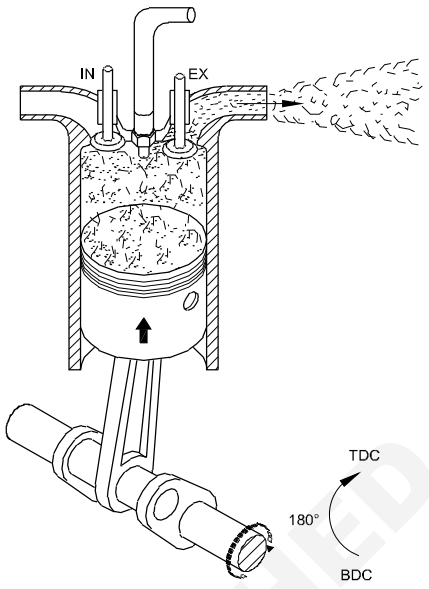
Fig 5



**Exhaust stroke:** The inlet valve remains in closed position. The exhaust valve opens, the piston moves from BDC to TDC (Fig 6) due to the energy stored in the flywheel. The burnt gases inside the cylinder go out through the exhaust valves.

The cycle of suction, compression power and exhaust are repeated. In this type of engines one power stroke is obtained in two revolutions of the crankshaft.

Fig 6




EXHAUST STROKE

## Working of spark ignition engine (Petrol engine)

**Objectives:** At the end of this lesson you shall be able to
- **describe the function of a two-stroke engine**
- **describe the function of a four-stroke engine**
- **differentiate between a four-stroke and a two-stroke engine**
- **explain an OTTO cycle**
- **explain a diesel cycle.**

**Two-Stroke spark ignition engine**

To produce power in two stroke engine the following operations take place in the sequence given below.

**First stroke (Suction and compression) (Fig 1)**

As the piston moves up from BDC,(Fig 1) it closes the inlet port (1), the exhaust port (3) and the transfer port (2). Further upward movement of the piston results in compressing the mixture in the cylinder and opening of the inlet port (1).

The upward motion of the piston creates a partial vacuum inside the crank-case below the piston, and the air/fuel mixture is drawn into the crank-case through the inlet port (I). The exhaust and transfer ports remain closed during the operation of the upward stroke and the charge which reached above the piston during the previous stroke is compressed.

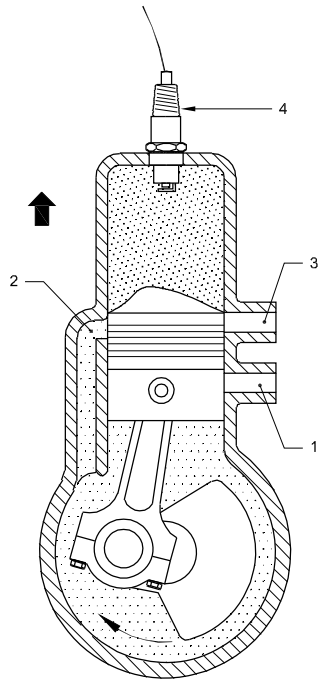
At the end of this stroke the mixture is ignited by an electric spark (4). This causes the pressure to rise.

**Second stroke (power and exhaust)**

The piston is forced downward from the TDC (Fig 2). During this stroke the exhaust port opens and burnt gases escape into the atmosphere.

Further downward movement of the piston opens the transfer port and allows the partially compressed mixture, received during the previous stroke, to reach the combustion chamber from the crankcase.

Fig 1

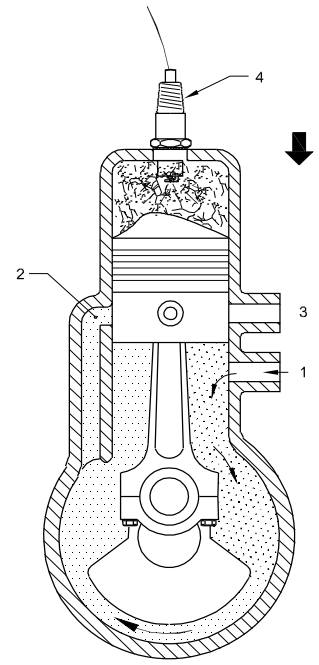



FIRST STROKE

The piston head has a special shape. It deflects a fresh change of fuel mixture up into the cylinder. The mixture flows down and pushes the burnt gas out. Through the exhaust port. This process is called scavenging. Once the flywheel has completed one revolution, the cycle is

repeated. In this engine one power stroke is obtained in each revolution of the crankshaft.

Fig 2

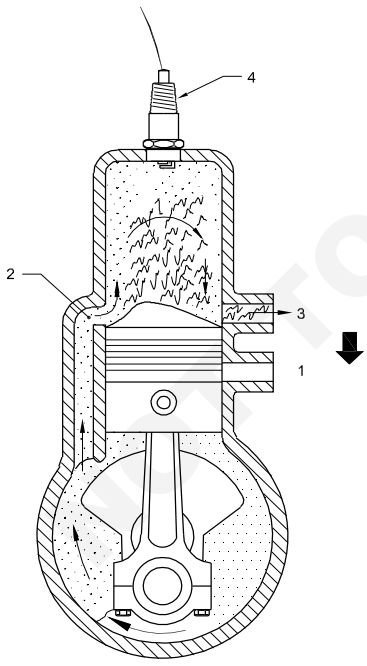



FIRST STROKE

MVN163732

**Spark ignition (Fig 3):** In a spark ignition (SI) engine, petrol is used as fuel. During the suction stroke the air and fuel mixture is sucked into the cylinder. The quantity of the mixture is metered by the carburettor according to the load and speed. The ratio of air/fuel mixture is also metered by the carburettor.

Fig 3




SECOND STROKE

MVN163733

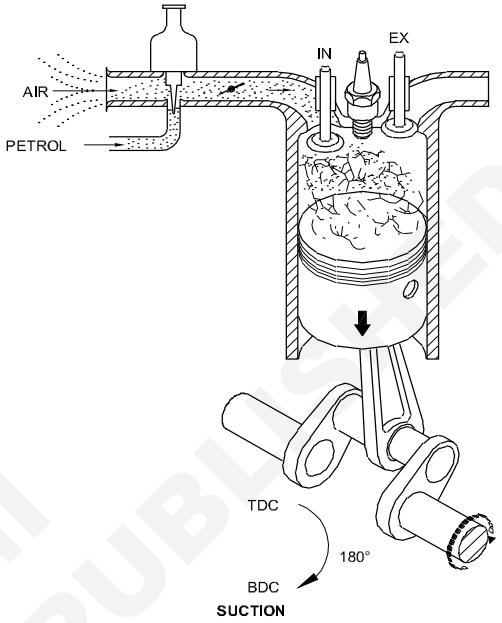
During the compression stroke, this air/fuel mixture is ignited by the spark and the mixture is burnt. It raises the pressure of the gas above the piston. The piston is forced down and this power is supplied to the flywheel. During the exhaust stroke burnt gases escape through the exhaust port/valve.

In this type of engine the compression ratio is low.

**Four-stroke spark ignition engine:** To produce power in a four-stroke engine the following operations take place in the sequence given below.

**Suction stroke:** The piston moves from TDC to BDC (Fig 4). A vacuum is created inside the cylinder. The inlet valve opens while the exhaust valve remains closed. The charge (air/air-fuel mixture) enters the cylinder.

Fig 4

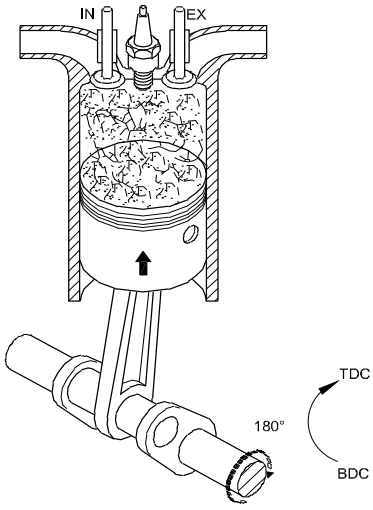



SUCTION STROKE

MVN163734

**Compression stroke:** The inlet valve closes. The exhaust valve remains closed. The piston moves from BDC to TDC (Fig 5). The charge (air/air-fuel mixture) is compressed. The pressure and temperature rise.

Fig 5

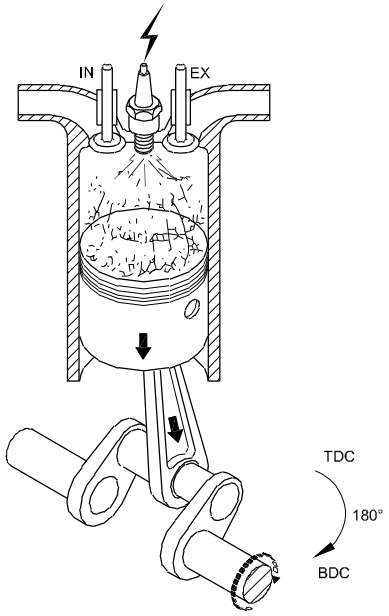



COMPRESSION STROKE

MVN163735

**Power stroke:** At the end of the compression the air fuel mixture is ignitial by means of a spark plug and the burning air fuel mixture expands and pressure develops inside the cylinder and the piston is forced down from TDC to BDC (Fig 6). Both the valves remain closed. Power is supplied to the flywheel.

Fig 6

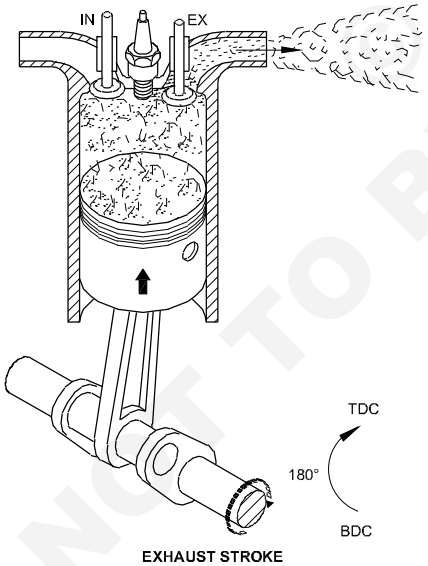



POWER STROKE

**Exhaust stroke:** The inlet valve remains in the closed position. The exhaust valve opens, the piston moves from BDC to TDC (Fig 7) due to the energy stored in the flywheel. The burnt gases inside the cylinder go out through the exhaust valves. At the end of the stroke the exhaust valve closes.

The cycle of suction, compression power and exhaust are repeated. In this type of engines one power stroke is obtained in two revolutions of the crankshaft.

Fig 7




EXHAUST STROKE

**Otto Cycle**

1 - 2 - Suction

2 - 3 - Compression

3 - 4 - Heat addition

4 - 5 - Power

5 - 2 - 1 - Exhaust

In otto cycle engine, (Fig 8) combustion takes place at constant volume.

Suction takes place at a pressure below atmospheric pressure when piston moves from TDC to BDC. (1-2)

Compression takes place when piston moves from BDC to TDC. (2-3)

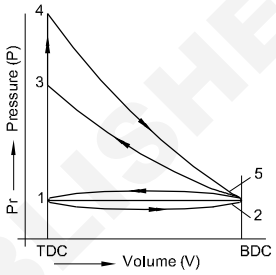
Fuel mixture is ignited by introducing a spark at constant volume. (3-4)

The gas expands during the power stroke (4-5), reducing both pressure and temperature.

Heat is rejected at constant volume. (5-2)

Burnt gases exhaust when piston moves from BDC to TDC. (2-1)

Fig 8




**Diesel Cycle**

1 - 2 - Suction

2 - 3 - Compression

3 - 4 - Heat addition

4 - 5 - Power

Suction takes place at (Fig 9) pressure below atmospheric pressure when piston moves from TDC to BDC. (1-2)

Compression takes place when piston moves BDC to TDC. (2-3) (Both the valves closed).

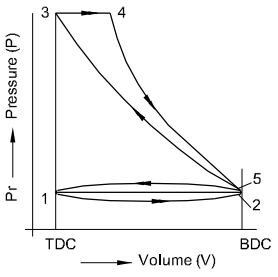
Fuel is sprayed at high pressure and ignited by hot compressed air (3-4), and this process takes place at constant pressure.

Fuel ignites, pressure of burnt gas increases, gas expands and piston is forced from TDC to BDC. (4-5)

Heat is rejected at constant volume. (5-2)

Burnt gases exhaust when piston moves from BDC to TDC. (2-1)

Fig 9



**Comparison between four-stroke engine and two-stroke engine**

| Four-stroke engine | Two-stroke engine |
|---|---|
| - Four operations (suction, compression, power and exhaust) take place in the four strokes of the piston. | - The four operations take place in two strokes of the piston. |
| - It gives one power stroke in two revolutions of the crankshaft. As such three strokes are idle strokes. | - The power stroke takes place in every two strokes i.e. one power stroke for one revolution of the crankshaft. |
| - Due to more idle strokes and non-uniform load on the crankshaft, a heavier flywheel is required. | - The engine has more uniform load as every time the piston comes down it is the power stroke. As such a lighter flywheel is used. |
| - The engine has more parts such as valves and its operating mechanism. Therefore, the engine is heavier. | - The engine has no valves and valve-operating mechanism therefore it is lighter in weight. |
| - The engine is costlier as it has more parts. | - The engine is less expensive as it has a lesser number of parts |
| - The engine efficiency is more as the charge gets completely burnt out. Consequently the fuel efficiency is more. | - The engine efficiency is less. A portion of the charge escapes through the exhaust port, and because of this, the fuel efficiency is less. |

**Comparison between S.I and C.I. Engine**

| SI engine | CI engine |
|---|---|
| Petrol is used as fuel. | Diesel is used as fuel. |
| During the suction stroke air and fuel mixture is sucked in the engine cylinder. (Example: MPFI engines) | During the suction stroke air alone is sucked in to the cylinder. |
| Compression ratio is low. (Max. 10:1) | Compression ratio is high. (Max. 24:1) |
| Compression pressure is low. (90 to 150 PSI) | Compression pressure is high. (400 to 550 PSI) |
| Compression temperature is low. | Compression temperature is high. |
| It operates under constant volume cycle (otto cycle). | It operates under constant pressure cycle (diesel cycle). |
| Fuel is ignited by electric spark. | Fuel is ignited due to the heat of the highly compressed air. Combustion takes place at constant pressure. |
| Spark plug is used | Injector is used. |
| A carburettor is used to atomize, vaporize and meter the correct amount of fuel according to the requirement. | Fuel injection pumps and atomizers are used to inject metered quantities of fuel at high pressure according to the requirement. |
| Less vibration, and hence, smooth running. | More vibration, and hence, rough running and more noisy. |
| Engine weight is less. | Engine weight is more. |
| No particulate matter present in emission. | Emits particulate matter. |

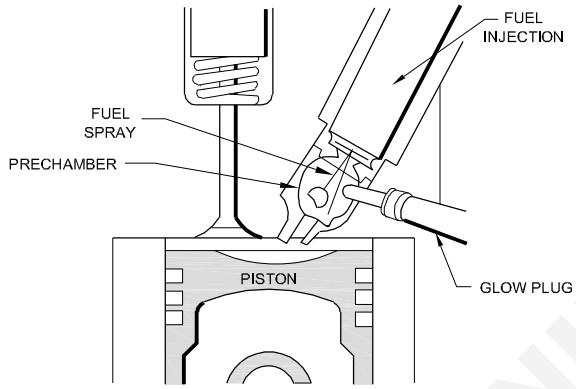
# Direct and indirect fuel injection system

**Objectives:** At the end of this lesson you shall be able to
- **state the function of direct fuel injection**
- **state the function of indirect fuel injection.**

### Direct Fuel Injection Works (Fig 1)

Gasoline engines work by sucking a mixture of gasoline and air into a cylinder, compressing it with a piston, and igniting it with a spark. The resulting explosion drives the piston downwards, producing power. Traditional indirect fuel injection systems pre-mix the gasoline and air in a chamber just outside the cylinder called the intake manifold. In a direct injection system, the air and gasoline are not pre-mixed. Rather, air comes in via the intake manifold, while the gasoline is injected directly into the cylinder.

Fig 1




DIRECT INJECTION

### Advantages of Direct Fuel Injection

Combined with ultra-precise computer management, direct injection allows more accurate control over fuel metering, which is the amount of fuel injected and injection timing, the exact point when the fuel is introduced into the cylinder. The location of the injector also allows for a more optimal spray pattern that breaks the gasoline up into smaller droplets. The result is a more complete combustion - in other words, more of the gasoline is burned, which translates to more power and less pollution from each drop of gasoline.

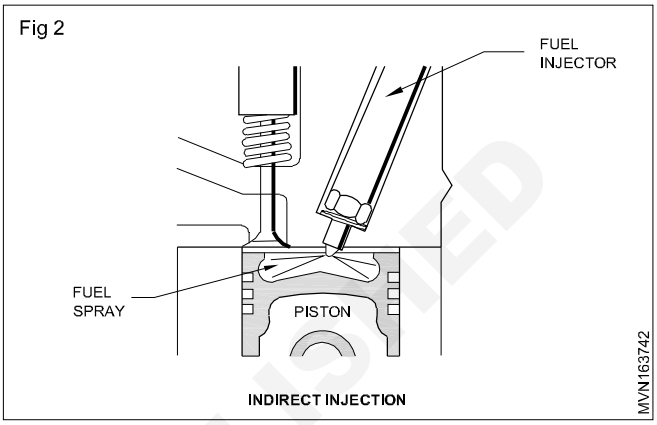
### Disadvantages of Direct Fuel Injection

The primary disadvantages of direct injection engines are complexity and cost. Direct injection systems are more expensive to build because their components must be more rugged. They handle fuel at significantly higher pressures than indirect injection systems and the injectors themselves must be able to withstand the heat and pressure of combustion inside the cylinder.

### Indirect injection (Fig 2)

Indirect injection in an internal combustion engine is fuel injection where fuel is not directly injected into the combustion chamber. In the last decade, gasoline engines equipped with indirect injection systems, wherein a fuel injector delivers the fuel at some point before the intake valve, have mostly fallen out of favor to direct injection. However, certain manufacturers such as Volkswagen and Toyota have developed a 'dual injection' system, combining direct injectors with port (indirect) injectors, combining the benefits of both types of fuel injection.

Fig 2




INDIRECT INJECTION

Direct injection allows the fuel to be precisely metered into the combustion chamber under high pressure which can lead to greater power, fuel efficiency. The issue with direct injection is that it typically leads to greater amounts of particulate matter and with the fuel no longer contacting the intake valves, carbon can accumulate on the intake valves over time.

Adding indirect injection keeps fuel spraying on the intake valves, reducing or eliminating the carbon accumulation on intake valves and in low load conditions, indirect injection allows for better fuel-air mixing. This system is mainly used in higher cost models due to the added expense and complexity.

Port injection refers to the spraying of the fuel onto the back of the intake port, which speeds up its evaporation.

An indirect injection diesel engine delivers fuel into a chamber off the combustion chamber, called a prechamber, where combustion begins and then spreads into the main combustion chamber. The prechamber is carefully designed to ensure adequate mixing of the atomized fuel with the compression-heated air.

### Classification of indirect combustion chambers

- Swirl chamber
- Precombustion chamber
- Air cell chamber

**Overview:** The purpose of the divided combustion chamber is to speed up the combustion process, in order to increase the power output by increasing engine speed.[2] The addition of a prechamber, however, increases heat loss to the cooling system and thereby lowers engine efficiency. The engine requires glow plugs for starting.

In an indirect injection system the air moves fast, mixing the fuel and air. This simplifies injector design and allows the use of smaller engines and less tightly toleranced designs which are simpler to manufacture and more reliable. Direct injection, by contrast, uses slow-moving air and fast-moving fuel; both the design and manufacture of the injectors is more difficult.

The optimisation of the in-cylinder air flow is much more difficult than designing a prechamber. There is much more integration between the design of the injector and the engine.[3] It is for this reason that car diesel engines were almost all indirect injection until the ready availability of powerful CFD simulation systems made the adoption of direct injection practical.

**Advantages of indirect injection combustion chambers**

- Smaller diesels can be produced.
- The injection pressure required is low, so the injector is cheaper to produce.
- The injection direction is of less importance.
- Indirect injection is much simpler to design and manufacture; less injector development is required and the injection pressures are low (1500 psi/100 bar versus 5000 psi/345 bar and higher for direct injection)
- The lower stresses that indirect injection imposes on internal components mean that it is possible to produce petrol and indirect injection diesel versions of the same basic engine. At best such types differ only in the cylinder head and the need to fit a distributor and spark plugs in the petrol version whilst fitting an injection pump and injectors to the diesel. Examples include the BMC A-Series and B-Series engines and the Land Rover 2.25/2.5-litre 4-cylinder types. Such designs allow petrol and diesel versions of the same vehicle to be built with minimal design changes between them.
- Higher engine speeds can be reached, since burning continues in the prechamber.

**Disadvantages**

- Fuel efficiency is lower than with direct injection because of heat loss due to large exposed areas and pressure loss due to air motion through the throats. This is somewhat offset due to indirect injection having a much higher compression ratio and typically having no emissions equipment.
- Glow plugs are needed for a cold engine start on diesel engines.
- Because the heat and pressure of combustion is applied to one specific point on the piston as it exits the precombustion chamber or swirl chamber, such engines are less suited to high specific power outputs (such as turbocharging or tuning) than direct injection diesels. The increased temperature and pressure on one part of the piston crown causes uneven expansion which can lead to cracking, distortion or other damage due to improper use; use of " starting fluid" (ether) is not recommended in glow plug, indirect injection systems, because explosive knock can occur, causing engine damage.

**Basic technical terms used in relation to engines**

**T.D.C. (Top dead centre):** It is the position of the piston at the top of a cylinder, where the piston changes its direction of motion from the top to the bottom.

**B.D.C. (Bottom dead centre):** It is the position of the piston at the bottom of the cylinder where the piston changes its direction of motion from the bottom to the top.

**Stroke:** The distance travelled by the piston from TDC to BDC or BDC to TDC.

**Cycle**

A set of operations performed in sequence by the motion of the piston in an engine to produce power.

**Swept volume** (VS)

Displacement volume of a piston between TDC x BDC.

**Clearance volume** (VC)

Volume of the space above the piston when it is at TDC.

**Compression ratio** (CR)

Ratio of compression volumes before the stroke and after.

$$CR = \frac{VS + VC}{VC}$$

where VS = Swept volume

VC = Clearance volume

VS+VC = Total volume at BDC.

**Power**

Power is the rate at which work is done in a specific time.

$$Power = \frac{(Force \times Distance\ moved)}{Time}$$

**Horsepower (HP):** It is the measurement of power in SAE. One hp is the power required to lift a load of 33000 lbs, through one foot in one minute or 4500 kg through one meter in one minute (in metric system)

**Thermal efficiency**

It is the ratio of work output to the fuel energy burnt in the engine. This relationship is expressed in percentage.

**Brake horsepower (BHP)**

It is the power output of an engine, available at the flywheel,

$$BHP = \frac{2\pi NT}{4500}$$

where N is r.p.m of the crankshaft, and T is the torque produced.

**Bore:** The diameter of engine cylinder is termed as bore.

**Indicated horsepower (IHP)**

It is the power developed in the engine cylinder.

$$IHP = \frac{PLAN}{4500} X K$$

Where Pm is the mean effective pressure in kg./cm².

L is length of stroke in metres

A is the area of the piston in cm²

N is the No. of power strokes per minute

K is the No. of cylinders.

**Frictional horsepower**

It is the horsepower lost in the engine due to friction.

FHP = IHP - BHP

**Mechanical efficiency**

It is the ratio of power delivered (BHP) and the power available in the engine (IHP). It is expressed in percentage

$$\text{Mechanical efficiency} = = \frac{BHP}{IHP} \times 100$$

**Volumetric efficiency:** It is the ratio between the air drawn in the cylinder during the suction stroke and the volume of the cylinder.

**Throw:** It is the distance between the centre of the crank pin to the centre of the main journal. The piston stroke is double the throw.

**Firing order:** The firing order is the sequence in which the power stroke takes place in each cylinder in a multi-cylinder engine.

- Technical Specification of an engine
- Engines are specified as per the following types.
- Number of cylinders
- Bore diameter
- Stroke length
- Capacity in cu.cm/cu.inch
- Maximum engine output at specified r.p.m.
- Maximum torque
- Compression ratio
- Firing order
- Idling speed
- Air cleaner (Type)
- Oil filter (Type)
- Fuel filter
- Fuel injection pump
- Weight of engine
- Cooling system (type)
- Type of fuel

**Technical specifications of vehicles**

**LPT - 1210 D**

**Specifications**

**Engine**

| | |
|---|---|
| Model | 6692 D.I. |
| Number of cylinders | 6 |
| Bore | 92mm |
| Stroke | 120mm |
| Capacity | 4788 cc |
| Gross H.P. (S.A.E.) | 125 at 2800 R.P.M. |
| Taxable H.P. | 31.5 |
| Maximum Torque | 30 mkg at 2000 R.P.M |
| Compression Ratio | 17 : 1 |
| Compression pressure at 150-200 R.P.M. | Minimum 20 kg/cm² |
| Fuel injection begins | 23° before T.D.C. |
| Firing order | 1-5-3-6-2-4 |
| Opening pressure of the injection nozzles | 200 + 10kg/cm² Newnozzels<br>Min. 180 kg/cm² Used nozzels |
| Maximum variation permissible in injection: nozzle pressure | 5 kg/cm² |
| Inlet valve clearance | 0.20 mm |
| Exhaust valve clearance | 0.30 mm |
| Air cleaner | oil bath |
| Total bearing area per bearing | 55 sq.cm |
| No.of main bearings | 7 |
| Fuel injection pump | MICOBOSCH |
| Weight (Dry) | 382 kg |
| Capacity of cooling system | 20 litres |
| Crankcase oil capacity | Maximum - 14 litres<br>Minimum - 10 litres |
| Cooling water temperature | 75°C - 95°C |

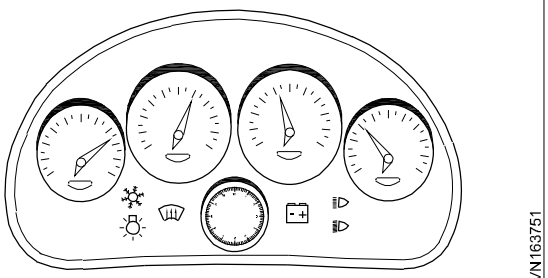
Depth max : 223 mm $\left(8\frac{3}{4}''\right)$

# Dashboard gauges, meters and warnings lights

**Objectives:** At the end of this lesson you shall be able to
- **state different type of meters and their uses**
- **describe the purpose of each warning lights**
- **specify the purpose of each gauges.**

**Odometer:** An odometer (Fig 1) is an instrument that indicate distance travelled by a vehicle, such as motor cycle and motor vehicle Automotive. The device may be electronic, mechanical, or a combination of both. It is also called as trip meter in case of short trips of every ride. The distance mentioned in the odometer generally in kms.

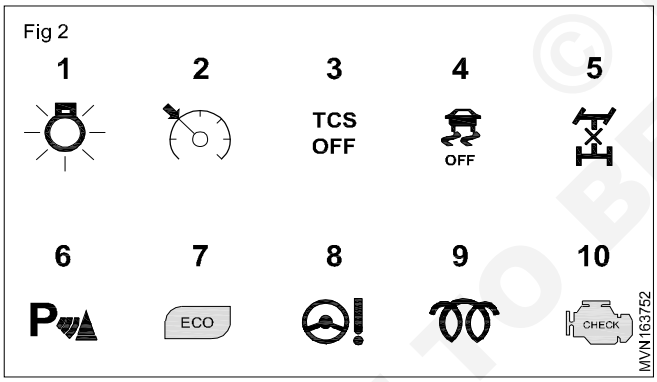
Fig 1




**Speedometer:** A speedometer or a speed meter is a gauge that measures and displays the instantaneous speed of a vehicle. The unit in which the display shown is in Km/hr. There are both analog and digital meters are available now a days.

**Engine RPM meter:** An engine rpm meter (Fig 2) is used to display the engine rotation in revolution per minute.

Fig 2




1 **Bulb indicator :** This shows you that you have a dead bulb. Not all cars have this, but it's a helpful warning.

2 **Cruise control indicator :** This indicator is used to display the accelerator opening level to maintain the set speed. This reminds you that cruise control is on.

3 **Traction control indicator:** This tells you the traction control is off. A blinking traction-control light indicates that the system is preventing wheel spin. In which case you should either; let off the gas a bit and drive a little slower; or let off the gas a bit and drive much slower.

4 **Stability control indicator:** This indicates that the stability control has been turned off. There's not much reason to turn it off on the road, and some cars can be dangerous in the wet without it. A blinking light indicates that the stability control system is actively preventing loss of control. If this happens, pay attention and stop trying to drive like an idiot.

5 **Centre differential lock (or 4Hi/Lo):** This indicates that the center differential on or car with part-time four-wheel drive has been engaged. We can't stress this enough; Part time all-wheel drive is not meant for on-road use, and running it on dry tarmac can cause "binding" and other problems. We've heard sob stories from dealerships where customers had to pay for costly repairs because the later didn't realize this.

6 **Proximity sensor indicator:** Some cars have proximity sensors all around instead of just the rear bumper. This helps you park your big, cumbersome vehicle in tight parking spots. It also makes for incessant buzzing as motorcyclists and pedestrians filter around you in traffic. Recognizing whether it's on or off can help prevent a nasty scrape.

7 **Econ indicator:** This can mean different things on different cars. Some cars use it to tell you that economy mode is engaged, which means that the accelerator and the transmission are in their most relaxed mode. On some cars with cylinder deactivation, this tells you that the system is turned on (typically when you're cruising or coasting), and half your cylinders are not burning gas at the moment. On other cars, this lights up when you are driving in an "economical" manner, and it can be used as a training tool for good, efficient driving. Other cars use color-changing dash lights for the same purpose. They're educational, helpful and rather cool.

8 **Electric power steering indicator:** This indicates a fault in the EPS system. It could mean temporary overheating of the assist motor or a major fault in the system. Electric steering motors are usually compact, and violent sawing at the wheel can sometimes overtax them. This can happen when you're doing a 30-point turn in a tight garage, or when you're banging comes on a tight autocross. Best let things cool down and see if the problem goes away; otherwise, it's time for a checkup.

9 **Glow plug indicator:** Lacking spark plugs, diesels rely on pressure and heat to burn their fuel. As there's little heat in the combustion champer when you first start it in the morning, glow plugs heat up the fuel coming out of the injectors to give the engine a better chance of starting. The light should turn on briefly after you switch the ignition to the 'on' position. Once it's off, the plugs are hot enough to start the car. A flashing light may indicate busted plugs, but some cars use the glow plug light as a catch-all indicator for problems

ranging from bad injectors to exhaust gas recirculation valve issues. Get it checked as soon as possible.

10 **Check engine light:** It can signal any number of issues or faults with the sensors and electronic equipment on the engine, some of which are serious, some of which are not. The most common cause is a busted exhaust oxygen sensor, which is bad for emissions but won't prevent your car from running. Other common causes include ignition coil and spark plug problems on gasoline cars, or an issue with any of the dozen-odd sensors that keep your engine happy. Even if you think it's nothing serious, don't ignore it. Have your car subjected to a diagnostic scan as soon as possible.

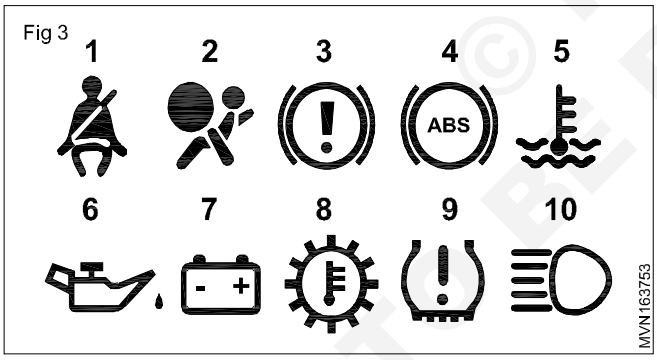
**Panel board indicator lights**

1 **Seatbelt indicator:** This indicates that the driver is not wearing the seatbelt. On newer vehicles, weight sensors in the seat tell the car if someone is sitting there, and warnings will appear for passengers, too. If the driver or passengers remain unbelted, a warning chime will sound. Don't ignore it. Studies show that seatbelt use reduces the chance of injury in a crash by 50%. Worse yet, being hit by an air bag with out your seat belt on can be fatal.

2 **Airbag indictor:** This signals a malfunction with the airbags or air bag sensor. This means that they may not go off in a crash.

3 **Brake indicator:** This signals light indicate such as several things. (Fig 3)

Fig 3




a Vehicle parking brake is engaged, so disengage it;

b The parking brake sensor is out of alignment, so have align and fixed it properly.

c The brake fluid level is low

d The hydraulic pressure between the two braking circuits are mismatched. The last two are potentially dangerous, and could mean a possible fluid leak, as well as reduced or even completely absent braking performance.

Don't wait for the light to go off; check your fluid every morning before you go out, because sometimes the warning light comes on too late. Some newer cars also have a brake pad warning light that goes off if the pads need to be replaced.

4 **ABS indicator:** Some cars have a separate ABS light that signals a problem with the ABS system. If this goes off, that means that the Antilock Braking System has malfunctioned and the brakes may lock up under hard braking. Bring the car in for servicing immediately.

5 **Temperature warning:** Some older cars with temperature gauges merely have a red light, but many modern cars have this symbol. This indicates that your engine is overheating or is about to overheat. Best to pull over immediately to cool down, to avoid potentially expensive engine repair bills.

6 **Oil level/Pressure warning:** There's no genie in this lamp. Just the magic slippery stuff that keeps your engine lubricated. This typically signals your oil level is low by about two liters. No lasting damage should occur if you top off the oil the moment you see this warning. But if you ignore it, your engine could end up looking like a frying pen that's been left on the burner for a few hours. Not a pretty sight and a new engine is much more expensive than a new frying pan.

7 **Electrical system warning:** This one looks like a battery, which means battery problems. It could also mean alternator problems, so simply buying a new battery may not be enough. Thankfully, many shops can test the alternator's charging capacity when you go in for a battery replacement.

8 **Transmission warning light:** This comes in many different forms, and can indicate a malfunction with the transmission itself, the gearshift or transmission fluid overheating. You most often see this on trucks when you're hauling heavy loads, or in high performance cars with automatic transmission if you drive them a little too hard. Needless to say, pulling over to let the transmission cool down is a good idea.

9 **Tyre pressure monitoring system:** This indicates either an issue with the TPMS itself or low pressure in one of your tires. Check immediately, Low pressure carry increased risk of blowout on the highway due to tire overheating. Not to mention the danger of hydroplaning in the rain, as wider tires slide over the water more easily than narrower one.

10 **High beam indicator:** While not a warning light perse, this bright-icon represents a big danger to other motorists, and it is one of the most ignored indicators in the Philippines. Leaving your high beams on will blind other motorists and can lead to nasty accidents. Remember to turn them off when there's oncoming traffic or when driving behind another car.

You don't need to see the road 2km ahead when you can simply follow the other guy ahead of you.

You don't need to be a "car whisperer" to know something's wrong when your dashboard lights up like a Christmas tree. But knowing what these lights denote can mean the difference between a quick fix and a long walk home.

# Gauges used in Automotives

**Objectives:** At the end of this lesson you shall be able to
- **explain the location of various gauges in a vehicle**
- **explain the purpose of a fuel gauge**
- **explain the working of a fuel gauge**
- **explain the purpose of a temperature gauge**
- **explain the working of a temperature gauge**
- **explain the purpose of an oil pressure gauge**
- **explain the working of an oil pressure gauge.**

The gauges indicate to the driver the working of the particular system to which they are connected. These gauges are located on the dashboard of the vehicle.

Some of the electrically operated gauges are the following.

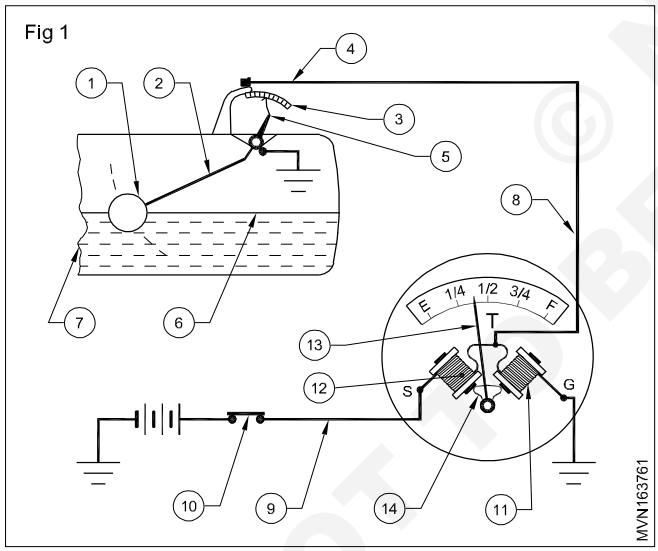
- Fuel gauge (Balancing coil type)
- Temperature gauge (Balancing coil type)
- Oil pressure gauge (Balancing coil type)

**Fuel gauge**

**Purpose:** It is used to know the quantity of fuel available in the fuel tank.

**Tank unit:** It consists of a tank unit and the indicator unit (Fig 1). The two units are connected in series by a single wire to the battery through the Ignition switch. When the ignition switch is turned on, current passes through both the units.

Fig 1




The tank unit is fitted on the fuel tank and the indicator unit on the dashboard. The tank unit consists of a hinged arm with a float fitted at one end and a sliding contact at the other end and also a variable resistance. The sliding contact moves along the resistance. The float arm moves up and down as the level of fuel in the tank changes. The movement of the float arm changes the electrical resistance in the circuit.

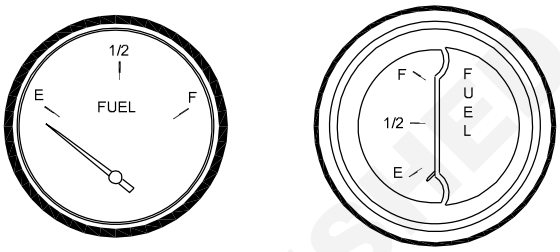
**Gauge unit (Dash unit)**

It is fitted on the panel board.

Two terminals (8) & (9) are connected to the tank unit's terminal (4) and ignition switch (10) respectively.

It consists of two coils (11) & (12) and a pointer (13) with the magnet (14) attached to it.

Fig 2




FUEL GAUGES

**Working:** When the ignition switch (10) (Fig 2) is on, current from the battery flows to the coils and a magnetic field is produced. When the tank (7) is full, the float (1) raises above and moves the sliding contact (5) to the high resistance position on the resistance coil (3). The current flowing through the coil (12) also flows through the coil (11). The magnetism of the coil (12) becomes weaker.

The magnetism of the coil (11) thus becomes stronger and pulls the armature (14) and the pointer (13) to the full side of the dial. When the fuel level (6) comes down the float in the tank falls down and resistance also becomes less, thereby strengthening the magnetic field around coil (12) and forcing the armature and pointer towards the empty side of the dial.

**Temperature gauge**

**Purpose:** It is used to know the temperature of water in the cooling system of engine at all times. It cautions the driver against overheating of the engine.

- It consists of an engine unit (1) immersed in the engine coolant in the cylinder head or cylinder block in the form of a pellet. (Fig 3)
- It is made of special material whose electrical resistance increases when temperature is lowered and it reduces when the temperature is increased.
- The resistance unit is provided with the dash unit (2) and it is fitted on the panel board.
- The dash unit consists of a dial (3) pointer (4), a magnet (5) and coil (6) and (7). (Fig 4)
- The two terminals of gauge are connected to the ignition switch (8) and the engine unit (1). The operating current is supplied from the battery through the ignition switch.

Fig 3

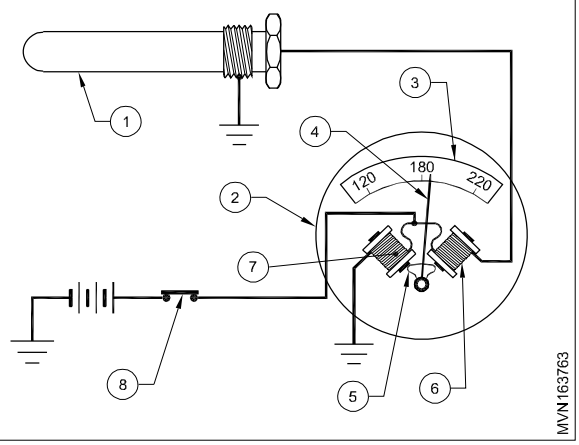
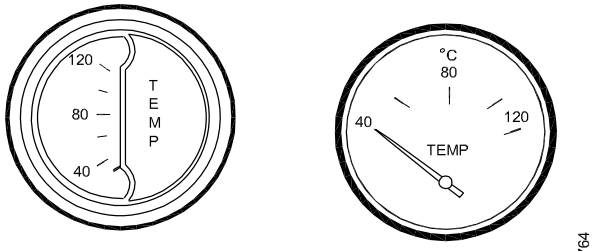



Fig 4




TEMPERATURE GAUGES

**Working:** When the coolant temperature rises, the engine unit becomes hot. When the engine unit temperature is high the resistance is less and more current passes to the right coil of the indicating units.

The difference in the strength of the magnetic field between the two coils increases and the armature and pointer move towards the right to indicate a high temperature.

When the engine coolant temperature falls down, the resistance becomes high. This results in less current flowing through the left coil, and the magnetic field becomes less and causes the armature and pointer to move towards the left to indicate lower temperature.

### Oil pressure gauge

**Purpose:** This device is used to know the pressure of lubricating oil during the working of the engine and serves as a warning signal to the driver against any sudden failure of the lubrication system.

### Types

- Bourdon tube type gauge (non-electric)
- Balancing coil type (electric)

The Bourdon tube gauge is not widely used nowadays, as it has certain drawbacks i.e. the connecting tube leaks at joints.

In modern vehicles balancing coil type (electric) oil pressure gauges are used.

**Working:** It consists of two units (i.e) engine unit and the dash unit. (Fig 5 & 6)

The engine unit consists of a diaphragm, sliding contact, variable resistance.

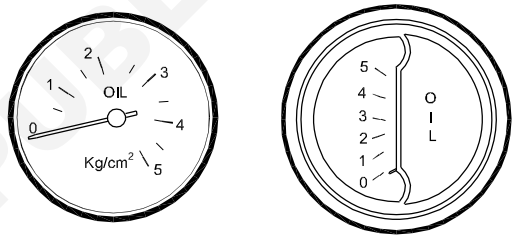
The dash unit consists of two coils (11) & (12) and a pointer (13) with a magnet (14) attached to it. Both coils are connected in series with battery through ignition switch.

The increase in oil pressure pushes the diaphragm outward. This action results in increase in the resistance at the engine unit.

The right hand coil of the dash unit becomes magnetically stronger than the left hand coil.

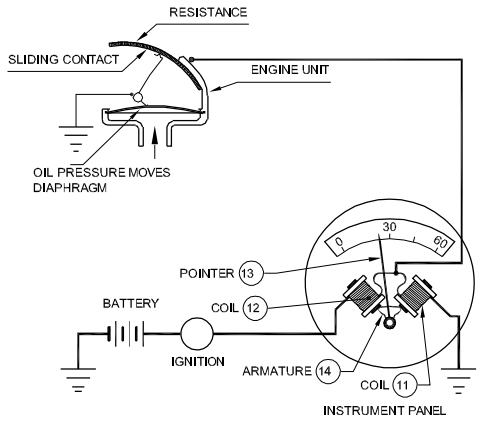
Consequently the armature and the pointer swing towards the right side in indicate higher oil pressure.

Fig 5




OIL PRESSURE GAUGES

Fig 6




SCHEMATIC WIRING CIRCUIT OF A BALANCING-COIL OIL-PRESSURE INDICATING SYSTEM.

## Starting and stopping methods of engine

**Objectives:** At the end of this lesson you shall be able to
- **list out different types of engine cranking methods**
- **explain the different types of starting methods of diesel engine**
- **explain method of stopping the diesel engines.**

For starting the engine the following different methods are used.

1 Hand cranking

2 Electric Motor cranking

3 Hydraulic cranking motors

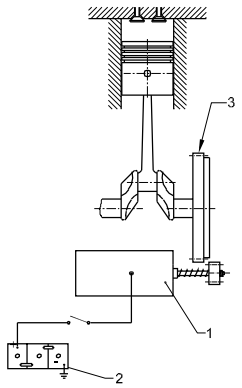
4 Compressed air cranking

5 Gasoline engine starting

**Hand cranking:** Usually small diesel engines are being started using crank handle or rope.

**Electric motor cranking:** In this system a starter motor (1) is used to rotate flywheel (3) of the engine. A battery (2) is used to supply power to the starter motor. (Fig 1)

Fig 1




**Hydraulic cranking motors:** In this system hydraulic fluid under pressures passes through hydraulic starter motor (1) to rotate the engine flywheel. A hand pump (2) or an engine driven pump (3) is provided to create and develop pressure of fluid. This fluid under pressure accumulates in the accumulator (4). After pressing the starting lever, control valve (5) allows the hydraulic fluid under pressure to pass through the hydraulic starter motor. (Fig 2)

**Compressed air cranking:** In this method compressed air from the reservoir (1) is admitted through an automatic starting valve in the engine cylinder head when the piston is at the top dead centre at the beginning of the power stroke, at a pressure capable of cranking the engine (2). When the engine is turning fast enough, the injected fuel ignites and the engine runs on its own power, whereupon the air supply is cut off. An air compressor (3) is used to create air pressure. Air compressor (3) is driven by the engine or electric motor (4). (Fig 3)

**Gasoline engine starting:** This is used to start the heavy duty earth moving engines. Starting of the gasoline engine is done either by hand cranking or by an electric motor. The gasoline engine then cranks the heavy engine.

Generally diesel engines are stopped by cutting the fuel supply after reducing the engine speed to the minimum level.

Fig 2

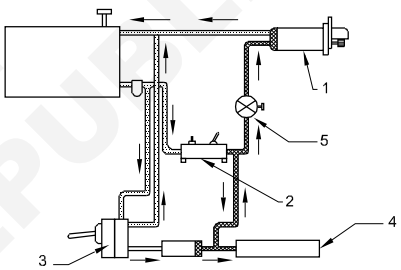
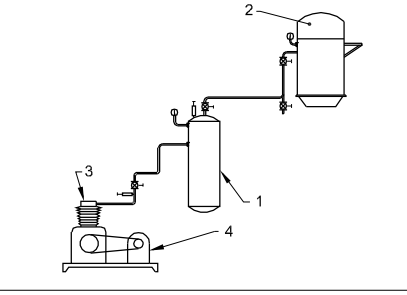



Fig 3




## Procedure for dismantling of diesel engine from the vehicle

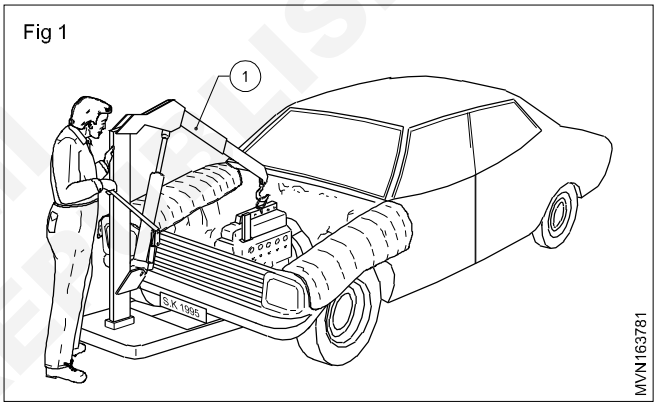
**Objective:** At the end of this lesson you shall be able to
- **remove the engine from the vehicle.**

**Remove the engine from the vehicle**

- Park the vehicle on a level surface.
- Choke all the four wheels with wooden blocks.
- Unscrew the bonnet mountings and remove it along with the grill.
- Disconnect the battery connections and take out the battery.
- Drain the radiator.
- Drain the engine oil.
- Remove the air cleaner.
- Remove the lower and upper hoses of the radiator.
- Remove the radiator mounting bolts/bracket bolts and remove the radiator without damaging the radiator core.

- Disconnect the wire connections of the starting motor, generator/alternator and heater plugs, oil pressure unit and other electrical connections to the dashboard instruments.
- Remove the oil pipe to oil pressure gauge connections (if provided).
- Remove the exhaust pipe from the exhaust manifold. (The pipe hole to be covered by a cardboard to prevent foreign material getting into it)
- Disconnect the fuel supply pipes at the feed pump, filter connections, fuel return lines to the tank.
- Disconnect the oil pressure and air pressure gauge connections.
- Disconnect the temperature gauge connections.
- Disconnect the accelerator connections.
- Remove the accelerator control shaft.
- Disconnect the engine stop connections.
- Remove the air compressor and its connections.
- Remove the clutch and gear linkages.
- Disconnect the propeller shaft at the gearbox end and support it at a convenient point on the chassis.
- Support the engine at the rear by wooden blocks.
- Disconnect gearbox mounting bolts and remove the gearbox with flywheel housing.
- Remove the dip stick.
- Fit a suitable engine lifting bracket.
- Align the left hook of the crane with engine lifting bracket.
- Support the engine at the front with wooden blocks.
- Remove the engine's mounting brackets and bolts and nuts.
- Attach the engine lifting bracket to the engine hoist (1). Fig 1
- Lift the engine slightly.
- Pull the engine forward until it comes out from the gearbox side.
- Lift the engine. Avoid oscillations and jerks. Ensure that the engine hoist does not shift/oscillate while removing it from the vehicle and does not hit the body of the vehicle or any accessories.
- Place it on a suitable workbench/engine stand. If placed on the floor, provide sufficient support below the front and rear brackets so that the engine does not rest on the oil sump.

Fig 1




## Petrol engine basics

**Objectives:** At the end of this lesson you shall be able to
- **explain the characteristics of gasoline fuel**
- **state that engine power transfer**
- **state the engine components.**

**Gasoline fuel system:** The fuel system is made of the fuel tank, pump, filter and injectors or carburettor and it is responsible for delivering fuel to the engine as needed. Each fuel system components perform easy flow to achieve expected engine performance and reliability.

**Fuel system injectors/ carburettor:** The fuel injector is a last stop for fuel inside the engine combustion chamber it is basically an electrically operated and injected fuel is enough to run the engine.

Carburators are used for mixing vaporized fuel with air to produce explosive mixture for internal combustion engines.

**Cam and camshaft**

Most of inline engine camshaft is mounted on lower part of cylinder block and modern engines camshaft is mounted on the cylinder head. Camshaft gets drive from crankshaft and it is operate the valves through operating mechanism.

**Engine power transfer:** Engine power is transferred through piston, connecting rod, crankshaft, fly wheel and then clutch, gearbox, universal joint, propeller shaft, final drive, differential to wheels. The vehicle wheels move the vehicle.

**Counter weights:** Counterweights are used for balancing the crank shaft of the engine. It helps to run the engine smoothly at higher RPM. The weight of the piston and connecting rod combination affects the size and placement of the counter weight.

**Piston components:** Piston is one of the most important parts in a reciprocating engine. Piston helps to convert the heat energy obtained by the combustion of fuel into mechanical energy piston is incorporated with piston rings piston pin, connecting rod and other components to achieve the high compression pressure inside of the cylinder.

**EFI air cleaner:** Air cleaner contains an air filter in a device composed of fibrous or porous materials which removes solid particulates such as dust, pollens and bacteria from air. Filters containing an absorbent (or) catalyst such a charcoal also remove odors and gaseous pollutants (Ex.volatile organic)

Airfilters are used in application where air quality is important, notability in building ventilation in engines. Air compressors tend to use either paper foam or cotton filters, oil bath filters have fallen out of favour. The technology of air intake filters of gas turbine has improvements in the I.C engines air filters). Air enters the engine through the air intake or air induction system. The grit and dust particles in this air must be removed before it enters the engines

**Gasoline fuel:** Gasoline is the hightest and most volatile liquid by refining the petroleum. The major characteristics of gasoline is as follows.

**Velocity:** Easy starting, quick warning, good economy smooth acceleration, freedom from vapour lock, freedom from crankcase dilution, volatility bend, indication of volatility. The more volatile of gasoline give more uniform its distribution to the various cylinders and the smoother operation of the engine.

**Purity:** The gasoline must be free from dirt, grease and trees of chemical and water.

Sulphur content: Too much sulphur is likely to corrode cylinder bores and bearing surfaces.

**Gum content:** Fuel gun content creates a number of operating difficulties such as carbon deposits, sticking valves and piston rings, clogged carburettor jet. Gasoline should have a minimum amount of gum.

**Antiknock quality:** The antiknock compound is able to slow down the combustion of fuel and so preventing the knocking.

**Calorific value:** Fuel must have a high calorific value.

**Operating economy**: The nature of the fuel is determines kilometres per litre of the fuel.

**Viscosity:** This is a physical property. This indicates the quality of fuel flow.

**Carburattor air cleaner:** The atmospheric air enters the air cleaner through the side passage and clean the dust particles. Fine particles are collected by the filter element and then cleaned air is passes via carburettor unit into the inlet manifold. Then air fuel mixture enter into the cylinder during suction stroke.

**Inlet manifold:** The inlet manifold is used to supply the air fuel mixture in carburettor system and fresh compressed air in EFI system to the intake ports in the cylinder head.

**Pressure and vacuum**

When an engine is idling there is a vacuum in the intake manifold. This vacuum pulls fuel and increases the effective pressure.

**Intake air heating:** Heating charge air an important measure to ensure reliable cold starting and to reduce white smoke and unburned hydrocarbon emissions. In take air heating can be provided in cylinder with glow plugs. In some engine glow plugs are provided in air intake system.

**Stoichiometeric ratio:** The stoichiometric ratio is the exact ratio between air and flammable gas or vapor at which complete combustion takes place. The stoichiometric ration of combustion verify from different types of fuels and oxidizers.

**Air density:** The density of air is mass per unit volume of earth's atmosphere. Air density like air pressure, decreases with increasing high attitude. It also changes with variation in atmospheric pressure, temperature and humidity.

**Electronic fuel injection (Fig 1)**

Engine is the heart of a car, then its brain must be the Engine Control Unit (ECU). Also known as a Powertrain Control Module (PCM), the ECU optimizes engine performance by using sensors to decide how to control certain actuators in an engine. A car's ECU is primarily responsible for four tasks. Firstly, the ECU controls the fuel mixture. Secondly, the ECU controls idle speed. Thirdly, the ECU is responsible for ignition timing. Lastly, in some applications, the ECU controls valve timing.

The electric fuel pump usually comes in an in-tank module that consists of a pump, a filter, and a sending unit. The sending unit uses a voltage divider to tell your gas gauge how much fuel you have left in your tank. The pump sends the gasoline through a fuel filter, through fuel lines, and into a fuel rail.

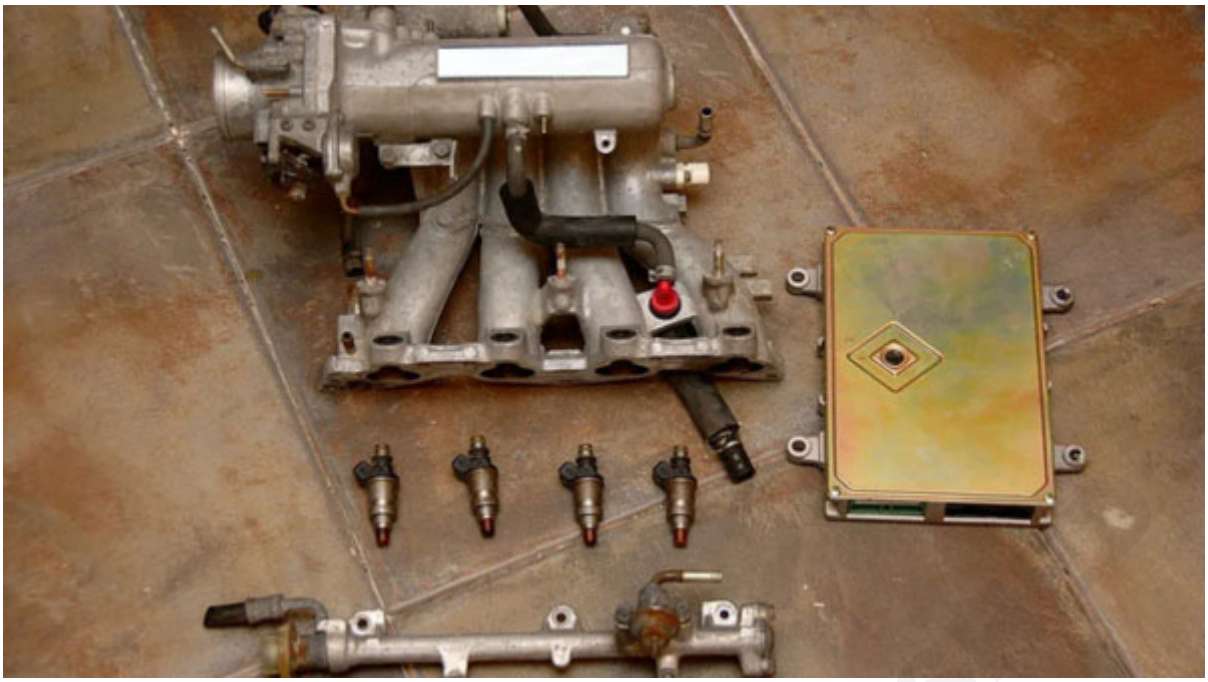
A vacuum-powered fuel pressure regulator at the end of the fuel rail ensures that the fuel pressure in the rail remains constant relative to the intake pressure. For a gasoline engine, fuel pressure is usually on the order of 35-50 psi. Fuel injectors connect to the rail, but their valves remain closed until the ECU decides to send fuel into the cylinders.

Usually, the injectors have two pins. One pin is connected to the battery through the ignition relay and the other pin goes to the ECU. The ECU sends a pulsing ground to the injector, which closes the circuit, providing the injector's solenoid with current. The magnet on top of the plunger is attracted to the solenoid's magnetic field, opening the valve. Since there is high pressure in the rail, opening the valve sends fuel at a high velocity through the injector's spray tip. The duration that the valve is open- and consequently the amount of fuel sent into the cylinder- depends on the pulse width (i.e. how long the ECU sends the ground signal to the injector).

When the plunger rises, it opens a valve and the injector (Fig 2) 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 multiport fuel injection and the latter is direct injection.

When a driver pushes his or her gas pedal, an accelerator pedal position sensor (APP) sends a signal to the ECU, which then commands the throttle to open. The ECU takes information from the throttle position sensor and APP until the throttle has reached the desired position set by the driver.

Fig 1



Either a mass air flow sensor (MAF) or a Manifold Absolute Pressure Sensor (MAP) determines how much air is entering the throttle body and sends the information to the ECU. The ECU uses the information to decide how much fuel to inject into the cylinders to keep the mixture stoichiometric.

The computer continually uses the TPS to check the throttle's position and the MAF or MAP sensor to check how much air is flowing through the intake in order to adjust the pulse sent to the injectors, ensuring that the appropriate amount of fuel gets injected into the incoming air. In addition, the ECU uses the o2 sensors to figure out how much oxygen is in the exhaust.

The oxygen content in the exhaust provides an indication of how well the fuel is burning. Between the MAF sensors and the 02 sensor, the computer fine-tunes the pulse that it sends to the injectors.

**Controlling idle:** Let's talk about idling. Most early fuel injected vehicles utilized a solenoid-based idle air control valve (IAC) to vary air flow into the engine during idle (see the white plug in the above image).

Controlled by the ECU, the IAC bypasses the throttle valve and allows the computer to ensure smooth idle when the driver does not activate the accelerator pedal. The IAC is similar to a fuel injector in that they both alter fluid flow via a solenoid actuated pin.

Most new cars don't have IAC valves. With older cable-controlled throttles, the air entering the engine during idle had to go around the throttle plate. Today, that's not that case, as Electronic Throttle Control systems allow the ECU to open and close the butterfly valve via a stepper motor.

The ECU monitors the rotational speed of the engine via a crankshaft position sensor, which is commonly a Hall Effect sensor or optical sensor that reads the rotational speed of the crank pulley, engine flywheel, or the crankshaft itself. The ECU sends fuel to the engine based upon how fast the crankshaft rotates, which is directly related to the load on the engine. Let's say you turn on your air conditioning or shift your vehicle into drive.

The speed of your crankshaft will decrease below the threshold speed set by the ECU due to the added load. The crankshaft position sensor will communicate this decreased engine speed to the ECU, which will then open the throttle more and send longer pulses to the injectors, adding more fuel to compensate for the increased engine load. This is the feedback control.

**When you initially turn on the vehicle, the ECU checks the engine temperature via a coolant temperature sensor. If it notices that the engine is cold, it sets a higher idle threshold to warm the engine up.**

The ECU's tasks of maintaining engine idle speed, as well as maintaining a proper air/fuel mixture, let's talk about ignition timing. To achieve optimum operation, the spark plug must be provided with current at very precise moments, usually about 10 to 40 crankshaft degrees prior to top dead center depending on engine speed.

The exact moment that the spark plug fires relative to the piston's position is optimized to facilitate the development of peak pressure. This allows the engine to recover a maximum amount of work from the expanding gas.

Modern vehicles don't use a centrally located ignition coil. Instead, these distributor less ignition systems (DIS) have a coil located on each individual spark plug. Based on input from the crankshaft position sensor, knock sensor, coolant temperature sensor, mass airflow sensor, throttle position sensor, and others, the ECU determines when to

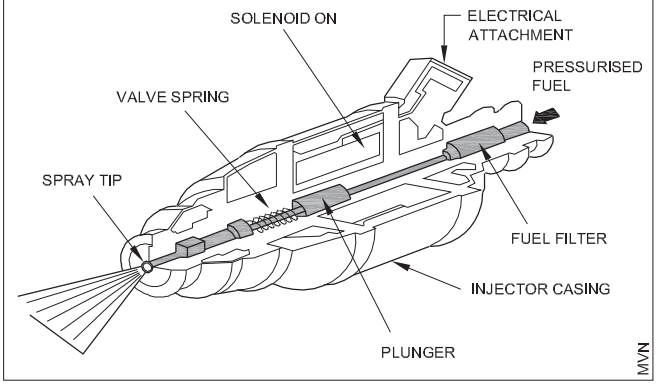
trigger a driver transistor, which then energizes the appropriate coil.

The ECU is able to monitor the piston's position via the crankshaft position sensor. The ECU continually receives information from the crankshaft position sensor and uses it to optimize spark timing. If the ECU receives information from the knock sensor (which is nothing more than a small microphone) that the engine has developed a knock (which is often caused by premature spark ignition), the ECU can retard ignition timing so as to alleviate the knock.

**Controlling Valve Timing**

The fourth major function of the ECU is to adjust valve timing. This applies to vehicles that utilize variable valve timing, which allows engines to achieve optimal efficiency at a multitude of engine speeds.

Fig 2




## Scavenging

**Objective:** At the end of this lesson you shall be able to
- **explain the process of scavenging in two stroke diesel engine.**

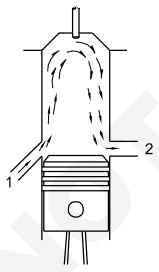
**Scavenging process:** The process of driving exhaust gases, out of the cylinder and replacing it with fresh air is called scavenging. In two-stroke diesel engines, all the four process take place in one revolution of the crank shaft or two strokes of the piston.

A series of ports or openings are arranged around the cylinder in such a position that openings are opened when the piston is at the bottom of the stroke. A blower (1) forces air into the cylinder through the opened ports exhaust valve (2) there by filling the cylinder with fresh air. This is called scavenging.

**Loop scavenging:** In this type, inlet (1) and exhaust (2) ports are provided on opposite sides of cylinder. Air entering the cylinder drives out burnt gases in the form of a loop.

Following types of scavenging methods are also used in two stroke engines, other that the one's described above.

Fig 1

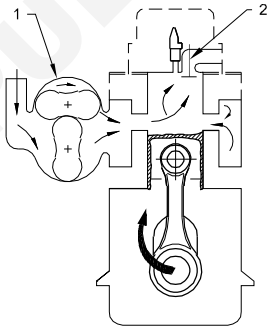



LOOP SCAVENGING

MVN163791

**Uniflow scavenging:** An exhaust valve (1) is provided on top of the cylinder. Air entering into the cylinder through the inlet port (2) drives out burnt gases flowing in the same direction.

Fig 2




SCAVENGING PROCESS

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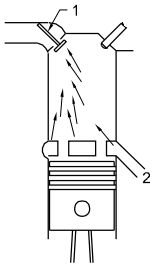
Fig 3




UNIFLOW SCAVENGE
G.M.DIESEL

MVN163793

# Description and constructional feature of cylinder head

**Objectives:** At the end of this lesson you shall be able to
- **state the constructional features of the cylinder head**
- **state the importance of cylinder head design.**

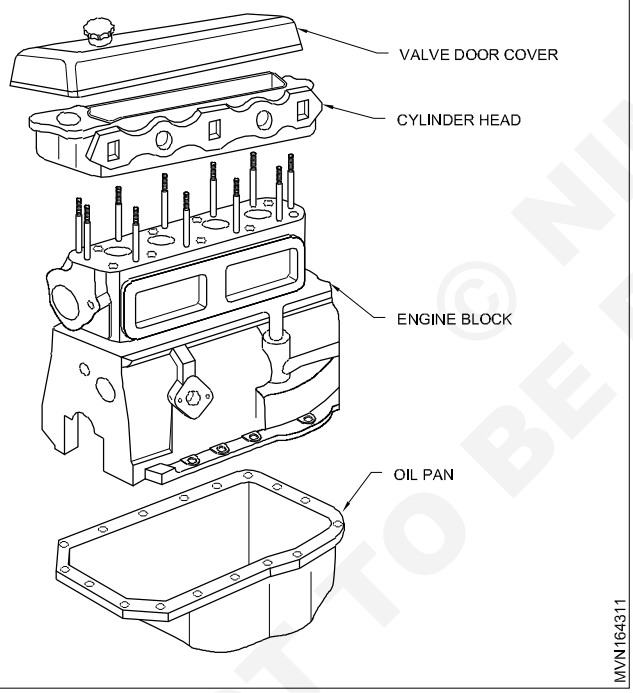
**Cylinder head (Fig 1):** The cylinder head is made of a single casting. It is bolted on the top of the cylinder block. It has passages for oil and water circulation. It accommodates valves, spark plugs/ injectors (in the case of diesel engines) and heater plug. A combustion chamber is also provided in some cylinder heads. In the case of the overhead valve system, the cylinder head supports the rocker shaft assembly.

The lower surface of the cylinder head is machined to the specified accuracy and a gasket is used in between the cylinder head and cylinder block to avoid leakage.

The head also provided spaces for the passages that feed air, water fuel to the cylinder and that allow the exhaust to escape.

Material: Cast iron, aluminium alloy.

Fig 1



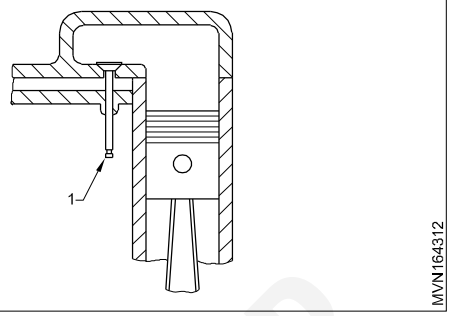

**Types of cylinder heads:** Four types of cylinder heads are used in an Automotive engine as per the valve arrangements.

They are as follows.

- 'L' head (Fig 2)
- 'I" head (Fig 3)
- 'F' head (Fig 4)
- 'T' head (Fig 5)

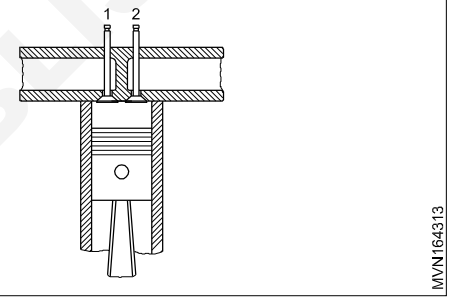
**'L' head:** In the 'L' head, the inlet and exhaust valves (1) are located on one side of the cylinder block and the valves are operated by a single camshaft through the tappet directly. (Eg. Dodge)

Fig 2




**'I' head:** In the 'I' head the inlet (1) and exhaust valves (2) are located on one side of the cylinder head. The valves are operated by a single camshaft through the tappet, push-rod and rocker arm mechanism. (Eg. Ambassador, Ashok Leyland).

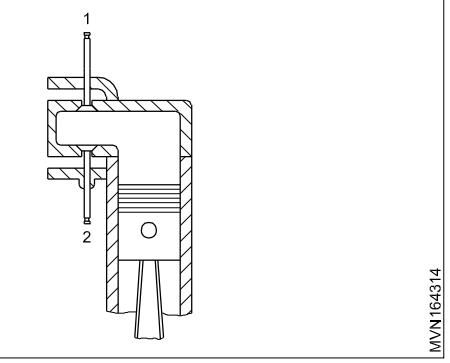
Fig 3




**'F' head:** In the 'F' head, the inlet valves (1) are located on one side of the cylinder head and the exhaust valves (2) are located on the other side of the cylinder block. The valves are operated by a single camshaft.

The inlet valves are operated by the tappet, push-road and rocker arm mechanism. The exhaust valves are operated by the tappet directly. (Eg.Mahindra & Mahindra jeep)

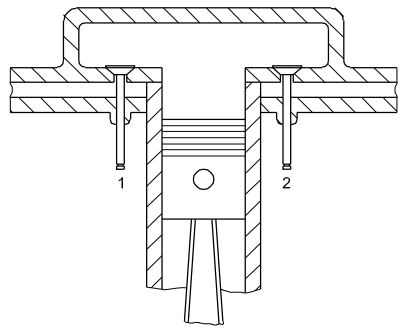
Fig 4




**'T' head:** In the 'T' head, inlet valves (1) are located on one side of the cylinder block and the exhaust valves (2) are located on the other side of the cylinder block. Two camshafts are used to operate the valves, one for inlet and the other for exhaust. The valves are operated by the tappet directly. (Eg. Ford)

In thick fuel is injected into the combustion chamber against height compressions pressure in the combustion chamber of the C.I. engine cylinder. The combustion depends upon the following factor.

Fig 5




- Fine atomization
- High temperature for quick ignition
- High relative velocity between air and fuel particles
- Good mixing of air and fuel particles.

Atomization, penetration and spreading of fuel depends on injection system, cylinder bore and stroke, compression ratio and cooling system is determine operating temperature. Fuel mixing depends upon air intake system, injection pattern and combustion chamber design.

**The design of combustion chamber plays an important part in the combustion process.** In diesel engines, the following types of combustion chambers have been used.

a Open combustion chambers (Fig 6)

b Turbulence chambers (Fig 7)

c Precombustion chamber (Fig 8)

d Air cells (Fig 9)

e Energy cells (Fig 10)

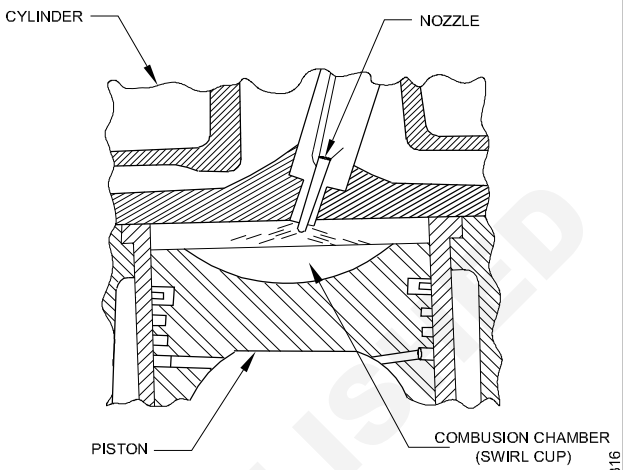
a **Open combustion chambers (Fig 6):** An open type of chamber is that in which all the air is contained in a single space at the time of injection. It is the simplest form of combustion chamber in which the injection nozzle sprays fuel direct into the combustion chamber. This arrangement is known as open system or direct injection system.

In this type of chamber, the fuel motion is greater than air upon which the nature of combustion largely depends. In order to bring fuel and air together, the flat head piston has been replaced by concave head piston in modern engines. The deep cut-out swirl cup on the piston crown is being widely used.

Open system combustion chambers are widely used in medium and large-bore engines operating at low and medium speeds.

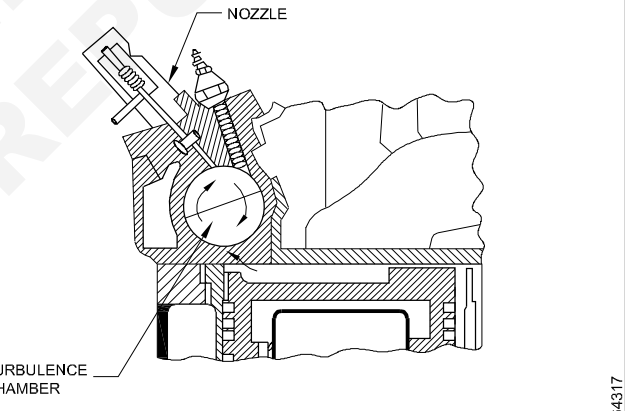
b **Turbulence chambers (Fig 7):** In this type of chamber, the fuel is injected into an auxiliary chamber known as turbulence chamber with the cylinder by an orifice. The auxiliary chamber houses almost full charge at the end of compression and is nearly spherical in shape. The piston forces air charge into the turbulence chamber and sets up a rapid rotary motion. As the piston rises up, the velocity of air increases through the throat of orifice and reaches at the peak some what before T.D.C. Near T.D.C. the injector nozzle injects fuel into the turbulent air currents which results in good mixing during combustion.

Fig 6




**OPEN COMBUSTION CHAMBER WITH SWIRL CUP**

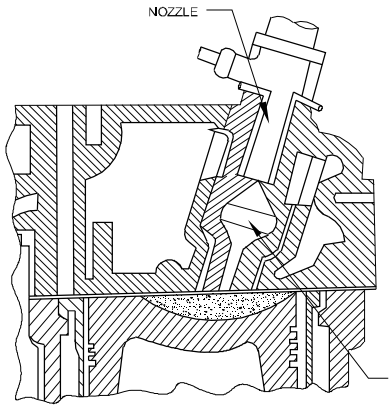
Fig 7




**TURBULENCE CHAMBER OF WAUKESHA DESIGN**

**C Precombustion chamber (Fig 8):** This chamber is located at the cylinder head and is connected to the engine cylinder by small holes. It occupies 40% of the total cylinder volume. During the compression stroke, air from the main cylinder enters the precombustion chamber. At this moment, fuel is injected into the precombustion chamber and combustion begins. Pressure increases and the fuel droplets are forced through the small holes into the main cylinder, resulting in a very good mix of the fuel and air. The bulk of the combustion actually takes place in the main cylinder. This type of combustion chamber has multi-fuel capability because the temperature of the prechamber vaporizes the fuel before the main combustion event occurs.

Fig 8

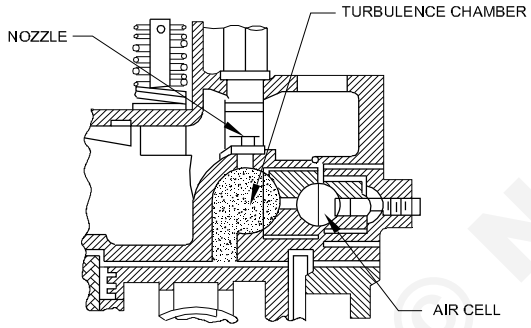



PRECOMBUSTION CHAMBER

MVN164318

**d Air cells (Fig 9):** Combustion chamber an air cell is a space provided in the cylinder head or piston crown in which a large part of air is trapped during compression. In air cell systems, the injector nozzle sprays fuel direct into the main chamber where combustion takes place.

Fig 9




AIR CELL

MVN164319

When the piston moves down on its working or power stroke, air pressure is at its maximum in the cell and pressure in the main combustion chamber starts to fall down. The higher pressure in the air cell causes its air to expand and blow out into the main chamber. Thus an additional turbulence is created and complete combustion of fuel charge is ensured.

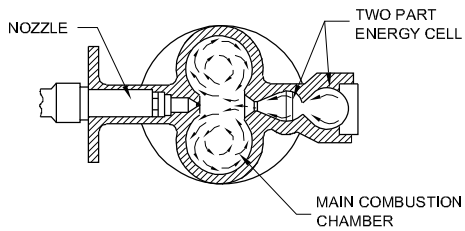
As a portion of air remains trapped without combustion in the cell so in improved designs, air cell is used in combination with turbulence or precombustion chamber to obtain better performance.

**e Energy cells (Fig 10):** The difference between air cell and energy cell is that fuel is blown into the energy cell where it burns using air in the cell. In air cell system, the cell simply stores and given up an air charge. The combustion in the energy cell creates a high pressure and grater turbulence and leaves no idle air in the cell.

The energy cell system consists of two rounded spaces cast in the cylinder head. The intake and exhaust valves open into the main combustion chamber. The horizontal the nozzle sprays fuel across the main chamber in the direction of energy cell mouth. While the fuel charge is passing across the centre of main chamber, near about half the fuel mixes with hot air and burns at once. The remaining fuel enters the energy cell and starts to burn there. At this point, the cell pressure rises rapidly, tending the combustion products to flow back into the main combustion chamber at a high velocity. As a result of this, a sharp swirling movement of fuel and air is set up in each lobe of main chamber, promoting final mixing of fuel and air and ensuring complete combustion. The two restricted openings of energy cell control the time and rate of expulsion of blast from energy cell into main combustion chamber.

The energy-cell combustion systems fulfil the requirements of high speed engines and give high power output without high excessive pressures in the main combustion chamber.

Fig 10




ENERGY CELL

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## Effect on size of intake and exhaust passages

**Objectives:** At the end of this lesson you shall be able to
- **state the effect and size of intake of exhaust passages**
- **importance of cylinder head gasket**
- **types of cylinder head gasket materials.**

**Inlet valve:** Is too larger than exhaust valve. Because they want to fill more quantity of Air/Fuel mixture (petrol) or Air (Diesel) in the combustion chamber to regulate the engine efficiency. Because engine efficiency depends upon Volumetric efficiency of an combustion chamber (Fig 1). There are two reasons behind the inlet valve larger than exhaust valve.

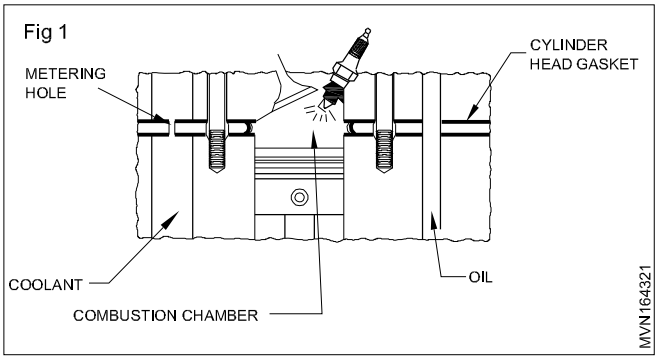
One main reason is to increase the volumetric efficiency of an engine. Another one is acting pressure behind the inlet valve. Exhaust gas pressure only react to the face portion of the valve. But in an inlet valve, the inlet air pressure are reacted to the behind /Rear portion the inlet valve face & larger face can withstand this pressure without any damage.

For that reason the inlet valve face is designed to larger size than exhaust valve.

The main reason for the size difference is to avoid preignition and knocking.

**Cylinder head gaskets:** It Form the most critical seal on an engine - between the cylinder head and the engine block deck. (Fig 1)

Fig 1




The head gasket must seal the combustion, pressures up to 1,000 psi (689.5 kPa) in gasoline engines and 2,700 psi (1,862 kPa) in turbocharged diesel engines. In addition, the head gasket must withstand combustion temperatures that are in excess of 2,000°F (1,100°C).

The head gasket also must seal coolant and hot, thin oil flowing under pressure between the block and head. Modern coolant formulas and oil detergents and additives tend to cling to surfaces and soak into gaskets. Gaskets materials must be chosen carefully to resist these fluids and maintain an effective seal. many head gasket coolant holes also meter the coolant flow to ensure proper circulation.

Head gaskets must resist the forces that tend to scuff gasket surfaces and inhibit proper sealing. One factor is engine vibration and head shifting and flexing that result from combustion pressures.

Another factor is the differing expansion rates of bi-metal (aluminum head and cast iron block) engines. Aluminum expands about twice as much as cast iron . The uneven expansion rates create a shearing action that the head gasket must accommodate.

Head gaskets also must resist crushing from cylinder claiming forces that may be unevenly distributed across the head. These claiming forces run as high 200,000 lbs (90,800 kg).

The following materials are used in cylinder head gasket

1 Copper - asbestos gasket

2 Steel - asbestos - copper gasket

3 Steel - asbestos gasket

4 Single steel ridged gasket

**Importance of turbulence**

Turbulent flow in an engine plays an important role in determining the combustion efficiency. It improves the thermal efficiency of engine, reduce the knocking, reduces NOX emission, oxidized carbon, hydrogen and other combustible elements. Turbulence ensure a thorough mixing of the air and fuel which ensures that fuel is quickly burnt and releasing the complete energy.

# Valves

**Objectives:** At the end of this lesson you shall be able to
- **describe the function of the valve**
- **state the constructional features of valves**
- **list out the different types of valves and their material.**

**Functions of valves**

- To open and close the inlet and exhaust passages of the cylinder.
- To dissipate heat, through its seat to the cylinder head.

**Construction of a valve:** The head (1) of the valve is ground with a margin (2) to provide strength. (Fig 1)

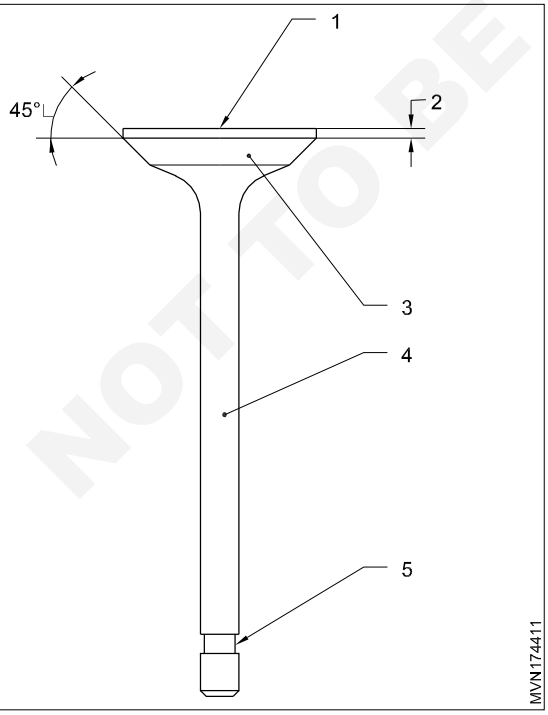
The valve face (3) is ground to 30° or 45° angle which matches with the seat angle to avoid leakage. The valve stem (4) is of a round shape. The length of the stem varies from engine to engine. At the end of the stem a groove (5) is provided to hold the spring lock.

In some heavy duty engines, the valves are hollow, and sodium is filled inside, which helps in the quick cooling of the valve.

**Types of valves**

- Poppet valves (Fig 1)
- Rotary valves (Fig 2)
- Sleeve valves (Fig 3)
- Reed valves (Fig 4)

Fig 1

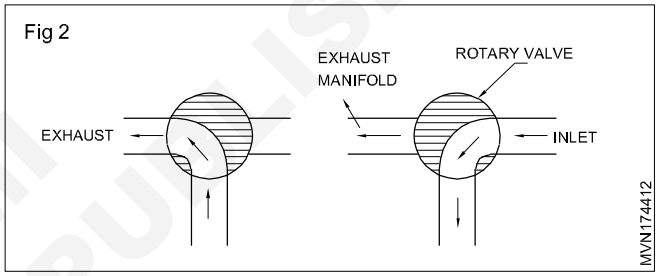



**Poppet-valves:** As the name indicates these valves pop on their seat. Three types of poppet-valves are in use.

- Standard valve
- Tulip valve
- Flat top valve

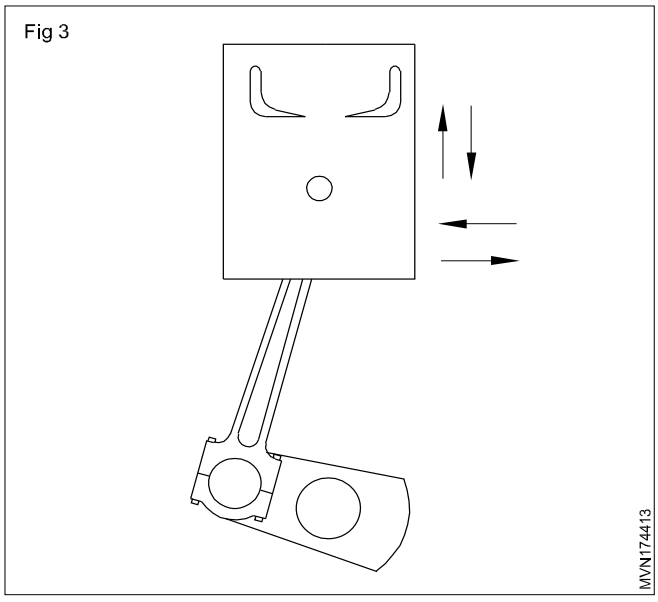
**Rotary valve (Fig 2):** In this type a hollow shaft runs in the housing which is attached to the cylinder head. This hollow shaft has two ports cut in it, and it aligns the opening in the cylinder head with the inlet manifold, and at the time of the exhaust stroke its opening aligns with the exhaust manifold. (Fig 2 & 3)

Fig 2



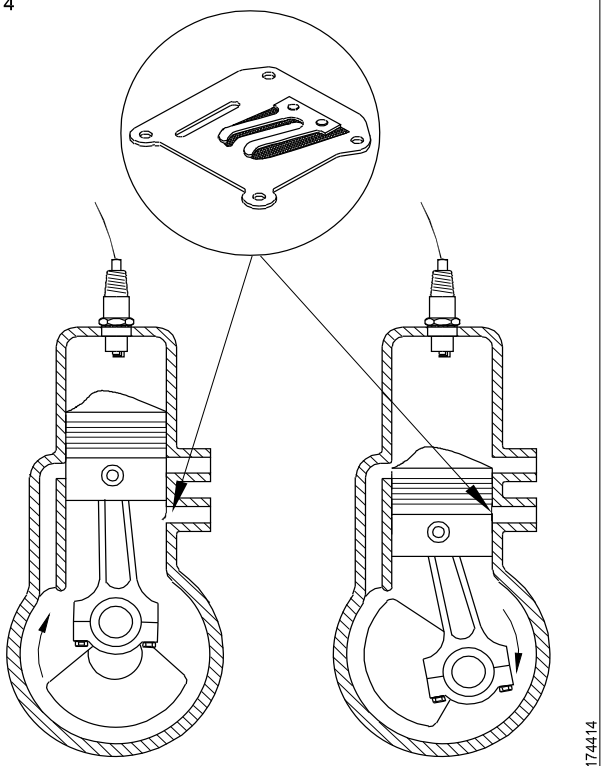

**Sleeve valve (Fig 3):** In this type, ports are cut in the cylinder liner. It runs with a slight up and down motion. It is also having rotary motion in another sleeve. This aligns with the inlet and exhaust ports at a set time when the inlet and exhaust manifold open.

Fig 3




**Reed valve (Fig 4):** It is a metallic strip hinged at one end. It covers the passages and allows air or charge to flow in one direction only. It is normally used in two-stroke engines and air compressors.

Fig 4




**Valve Materials**

Inlet valve - Nickel steel alloy stellite facing

Exhaust valve - Silicon - chrome alloy steel sodium filled valves

## Valve operating mechanism

**Objectives:** At the end of this lesson you shall be able to
- **state the requirements of valve operation**
- **state the types of valve operating mechanism**
- **list out the parts of the valve mechanism**
- **state the importance of valve seats**
- **method of valve seats inserts in cylinder heads.**

**Requirements for valve operation**

1 Valve must seat tightly and properly on its seat.

2 Valve must be properly timed.

3 Valve must be operate without log.

4 Valve tappet clearance must be correct.

5 Valve steam and guide clearance must be correct.

**Valve operating mechanisms:** Two types of value operating mechanisms are used in engines. They are as follows.

- Slide valve mechanism
- Overhead valve mechanism

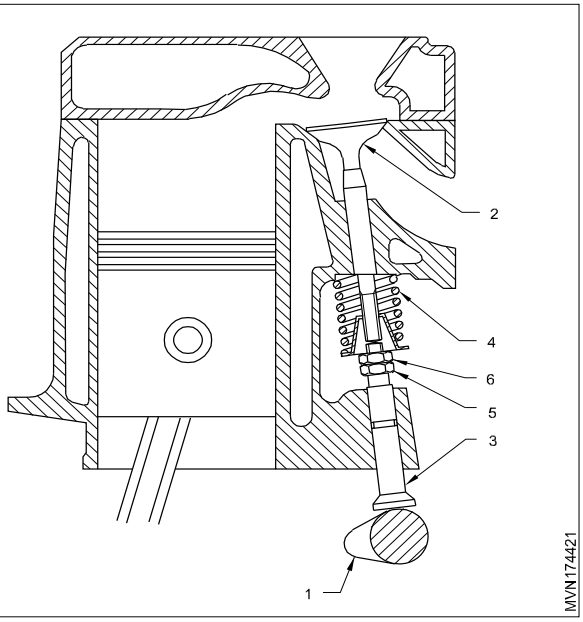
In overhead valve mechanism, the position of camshaft is considered as the types of valve mechanism i.e.,

1 Single overhead camshaft mechanism

2 Double overhead camshaft mechanism

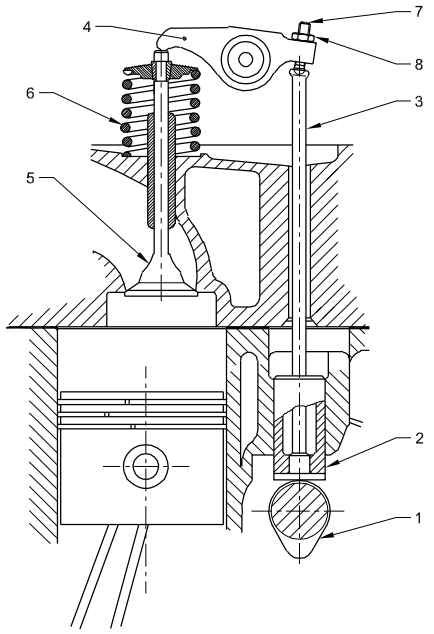
**Side valve mechanism (Fig 1):** In the side value mechanism both the inlet and exhaust valves are fitted in the cylinder block.

Fig 1




**Overhead valve mechanism (Fig 2):** In this mechanism, the valves are located in the cylinder head. Push-rods and rocker arms are used in addition to the side valve mechanism.

Fig 2




**Working**

When the cam shaft rotates, the cam lobe (1) lifts the tappet (2) upward. When the tappet (2) moves up, it pushes the push-rod (3) and one end of the rocker arm upwards. The other end of the rocker arm's (4) tip, moves downward and the valve (5) opens against the spring's (6) tension.

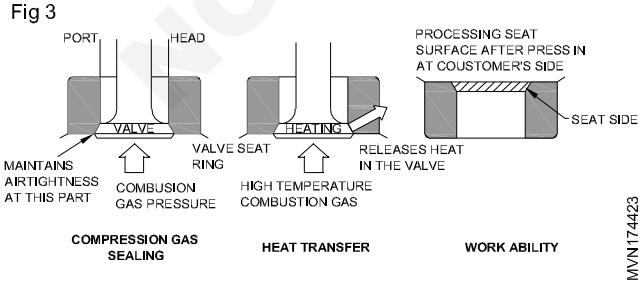
Wen the cam lobe (1) reaches the maximum height, the valve opens fully. Further rotation of the cam shaft causes the tappet (2) to move down and the valve is closed by the tension of the spring (6).

Tappet clearance is provided in between the valve (5) tip and the rocket arm's (4) tip. This clearance can be adjusted by the adjusting screw (7) and the lock-nut (8).

In many cases, even these rockers or followers (Fig 3) and their pivots are dispensed with and the valves are actuated directly by the camshaft through bucket type.

**Importance of valve seats (Fig 3):** Valve and valve seats are ground to correct and shape so that the valve may seat properly on the seat for effective valve seating and seating. The valve face angle must be match the valve seat angle. Value seating and sealing is closely related to the engine performance.

Fig 3




**Function of valve seats (Fig 4)**

1 Compression gas sealing prevents compressed gaseous bodies and combustion gas from leaking into the manifold.

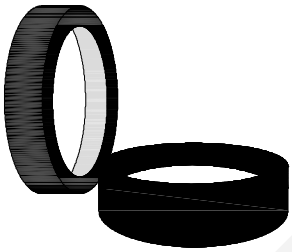
2 Heat transfer releases heat in the valve to the cylinder head.

3 Strength holds tight when the valve is mounted.

4 Wear-resistance hard to wear down under high heat and high load.

Importance of valve seats inserts in cylinder head

Fig 4




**Hydraulic tappet:** Hydraulic tappets (Fig 5) enable the valve gear to operate without fixed clearances. They consist of the tappet body, the tappet piston, a ball valve with spring and the clearance eliminating spring. When the engine is running, lubricating oil from the oil pump is forced through an oil way to the tappet. It flows through the outer chamber (to lubricate the tappet itself) and hence to the inner chamber (plunger lubrication) and to the interior of the piston. By way of a filling bore, the oil passes through the ball (check) valve to the pressure chamber.

The clearance eliminating spring (Fig 6) forces the tappet piston to prevent any valve clearance from occurring. When the camlifts the tappet, the ball valve closes and the oil-filling the pressure chamber acts as an almost rigid link. Thermal expansion of valve gear components is compensated for by precisely calculated oil loss as a result of tappet piston operating clearance. Although hydraulic tappets are heavier and therefore suffer from increased inertia, this drawback can be compensated for an engines which operate the valves by followers from the overhead camshaft. On these engines, the hydraulic clearance adjuster an be installed in the follower mount instead of in the tappet; it is of similar design to the hydraulic tappet just described.

Fig 5

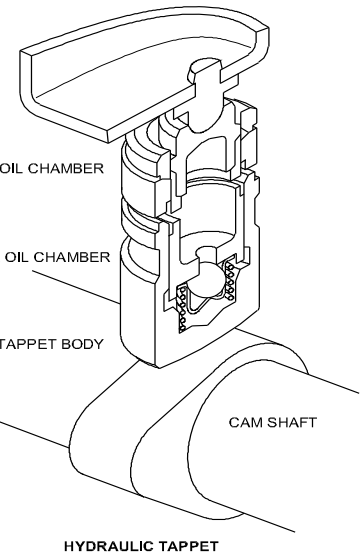
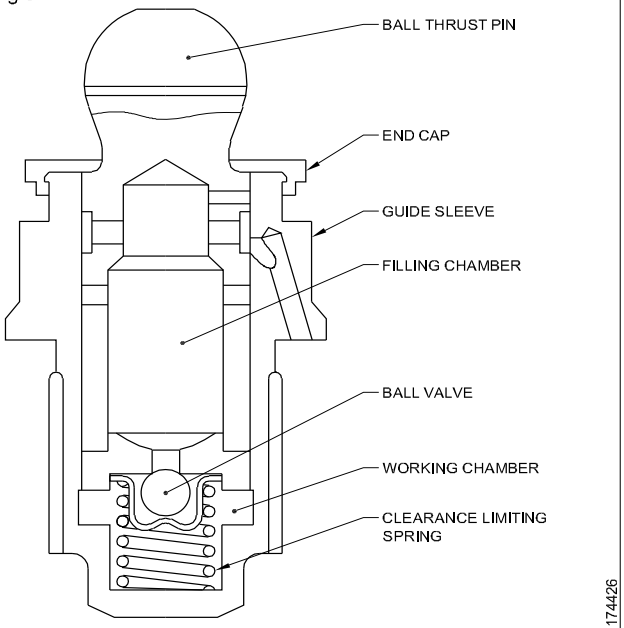


Fig 6

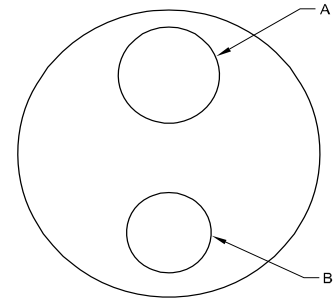



CLEARANCE ELIMINATING ELEMENT

**Types of valve arrangement**

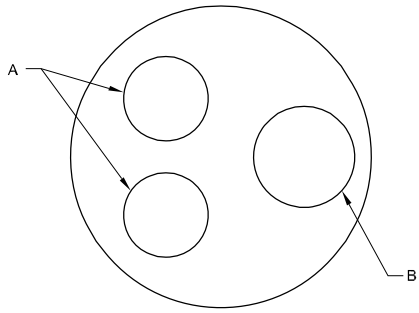
1 Two valve arrangement in one cylinder Fig 7
   A One inlet valve
   B One exhaust valve

Fig 7



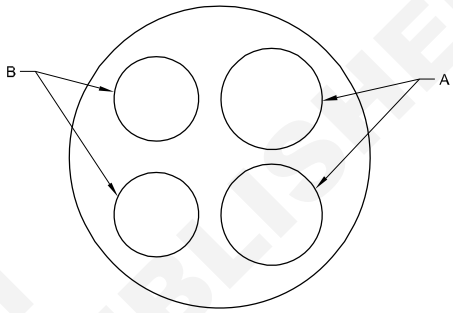

2 Three valve arrangement in one cylinder Fig 8
   A Two inlet valves
   B One exhaust valves

Fig 8



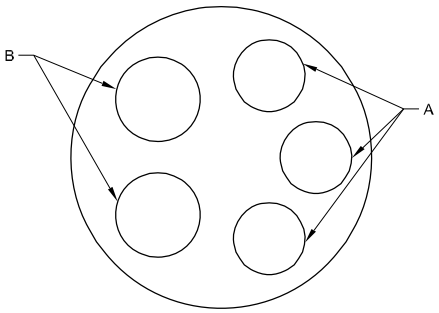

3 Four valve arrangement in one cylinder Fig 9
   A Two inlet valves
   B Two exhaust valves

Fig 9




4 Five valve arrangement in one cylinder Fig 10
   A Three inlet valves
   B Two exhaust valves

Fig 10






## Valve constructional features and valve timing

**Objectives:** At the end of this lesson you shall be able to
- **state the function of valve rotation**
- **state the function of valve stem oil seals**
- **state the size of intake valve**
- **describe the valve trains**
- **explain valve timing**
- **state the of variable valve timing.**

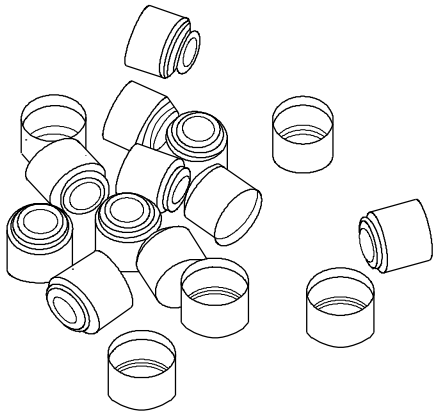
**Function of valve stem oil seal (Fig 1 & 2)**

The purpose of the valve stem oil seal is to prevent the oil from the cylinder head entering the combustion chamber value stem seals play a critical role in controlling valve lubrication as well as oil consumption.

There are two basic valve stem seal designs

1 Deflector seals - also called umbrella seals, deflect oil away from the valve stem. They are secured to the valve stem and move with the valve to shield the valve guide from excess oil. Umbrella type seals were commonly used prior to the development of positive type seals.

Fig 1



VALVE STEM OIL SEAL

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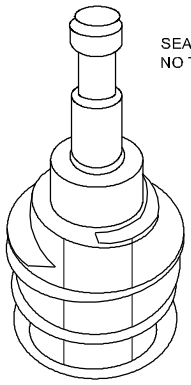
Fig 2

SEAL #3 DOES FIT INSIDE OF SPRING WHEN ON GUIDE

SEAL #4 FIT THE SAME BUT NO TEFLON



MVN174433

2 Positive seals - attach to the valve guide boss and function as squeegees, wiping and metering oil on the stem as they pass through the seals. State the size of in take valve.

Exhaust valves are made to close certain degrees after T.D.C. to develop a suction effect by the outgoing gases. It also helps in the scavenging of the exhaust gases by using the intake charge's momentum.

Causes the engine suck oil down the guides and into the cylinder

- Seal worn
- Seal cracked
- Seal missing
- Seal broken
- Seal improperly installed

When stem oil seals lose their ability to control the oil that enters oil through the guide, that can cause a variety of problem.

- Excessive smoke
- High oil consumption
- Carbon deposited in valve and piston
- OFF - throttle braking
- Running engine OFF in idle speed.

**Valve train (Fig 3):** The valve train of an internal combustion engine includes components required to control the flow of gases into and out of the combustion chamber valves and related component required to allow the air or air fuel mixture to enter the combustion chamber, the combustion chamber during compression and combustion and evacuate exhaust gases when combustion is compete. This type of valve train used for a reciprocating engine depends on the engine design and whether the engine is a four /two stroke cycle unit.

Fig 3

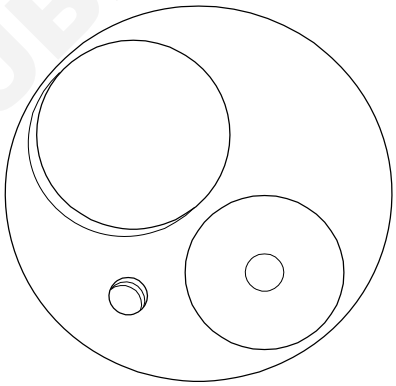
DEFLECTOR SEALS MOVE WITH VALVE STEM

POSITIVE SEALS ARE FIXED TO THE VALVE GUIDE BOSS

MDN226834

**State the size of intake valve (Fig 4):** In order to get adequate air flow into the cylinder, the inlet valve need enough opening with bigger diameter because over come air flow restriction, reduce the intake air heat, allow excess air for complete the combustion to increase the volumetric efficiency and scavenging effect.

Fig 4



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**Valve timing**

Each manufacturer specifies the timings of the opening and closing of the valves as per the design of the engine to give the maximum output under all loads and speeds.

The opening and closing of the valves in an IC engine in relation to the movement of the piston and flywheel is called valve timing (Fig 5).

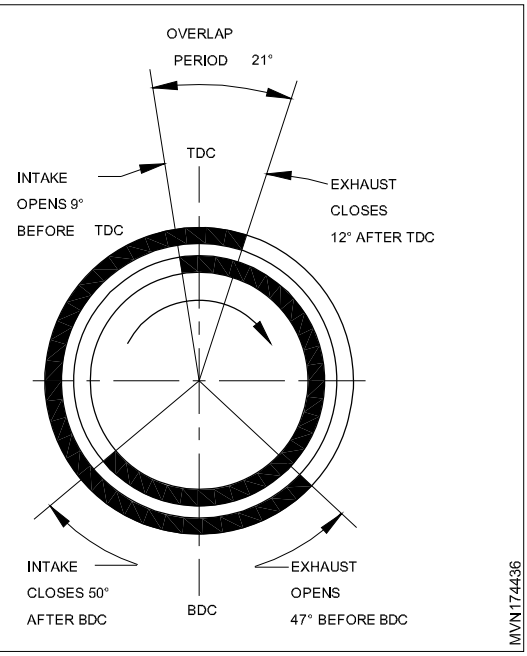
The opening and closing of the valves exactly at TDC & BDC do not improve the volumetric efficiency of an engine. Burnt gases also are not driven out fully.

Practically, the valves are arranged to open early and close late to fill the cylinder fully and to allow all burnt gases to escape from the cylinder.

**Inlet valve**

**Lead:** Inlet valves are made to open certain degrees earlier than T.D.C. This enables air fuel mixture to fill the cylinder to its capacity. It also helps in scavenging burnt gases by using the momentum of intake air/air fuel mixture.

Fig 5




**Lag:** Inlet valves are made to close certain degrees after B.D.C. to increase the volumetric efficiency by allowing more charge.

**Exhaust valve - Lead:** Exhaust valves are made to open certain degrees earlier than B.D.C.

**Lag -** Exhaust valves are made to close certain degrees after T.D.C. to develop a suction effect by the outgoing gases. It also helps in the scavenging of the exhaust gases by using the intake charge's momentum.

**Overlap period -** At the end of the exhaust stroke and the beginning of the suction stroke, both the valves remain open for certain degrees. This period during which both the valves remain open is called the valve overlap.

**Graphical representation of valve timing:** The valve timing is represented by a diagram drawn on the face of the flywheel in degrees of the crankshaft rotation.

**Valve timing (Jeep)**

- Inlet valve open 9 degrees before T.D.C.
- Inlet valve closes 50 degrees after B.D.C.
- Exhaust valve opens 47 degrees before B.D.C.
- Exhaust valve closes 12 degrees after T.D.C.
- Over lap period 21 degrees

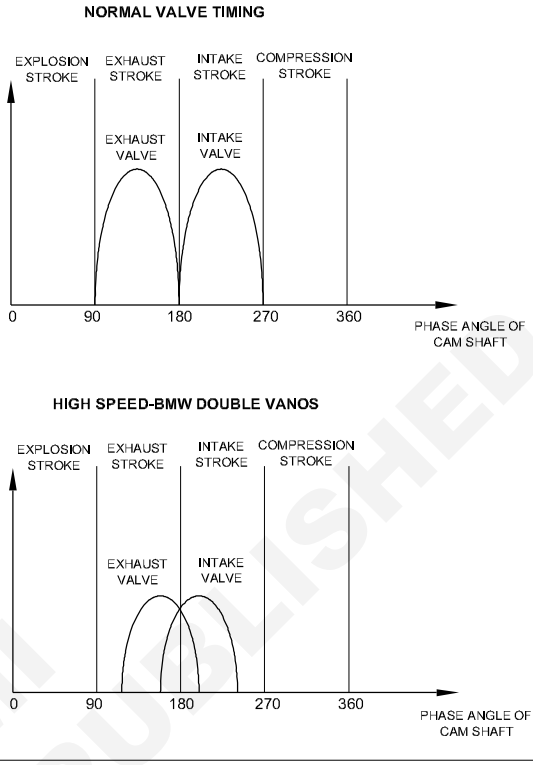
Valve timing varies from one make of engine to another valves are exposed to various chemical, mechanical and thermal stresses during operation. They must maintain their basic shape and dimensions throughout the expected life of the engine. In addition. the integrity of the sealing surface of the valve and mating valve seat is critical to durability and performance.

Engineers determine the valve material, shape, specifications, and surface coatings to match the specifications engine family, expected operating environment, and projected length of service. Valves commonly used in small engines are classified as one-piece, projection-tip welded, or two-piece-stem welded-stem valves.

**Variable Valve Timing (VVT) (Fig 6)**

Variable-valve (VVT) technology, became standard in engine design, variable valve timing becomes the next step to enhance engine output.

Fig 6




The valves activate the breathing of engine. The timing of breathing, that is, the timing of air intake and exhaust, is controlled by the shape and phase angle of cams. To optimse the breathing, engine requires different valve timing at different speed.

When the valve increases, the duration of in take and exhaust stroke decreases so that fresh air becomes not fast enough to enter the combustion chamber, while the exhaust becomes not fast enough to leave the combustion chamber. Therefore, the best solution is to open the inlet valves earlier and close the exhaust valves later. In other words, the overlapping between intake period and exhaust period should be increased as revolution increases.

With variable valve timing, power and torque can be optimised across a wide rpm band. The most noticeable results are:

- The engine rpm higher, thus raises peak power. For example, Nissan's 2-litre neo VVI engine output 25% more peak power than its non-VVT version
- Low-speed torque increases, thus improves drivability. For example, Flat barchetta's 1.8 VVT engine provides 90% peak torque between 2,000 and 6,000 rpm.

Moreover, all these benefits come without any drawback.

**Variable lift:** In some designs, valve lift can also be varied according to engine speed. At high speed higher lift quickness air intake and exhaust, thus further optimise the breathing. Of course, at lower speed such lift will generate counter effects like deteriorating the mixing process of fuel

and air, thus decease output even leads to misfire. Therefore the lift should be variable according to engine speed.

**Cam-changing VVT**

Many Automotive engine's are used VVT in the late 80s by launching its famous VTEC system (Valve timing electronic control).

It has 2 sets of cams having different shapes to enable different timing and lift. One set operates during normal speed, say, below 4,500 rpm. Another substitutes at higher speed.

However, cam-changing system remains to be the most powerful VVT, since no other system can vary the Lift of valve as it does.

Ex.Honda's 3-stage VTEC

**Cam-phasing VVT**

Cam-phasing VVT is commonly used mechanism and it varies the valve timing by shifting the phase angle of camshafts. For example, at high speed, the inlet camshaft will be rotated in advance by 30° so to enable earlier intake. This movement is controlled by engine management system according to need, and actuated by hydraulic valve gear.

## Camshaft

**Objectives:** At the end of this lesson you shall be able to
- **state the function of the camshaft**
- **state the constructional features and material of the camshaft.**

**Functions of the camshaft:** The camshaft is used to convert the rotary motion into reciprocating motion with the help of the cam lobe. This reciprocating motion is transmitted to the valve through the tappet, push-rod and rocker levers. The camshaft is driven by crank shaft and it rotates half the speed crankshaft. The camshaft also drives the oil pump shaft. In petrol engines the fuel pump and the distributor get their drive from the camshaft.

**Construction of the camshaft:** The camshaft (2) (Fig 1) is either forged or cast with the cam lobes (1) one for each valve. The camshaft has a series of support bearings along its length.

The cam surface (Fig 2) is hardened for longer life. In some engines the axis of the tappet/lifter (3) is slightly offset from the axis of the cam lobe (1). This off set gives a little rotation to tappet/lifter, when it moves up. So the bottom of the tappet/lifter (3) wears out uniformly. The lifter/tappet (3) rests on the cam lobe (1). The lifter (3) remains in its position on the base circle (4). When the cam rotates the lobe lifts the lifter (3).

**Material for camshaft:** Forged alloy steel

Fig 1

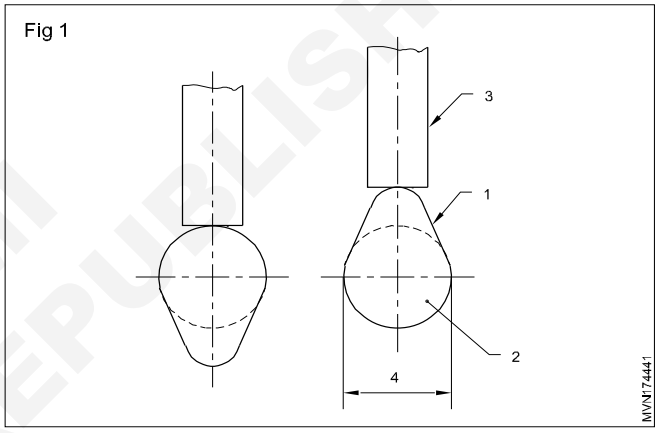
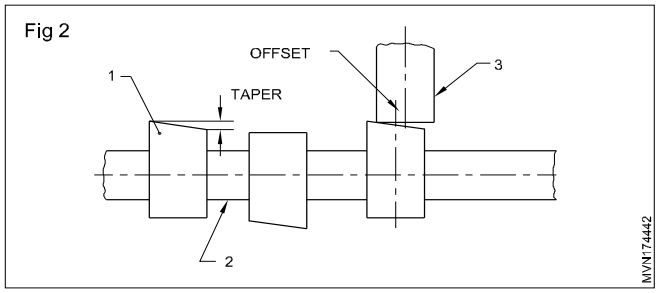



Fig 2




## Camshaft drive mechanisms

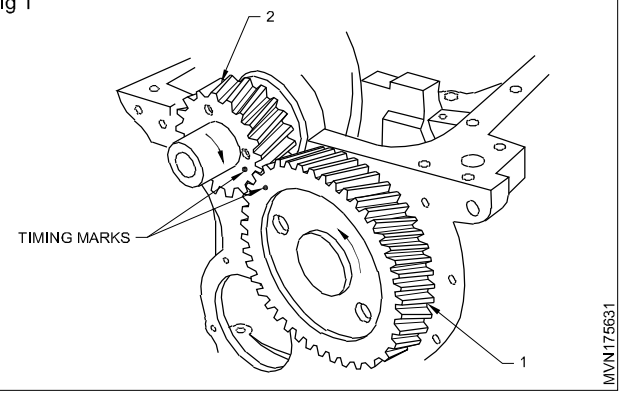
**Objective:** At the end of this lesson you shall be able to
- **state the different types of camshaft drive mechanisms.**

The camshaft gets the drive from the crankshaft and rotates at half the crankshaft speed, since each valve opens once in every two revolutions of the crankshaft. There are three types of camshaft drive mechanisms.

- Gear drive (Fig 1)
- Chain drive (Fig 2)
- Belt drive (Fig 3)

**Gear drive:** This direct drive (Fig 1) is used where the crankshaft and the camshaft are very close to each other. Since the r.p.m. of the camshaft is half of the crankshaft speed, the camshaft gear (1) teeth is twice as many as the crankshaft gear (2) teeth. In this, the engine's camshaft rotates in the reverse direction of the crankshaft. In some engines an idler gear is used to have the same direction of rotation for the crankshaft and the camshaft. When camshaft and crankshaft is assembled after overhauling the engine the timing marks should be coincides as in Fig 1.

Fig 1




**Chain drive (Fig 2):** With this type of sprocket drive the camshaft is driven by means of a chain with the aid of various.

Auxiliary components

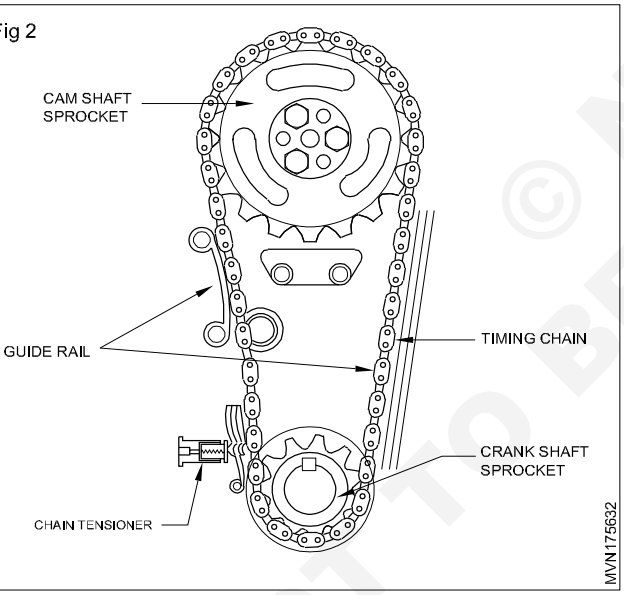
Single or multiple chains are used in this type of drive.

The chain is usually tensioned by means of a hydraulic chain tensioner which is controlled by the engine oil pressure.

The chain is additionally guided in rails to the chain vibration and noise.

The direction of crank shaft and camshaft is same.

Fig 2




The chain and chain tensioner are only subject to minimal wear so that servicing is unnecessary. If need be, i.e. in the event of excessive wear, the chain must be renewed. If a fault is found the chain tensioner is changed.

1 Camshaft sprocket

2 Timing chain

3 Crankshaft sprocket

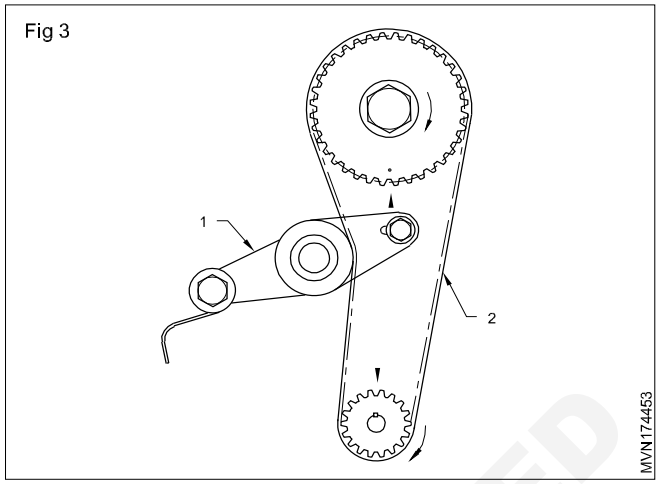
4 Chain tensioner

5 Guide rail

**Belt drive:** This drive (Fig 3) is similar to a chain drive. Instead of a chain a belt (2) is used to drive the camshaft. The belt drive is mostly used in overhead camshaft design.

The direction of rotation of the camshaft and crankshaft is the same. An automatic belt tensioner (1) is used to avoid slipping of the belt.

Fig 3




**Cam shaft classification:** Cam shaft are classified based on its location and number of shafts

1 Bottom mounted traditional camshaft (OHV) - (Fig 4) and single over head valve (SOHV) - (Fig 5)

2 Single over head cam shat. (Fig 6)

3 Double over head cam shaft (DOHC) (Fig 7)

The main disadvantages of an OHV design is that it's difficult to control precisely the valve timing at high rpm.

Advantages of an OHV engine include lower cost, proven durability, low-end torque and compact size. OHV design is better suited for slow speed engines. In heavy duty engines offers higher torque at lower rpms. (Fig 4)

**Bottom mounted traditional cam shaft (OHV Engine) (Fig 4) & SOHV (Fig 5)**

OHV in general means over head or valves are fitted in the cylinder head. Often the term "OHV is used to describe the engine design where the camshaft is fitted inside the engine block and valves are operated through lifters, pushrods and rocker arms. This design is also known as a "Pushrod" engine. The OHV design has been successfully used for decades.

Fig 4

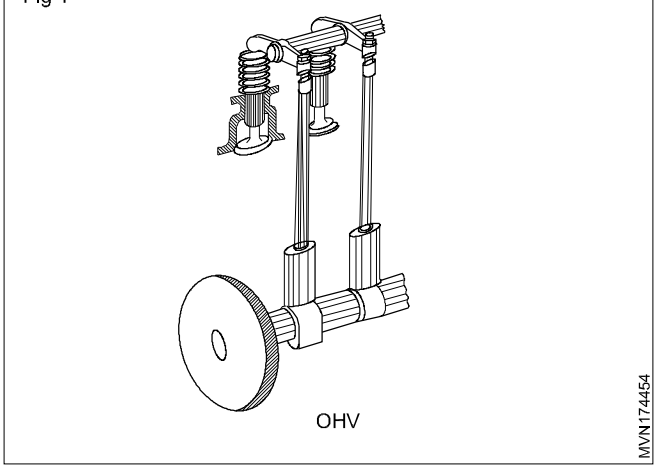
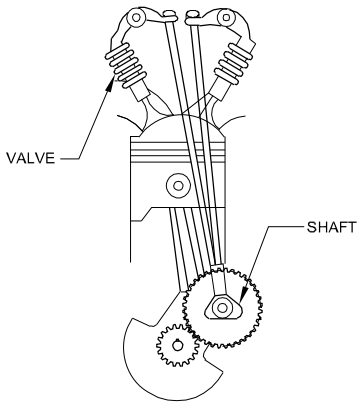


Fig 5

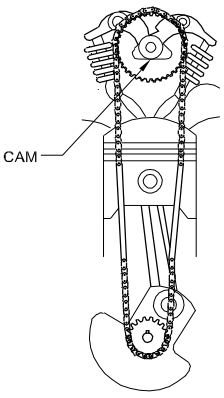



SOHV

MVN174455

**Over head cam/single over head cam shaft (OHC/ SOHC) (Fig 6):** OHC means over head cam in general, while SOHC means single over head cam or single cam. In SOHC engine the camshaft is installed in the cylinder head and valves are operated either by the rocker arms or directly through the lifters.

Fig 6



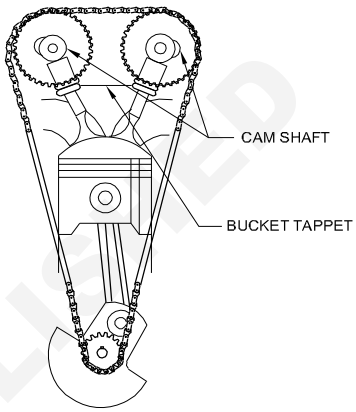

SOHC

MVN174456

The main advantage of an OHC design is that valves are operated almost directly by the camshaft, which makes it easier to maintain precise timing at higher rpms. It's also possible to install three or four valves per cylinder.

**Double over head cam shaft (DOHC) (Fig 7):** DOHC means double over head cam. Most modern vehicles have DOHC engines. DOHC engine has two camshafts and 4 valves per cylinder. One camshaft operates intake, while another camshaft operates exhaust valves. This allows the intake valves to be at a larger angle from the exhaust valves, so the volumetric efficiency increases and produces more horse power out of smaller engine volume.

Fig 7




DOHC

MVN174457

The main advantage of the DOHC design allow technologies like direct injection, variable valve timing and variable valve lift cab be easily implemented in a DOHC engine, further improving fuel efficiency.

The main disadvantage of the DOHC technology includes a larger size and more complex design with additional timing belt or chain components. A timing belt needs to be replaced at recommended intervals, adding to maintenance costs.



## Piston and piston rings

**Objectives:** At the end of this lesson you shall be able to
- **state the function and the requirements of a piston**
- **state the constructional features of a piston**
- **list out the different types of pistons**
- **list out the different types of piston rings**
- **state the constructional features of piston rings**
- **list out the material of piston rings.**

A piston is a cylindrical shape which reciprocates inside the cylinder bore. The main functions of the pistons are:

- to transmit the power developed by fuel combustion to the crankshaft through the connecting rod
- to transfer the heat generated due to combustion to the cylinder wall.

**Requirements of a piston: A piston should be:**

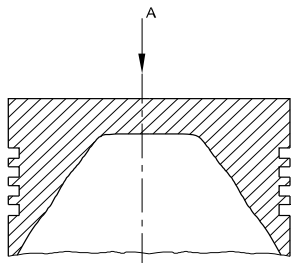
- able to withstand high temperature and pressure of combustion.
- a good conductor of heat.
- light enough to minimise the inertia load.

**Construction of a piston:** It has a special shape at different portions according to the design. A piston is designed with five portions according to the purpose and functional features.

**The crown or head:** It is the top most portion of the piston. It is subjected to high pressure and temperature due to the combustion of the fuel. Four types of heads are used.

**Flat head:** It is simple in shape and is most commonly used. It is simple in construction. Decarbonising of this is very easy. (Fig 1)

Fig 1

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**Domed head:** It has a projection shaped like a dome on the crown. (Fig 2 & Fig 3) The dome acts as a deflector and helps to make a homogeneous mixture of air and fuel. It is used in two-stroke cycle engines. It is difficult to manufacture compared to flat heads.

Fig 2

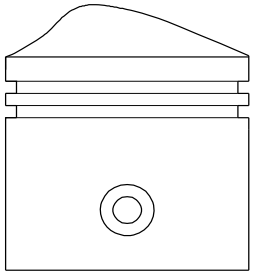

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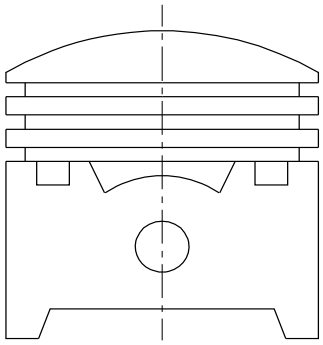
Fig 3



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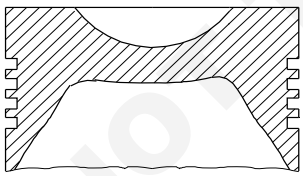
**Concave head:** It has a concave cavity on the top. (Fig 4) It is used in high compression diesel engines to reduce the clearance space.

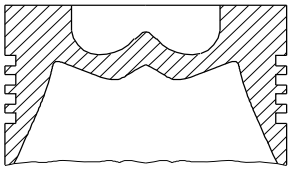
Fig 4



MVN174814

**Irregular head (cavity piston):** It has a cavity on the top, (Fig 5) and a conical shaped projection is provided inside the cavity. This helps in swirling of air and thereby making for it better homogeneous burning, and it improves combustion. It is used in high compression diesel engines.

Fig 5



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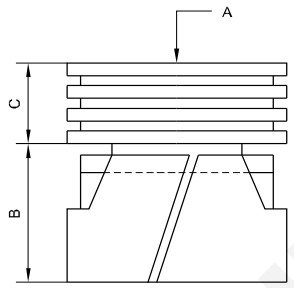
**Skirt:** Skirt is the lowest portion of the piston. It works as a guide to the piston in the bore and enables the piston to move in a straight line. The skirt has the least clearance with the liner. The piston to liner clearance is measured at the skirt.

**Ring section:** It is the portion between the top of the piston and the last ring groove. It has more clearance with the cylinder than with the skirt. There are two types of piston ring grooves. (Fig 6)

Fig 6



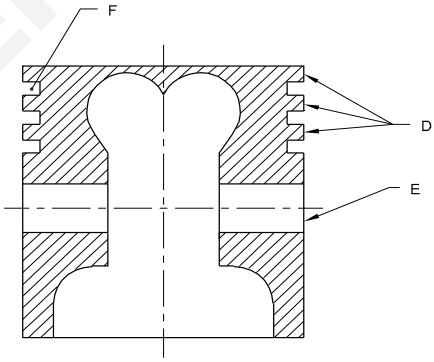

C - RING SECTION
B - SKIRT SECTION
A - CROWN

MVN174816

- Compression ring groove: These grooves accommodate compression rings.
- Oil ring groove: These grooves accommodate the oil scraper rings.

**Land:** This is the piston's circumference left above the top ring groove and between the ring grooves. (Fig 7)

Fig 7




D - RING LAND
E - GUDGEN PIN BOSS
F - RING GROOVES

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**Gudgeon pin boss:** At this portion (Fig 8) of the piston a gudgeon pin is fitted to connect the piston and the connecting rod. In some cases it is reinforced with ribs to withstand the combustion pressure. When the engine is running in clockwise direction, seen from the front of the engine, the left side of the piston is the maximum thrust side and right side is the minimum thrust side.

**Designs/Types of pistons:** Solid skirt piston: These pistons are used in compression, ignition engines or heavy petrol engines. This design can take heavy loads and thrusts. (Fig 9)

**Slipper pistons:** This type of pistons are used in modern engines to increase the area of contact at thrust faces. It is lighter in weight compared to the solid skirt piston. (Fig 10)

Fig 8

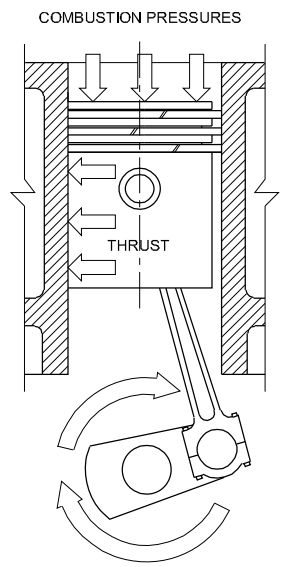



Fig 9

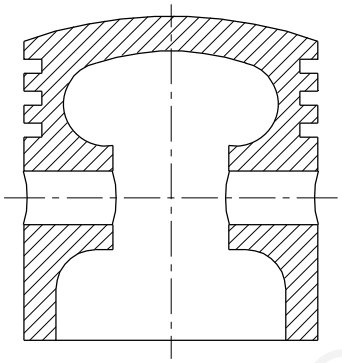
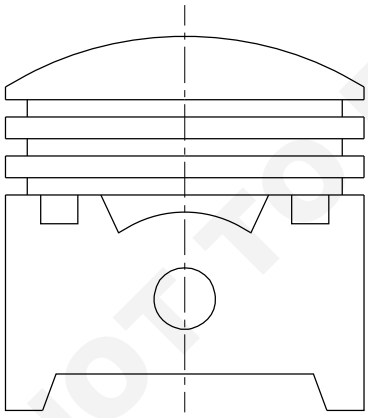



Fig 10




**Split skirt piston**

It is widely used in two-stroke scooters and mopeds. It is lighter in weight and has less inertia load. (Fig 11)

**Piston with steel alloy inserts**

Steel alloy inserts (1) are cast between the thrust faces on the inside of the gudgeon pin bosses. This gives strength and controls expansion of the piston at high temperature. (Fig 12)

Fig 11

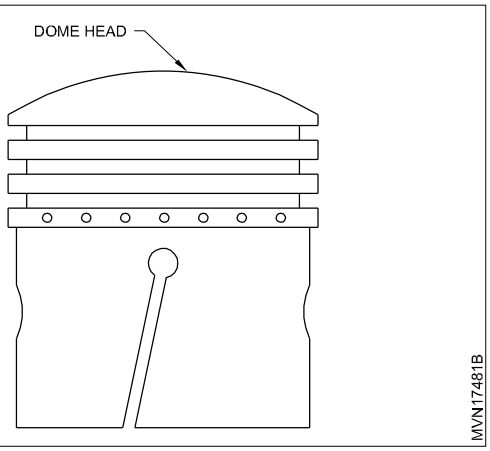
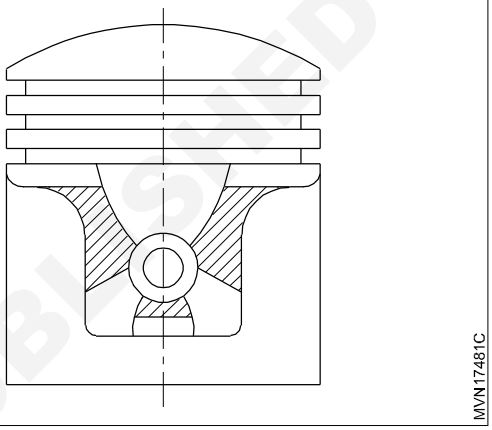
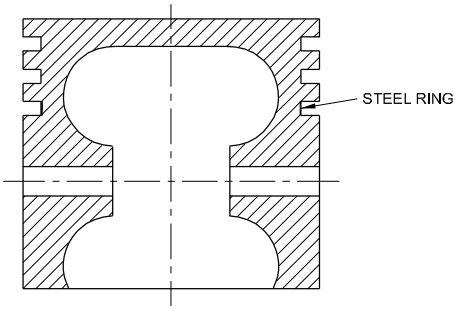



Fig 12




**Steel-belted pistons:** A steel ring is cast above the gudgeon pin boss for strength. It controls expansion. This type of pistons are used in heavy duty engines. (Fig 13)

Fig 13




**Cam ground pistons:** The skirt of this piston is ground oval in shape. The diameter across the gudgeon pin boss axis is less at the thrust side. When the engine runs and the piston heats up, the bosses expand outwards making the piston round, and the clearance with the cylinder bore uniform all round. (Fig 14)

**Constant clearance pistons (Slot skirts):** These pistons have one or two slots cut in the piston skirt. When the piston gets heated up, the width of the slots decreases. It helps in maintaining a constant clearance with the cylinder bore. These slots are located under the oil ring groove at the minimum thrust side. The end of the slots is divided with holes to avoid stress concentration. (Fig 15)

Fig 14

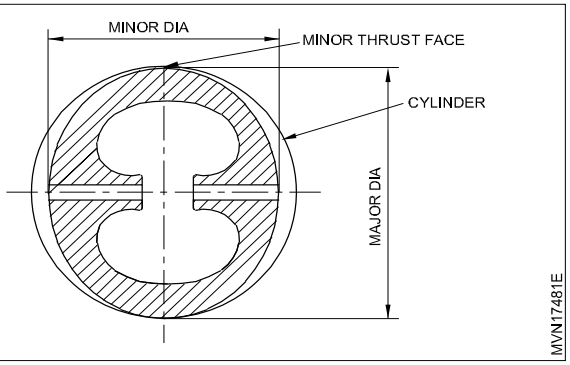
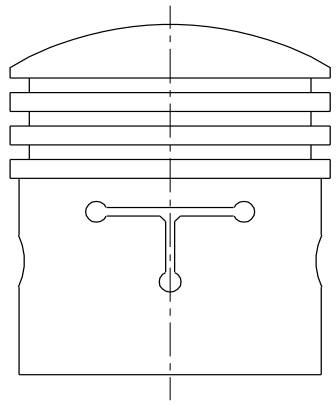
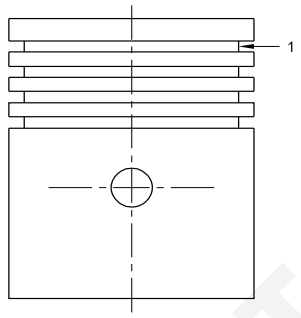



Fig 15



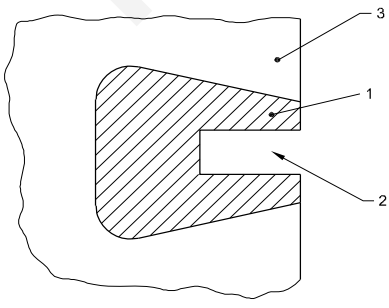

**Heat dam pistons:** These pistons have an extra groove (1) cast in between the top ring groove and piston crown. It is known as heat dam. It reduces the heat path on the piston head to the skirt. It enables the piston to run cooler. In this groove no ring is fitted. (Fig 16)

Fig 16




**Alfin piston/ring carrier piston:** Wear in the ring groove will result in excess oil reaching the combustion chamber. To reduce the wear on the top ring groove in piston(3), a ferrous ring (1) is inserted. This insert reduces the wear of the top ring groove (2). (Fig 17)

Fig 17




**Piston rings**

**Types**

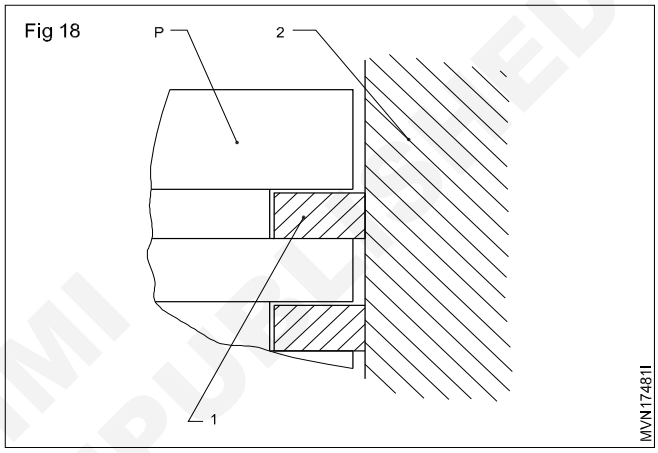
- Compression ring
- Oil control ring

**Compression rings:** These rings effectively seal the compression pressure and the leakage of the combustion gases. These are fitted in the top grooves. They also transfer heat from the piston to the cylinder walls. These rings vary in their cross-section.

The following types of compression rings are used.

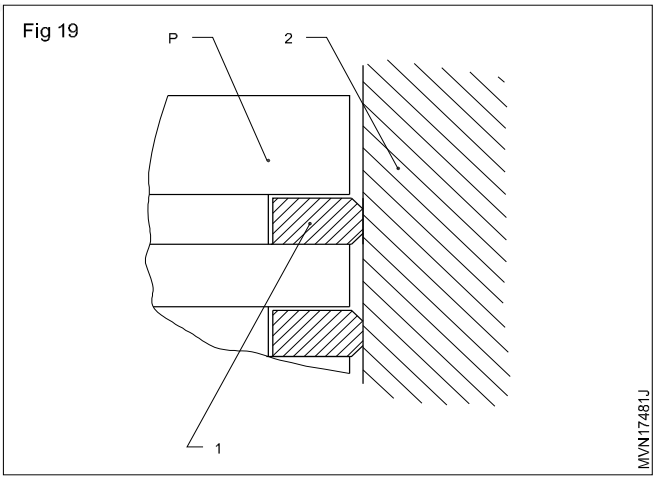
**Rectangular rings:** These rings are very popular and easy to manufacture at a lower cost. The face of the rings (1) remains in full contact with the wall of the liner (2) (Fig 18)

Fig 18




**Taper-faced rings:** The face of the ring (1) is tapered (Fig 19). The lower edge of the ring is in touch with the liner (2). These rings are good for controlling oil consumption by scraping all the oil from the liner (2). These rings cannot effectively control blow-by.

Fig 19




**Barrel-faced rings:** In this type, the corners of the rings (1) are rounded off to give a barrel shape. These rings are used only for top grooves to prevent blow-by. (Fig 20)

**Inside bevel rings:** In this type a step is cut on the top surface at the inner diameter of the ring (1). The step allows the ring to twist slightly when the piston moves. It is more effective in preventing blow-by. These rings are used in second grooves. (Fig 21)

Fig 20

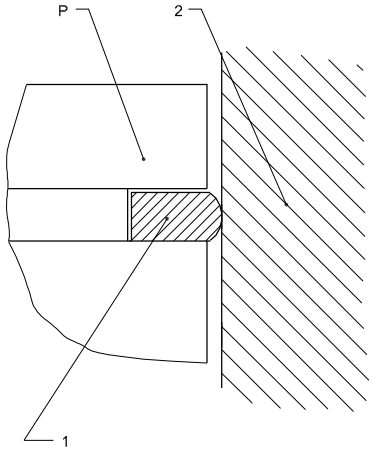



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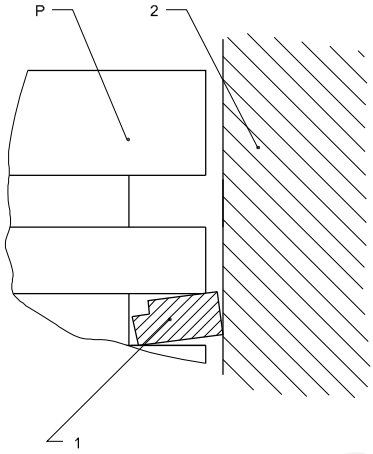
Fig 21

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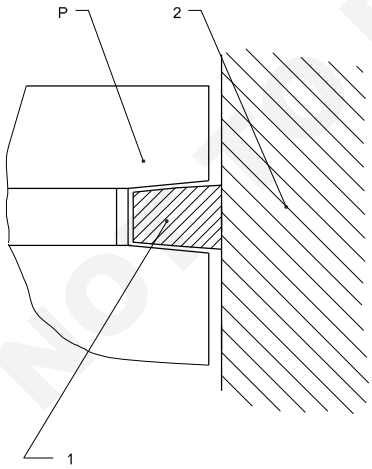
**Keystone ring**

This types of rings (1) does not allow carbon to settle in the ring groove. It is generally used in heavy vehicles. (Fig 22)

Fig 22

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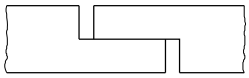
**Joints of compression rings**

**Step joint**

It is considered to be one of the best to prevent blow-by. It is difficult to manufacture, and to set a correct gap while fitting. These types of joints are not used much in Automotives. (Fig 23)

Fig 23

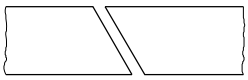


MVN17481N

**Angle joint (Diagonal cut)**

This type of joints is easy to manufacture and the gap can be set quickly. It is commonly used in Automotives. (Fig 24)

Fig 24



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**Straight joint**

These rings are easy to manufacture and the gap can be set easily. Most of the engine rings have straight joints. (Fig 25)

Fig 25

MVN17481P

**Oil control rings**

The main purpose of an oil ring (2) is to scrape the excess oil from the liner and drain it back to the oil sump during the downward movement of the piston. It prevents the oil from reaching the combustion chamber.

One or two oil control rings are used in a piston. If two rings are used, one is fitted above and the other is fitted below the gudgeon pin in the piston.

These rings exert enough pressure on the cylinder wall to scrape the oil film. To keep the sealing and avoid metal-to- metal contact, a thin film of oil stays on the liner. These rings are provided with drain holes or slots. These slots allow the scraped oil to reach the oil sump through the piston holes.

**Types of oil scraper rings**

**One piece (Solid rings)**

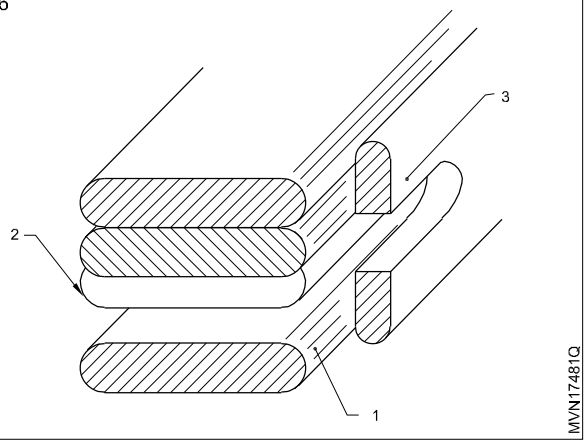
These rings are easy to install. They have greater force against the cylinder wall and reduce oil consumption.

**Duraflex rings (Three pieces)**

These rings (Fig 26) are used specially for re-ringing jobs, where the cylinder has worn out excessively. One set of rings consists of rails, a crimped spring and expander. The rail (1) is of a circular shape. It is made of high quality, polished spring steel. The number of rails vary in accordance with the width of the groove. It wipes oil from the liner. The crimped spring (2) keeps the rail space apart and seals the top and bottom of the groove. It ensures the ring tightens in the groove irrespective of wear.

The expander (3) exerts the correct amount of pressure against the rail and provides a sealing effect on the cylinder wall. The main advantage of this type of ring is that it provides enough pressure irrespective of cylinder wear in all conditions.

Fig 26



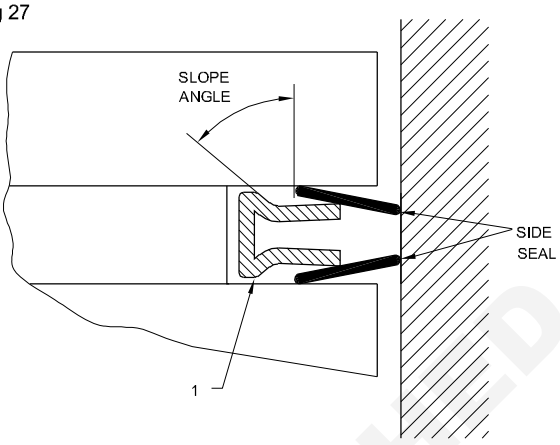

**`T' Flex rings:** It has one `T' shaped expander (1) with two scraper rails (2). The rails (2) also serve as spacers. The expander (1) forces the rails (2) against the cylinder wall. This enables the ring to scrape excess oil. The steel rail provides an effective side sealing of the cylinder walls. (Fig 27)

**Materials**

Piston rings are made of high grade cast iron, centrifugally cast and ground. This provides good elasticity, and minimises vibration. In some cases steel- chromium plated rings are also used in cast iron cylinders. Chromium plated rings are only used in the top groove.

These rings have less friction, less wear and longer life.

Fig 27



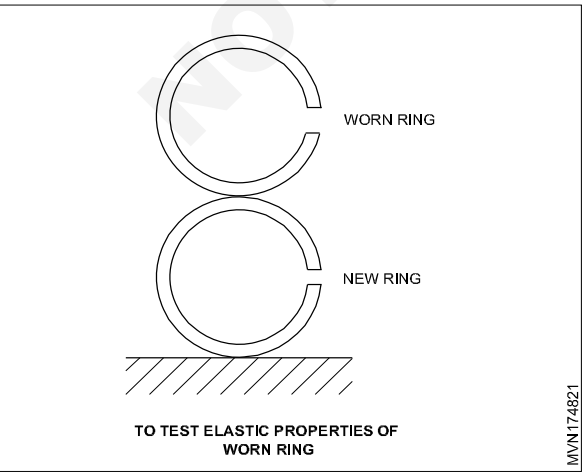

## Piston ring

**Objectives:** At the end of this lesson you shall be able to
- **state the recommended clearances for rings**
- **state the piston rings fitting precautions**
- **state the causes and remedies of piston rings**
- **state the compression ratio.**

**Piston clearance:** Piston rings have gap so that they may be installed into the piston grooves and removed when worn out by expanding them. The gap ensures radial pressure against the cylinder wall thus having effective seal to prevent leakage of heavy combustion pressure. This gap must be checked because if it is too great due to cylinder bore wear, the radial pressure will be reduced.

To check this gap clean the carbon from the ends of the ring and then check it with feeler gauges. This gap may be in the region 0.178 - 0.50 mm governed by the diameter of the bore but if it exceed 1 mm per 100 mm of bore diameter, new rings must be fitted (Fig 1).

Fig 1




The gap between the ring and the groove in the piston should also be checked by feeler gauges. This gap is usually 0.038 - 0.102 mm Fig 2 for compression rings and a little less for the oil control rings.

The gap between piston and liner is measured by feeler gauge from the bottom of the liner (skirt) is 25.4 mm Fig 3.

Fig 2

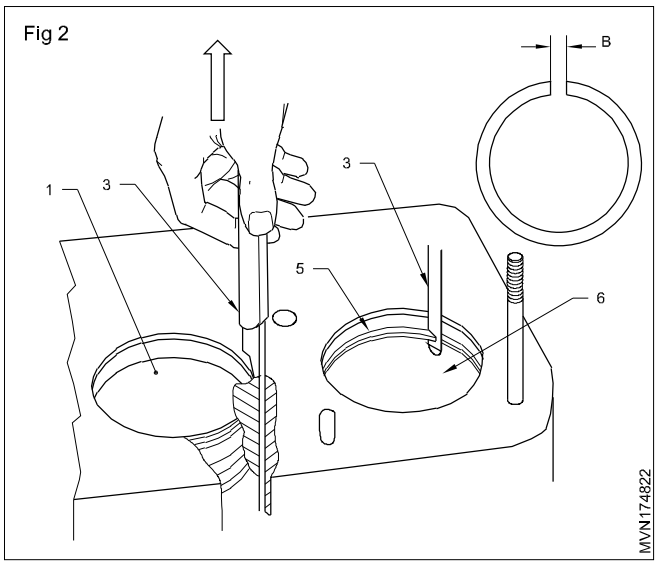
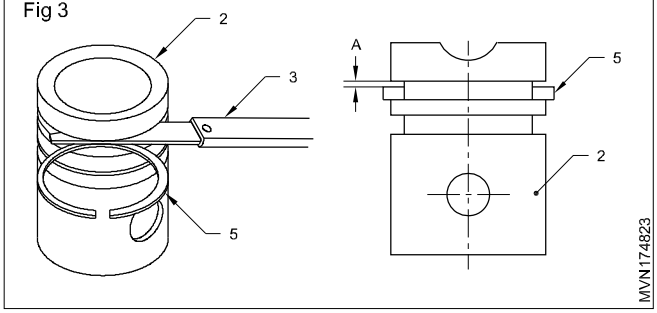


Fig 3




**Precautions while fitting rings in the piston**

There are two types of piston rings (compression ring and oil scraper ring) used in an i.c engines. While fitting the piston rings follow the precaution.

1 Remove the ridge in the liner.

2 Use proper ridge cutter.

3 Measure the end gap of new ring.

4 Use piston ring cutter to remove excess material.

5 Use piston ring grooves cleaner to remove carbon from groose.

6 Clean the piston groove, liner rings with specified cleaning liquid.

7 Excess piston ring expand lead broken , so limit the ring expansion as need

8 Use the ring expander to fit the ring in the piston.

9 Check the end gap clearance of the ring.

10 Check ring side clearance in the piston's groove.

11 Ensure the piston rings and gap should not be inline.

**Causes and remedy**

1 Wear in the piston ring grooves causes the rings to rise and fall during movement of piston and its pumping action resulting in high oil consumption.

2 Exercise gas blow by, loss of compression will also take place if gap is too much (cylinder wall and piston ring).

3 During service the piston ring may have lost some of its elastic properties due ti which radial pressure will be reduced on the cylinder wall. This properly can be checked by pressing together worn and a new ring and observing whether the gap of the worn ring closes more than the new ring.

**Compression ratio:** It is the ratio of the volume of the charge in the cylinder above the piston at bottom dead centre and the volume of the charge when the piston is at top dead centre. Since the volume above the piston at bottom dead centre is the displacement of the cylinder plus the clearance volume; and the volume above the piston at top dead centre is the clearance volume, the compression ratio can be stated as:

$$\frac{\text{Clearance volume} + \text{Displacement volume}}{\text{Clearance volume}}$$

For example, if clearance volume is 90 $cm^3$ and displacement volume is 540 $cm^3$, the compression ratio will be,

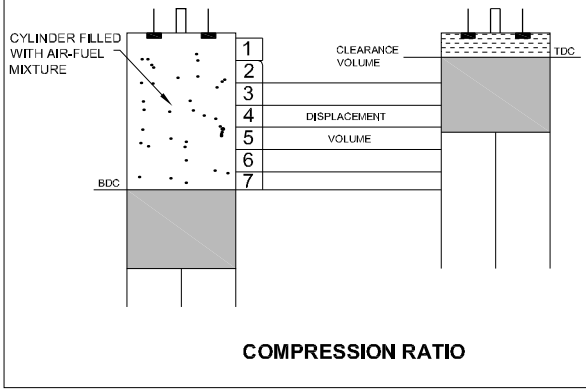
$$r - \frac{90+540}{90} = \frac{630}{90} = 7:1$$

The compression ratio 7:1 is illustrated in Fig.4. Early Automotive engines had low compression ratios 3:1 to 4:1. They are known as low compression engines. The fuel available at that time could not be subjected to greater pressure without detonation. The modern gasoline engines have compression ratios 7:1 to 10:1. Diesel engines have much higher compression ratios from 11: to 22:1.

The compression ratio of an engine will be increased by any condition that will decrease the size of the clearance volume such as the accumulation of carbon deposits. High compression ratio results in decreased operating efficiency and grater power output for a given engine.

The pressure of the mixture at maximum compression is determined by the compression ratio. Some other factors are also considered like engine speed, temperature, degree of vaporisation of the fuel and leakage past the piston rings.

Fig 4



# Description and function of connecting rod

**Objectives:** At the end of this lesson you shall be able to
- **describe the function of connecting rod**
- **describe the construction and materials of big and small end bearing of connecting rod.**

**Connecting rod**

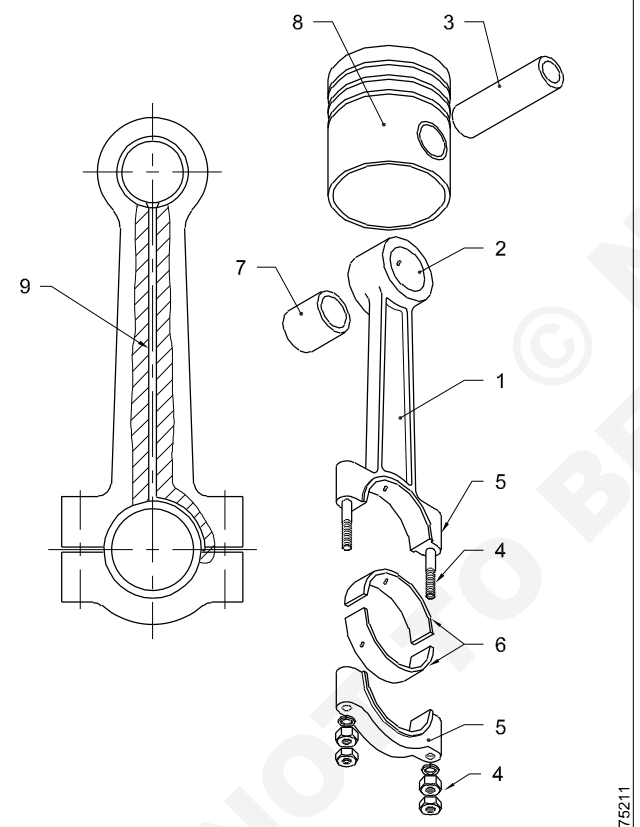
**Functions**

It is fitted in between the piston and crankshaft. It converts the reciprocating motion of the piston to the rotary motion in the crankshaft. It must be light and strong enough to withstand stress and twisting forces.

**Construction**

The connecting rod (1) (Fig 1) is made of high grade alloy steel. It is drop-forged to 'I' shape. In some engines aluminium alloy connecting rods are also used. The upper end of the connecting rod has a hole (2) for the piston pin (3). The lower end of the connecting rod (1) is split, so that the connecting rod can be installed on the crankshaft.

Fig 1




CONNECTING ROD SPILT AT RIGHT ANGLE

The top and bottom halves (5) of the lower end of the connecting rod are bolted together on the big end journal of the crankshaft, by bolt and nut (4).

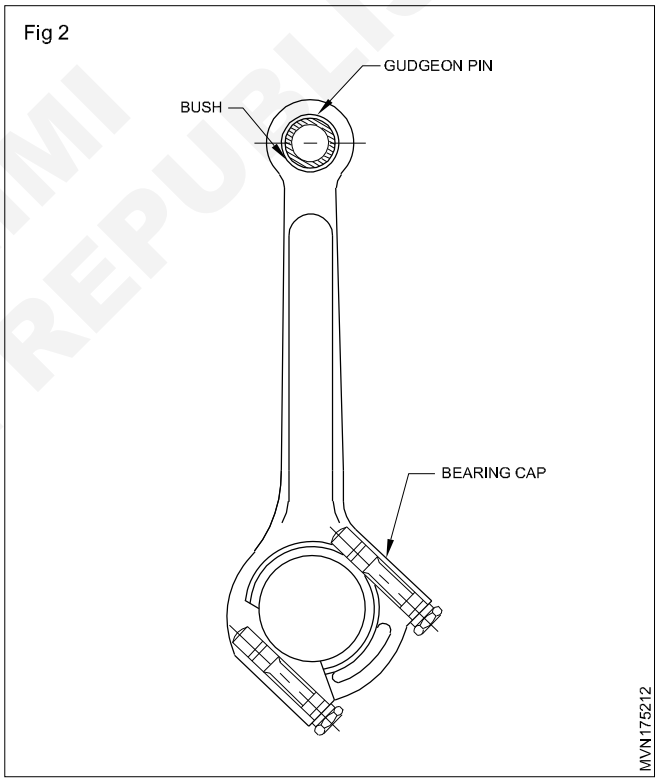
A large bearing area is provided to take the load, heat and wear. The split halves are usually fitted with babbitt bearings (6) or bearing lining steel-backed copper lead. In the upper end of the connecting rod a bronze bush (7) is fixed. The small end of the connecting rod is connected to the piston (8) by means of a piston pin (3).

In some engines a hole (9) is drilled in the connecting rods from the big end to the small end. It allows oil to flow from the big end to the small end bush.

**Control split at an angle (Oblique cutting) (Fig.2)**

The connecting rod big end is split at an angle for assembly easily on the crankpin.

Fig 2






# Locking methods of piston pin

**Objective:** At the end of this lesson you shall be able to
- **list out the various types of piston pins locking method and material of the position pin.**

The piston pin or gudgeon pin connects the piston with the connecting rod. It should be strong enough to transmit power and withstand pressure of combustion. Piston pins are made hollow to reduce inertia load due to the reciprocating motion.

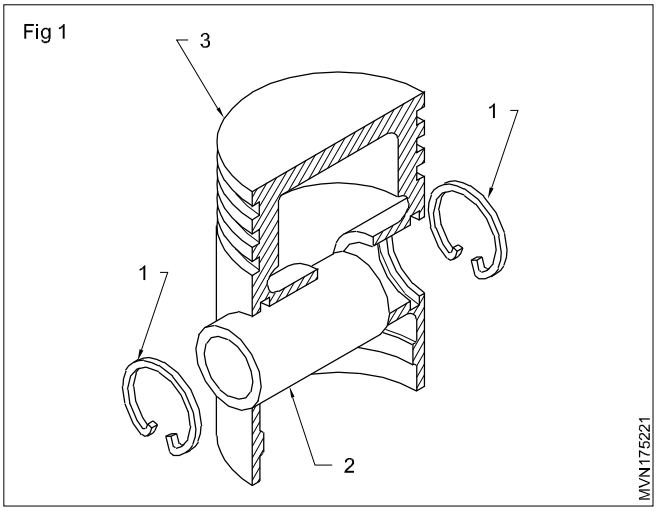
**Types of piston pins**

**Fully floating piston pin**

In this type (Fig 1) there are two circlips (1) on either side of the piston pin (2). The pin (2) is free to rotate both in the

piston (3) and the connecting rod.Circlips (1) are fitted into the grooves provided in the piston boss. This type of pins is used in engines which carry heavy loads. The gun metal or bronze bush is used between the small end of the connecting rod and the piston pin. Small two-stroke engines may have a needle bearing cage instead of a bush.

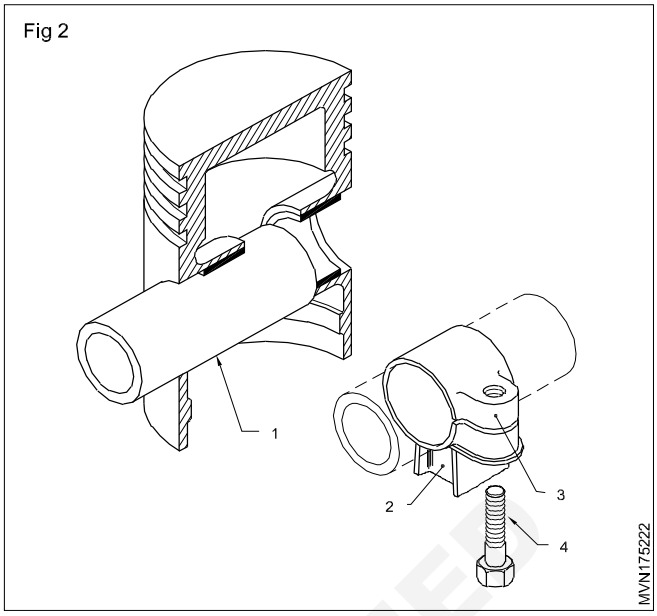
Fig 1




**Semi-floating piston pin**

The pin (1) is fastened to the connecting rod (2) with a clamp (3), screw (4) and nut. In this the piston boss forms the bearing. (Fig 2)

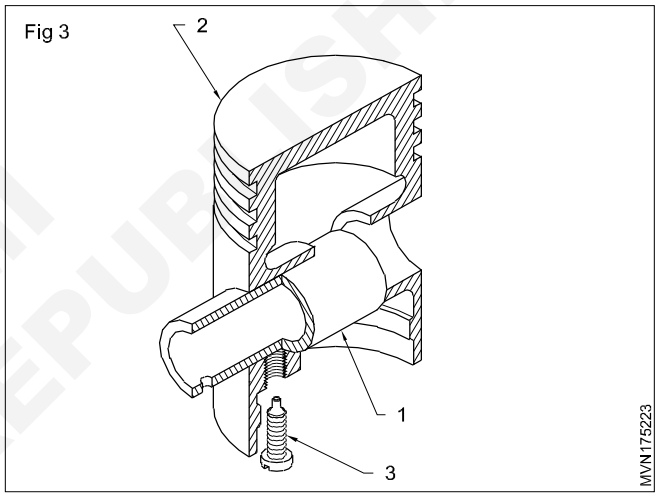
Fig 2




**Set screw type piston pin**

The pin (1) is fastened to the piston (2) by a set screw (3) through the piston boss and is provided with a bush in the small end of the connecting rod. (Fig 3)

Fig 3




**Piston pin materials**

The piston pin are made of Nickle / chromium alloy steel. The outer surface is ground, chromium plated and case hardened.



## Description and function of crankshaft

**Objectives:** At the end of this lesson you shall be able to

- **state the function of the crankshaft**
- **state the constructional features of crankshaft**
- **state the material of crankshaft**
- **state the necessity for heat treatment, and the balancing of the crankshaft**
- **state the constructional features of bearing shells**
- **list out material of the bearing shells.**

**Function of the crankshaft**

The crankshaft converts the reciprocating motion of the piston into rotary motion, and transmits the torque to the flywheel.

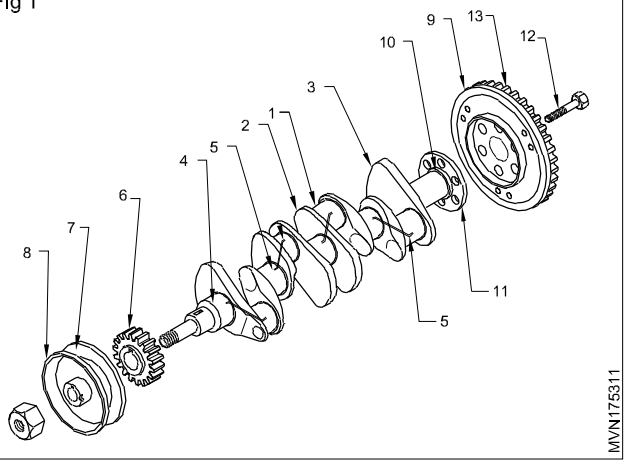
**Construction**

A crankshaft consists of a crank pin (1) (Fig 1), webs or crank arm (2) and balancing weights (3) which are provided on the opposite side of the crank arms for balancing the main journals (4). Crankshaft have drilled oil passages (5) through which oil flows from the main bearings to the connecting rod bearings.

The front end of the crankshaft carries the gear or sprocket (6) to drive the cam shaft. A vibration damper (7) and a fan belt pulley (8) are fitted in front. The pulley (8) drives the water pump, engine fan and generator/alternator, through a fan belt.

At the rear end of the crankshaft, a flywheel (9) is fitted. The inertia of the flywheel (9) tends to keep the crankshaft to rotate at a constant speed. Next to the rear end main journal an oil seal (10) is fitted. In some engines, oil return threads are provided which return the lubricating oil to the sump.

Fig 1




**Materials:** A crankshaft has to withstand the centrifugal force, the impact force by the piston and the connecting rod. It should be light in weight. It is made of the following material.

- Nickel steel
- Chrome, vanadium steel
- Nickel chrome steel
- Nickel chrome molybdenum steel

**Heat treatment of the crankshaft:** A crankshaft is made of forged and heat-treated alloy steel. It is machined and ground to provide suitable journals for the connecting rods and main bearings. The following methods are used to harden the crankshaft journals.

- Nitriding
- Carburising
- Chrome plating

In the above process the case of the crankshaft journal is hardened. These process give very little depth of hardness. Some manufacturers recommend hardening of the crankshaft journals after regrinding.

**Induction hardening:** Induction hardening gives more depth of hardness, and, therefore, the crankshaft need not be hardened again and again.

**Crankshaft bearings:** These bearings are made into two halves. These bearings operate at critical loads and high rotational speeds. These bearings run quieter and are easy to replace.

These bearings are also called thin wall bearings. These are made of a thin steel shell base with a thin lining on it.

The lining materials are copper-lead or lead-bronze or tin-lead or soft aluminium alloy. Cadmium alloy with copper or cadmium alloy with silver withstands high pressure. Iridium with copper and lead has excellent wear and corrosion resistance. The lining is plated to a thickness of about five thousandth of an inch.

Half shells are provided with an oil groove (1) (Fig 2 to 4) and oil feed holes (2). The bearing shell also has a locking lip (3) on it to fix it on the lip slot (4) of the bore and cap. In some cases dowel pins (5) are provided in the parent bore which aligns with the hole on the bearing shell and avoids rotation of the shell.

Fig 2

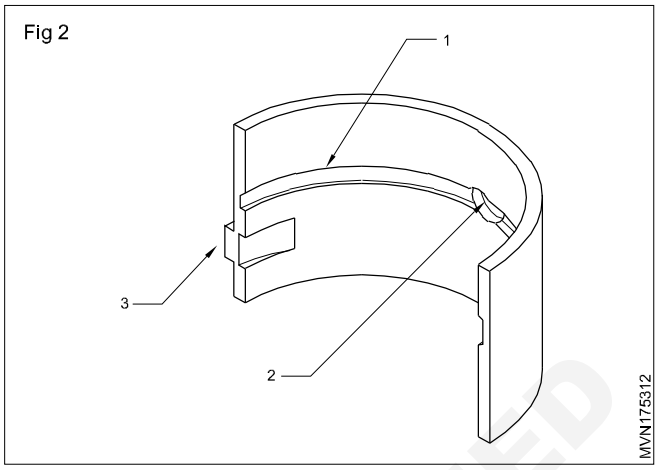



Fig 3

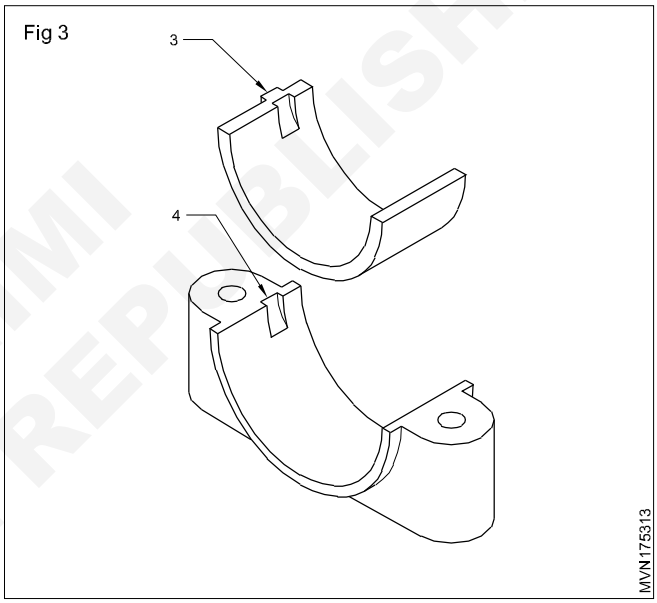
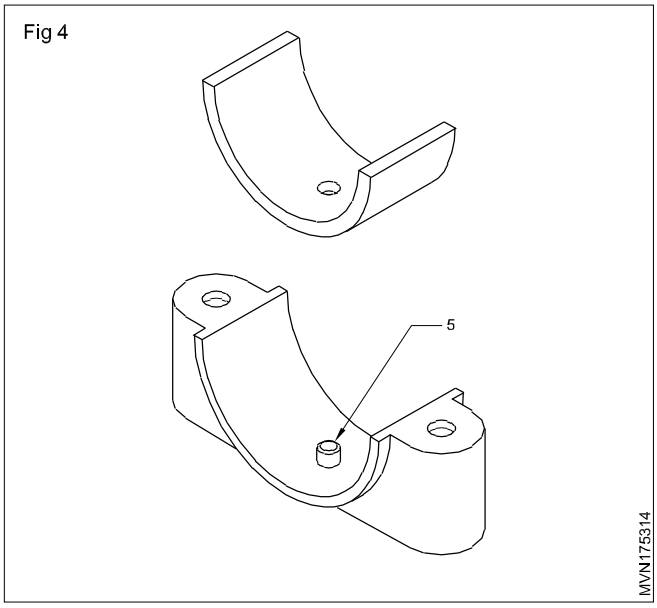
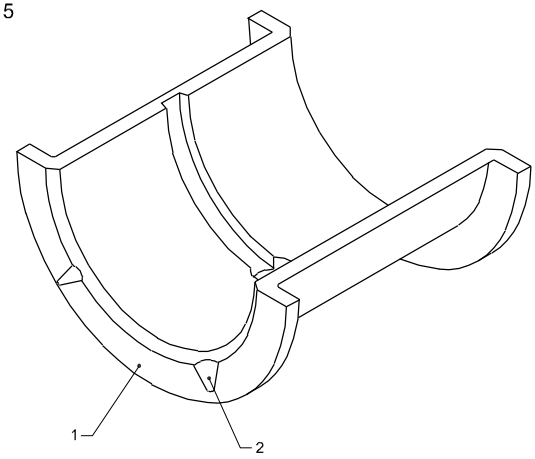



Fig 4



**Thrust bearings:** This type of bearing (Fig 5) takes care of thrust loads. The bearing shells on the crankshaft, which has thrust faces (1) on it, takes the end thrust of the crankshaft when it is in operation. The thrust faces have oil notches (2) to hold lubricating oil. In some cases separate thrust washers made up of bearing material are also used to take the end thrust.

Fig 5

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## Bearings

**Objectives:** At the end of this lesson you shall be able to

- **understand the need of bearings**
- **list out the different types of bearings used in vehicle**
- **list out the uses of the different types of bearings**
- **explain the function and application of different types of bearings.**

Bearings are used to support the rotating components and to reduce friction between the static and rolling components.

The following types of bearings are used in Automotives.

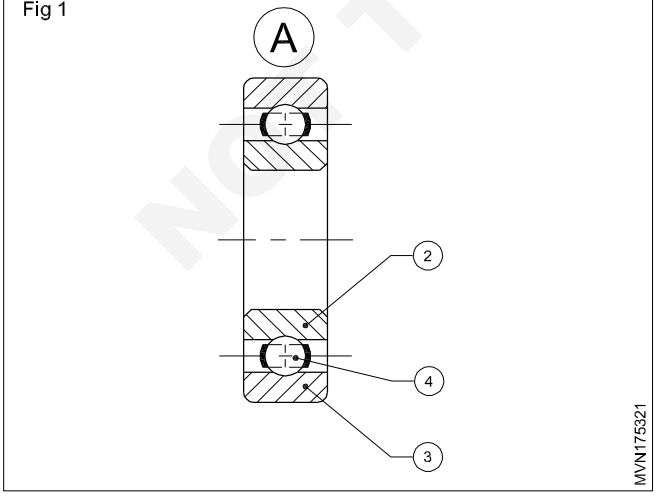
- Shell bearing
- Bush bearing
- Ball bearing
- Roller bearing
- Needle roller bearing
- Taper roller bearing

Bush bearings are made of copper-lead, tin-aluminium, tin-copper and used in the small end of the connecting rod, camshaft, oil pump drive shaft etc.

Ball bearings (A) (Fig 1) reduce friction between rotating parts to a minimum, and can take radial as well as axial load.

Ball bearings consist of an inner race (2), outer race (3) and balls (4). These bearings are used in the gearbox.

Fig 1

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Roller bearings (B) also consist of an inner race (5), outer race (6) and rollers (7). (Fig 2) These bearings can take heavy radial load but no axial load and are used in the final drive, flywheel, water pump etc.

Needle roller bearings (C) (Fig 3) are similar to roller bearings except that the ratio between the length of the needle roller (8) and the diameter of the roller is much more than that of a roller bearing.

Fig 2

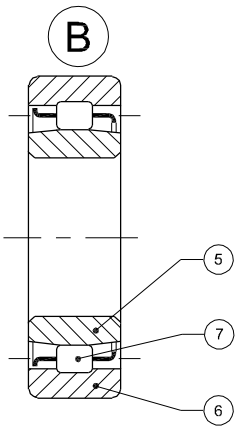


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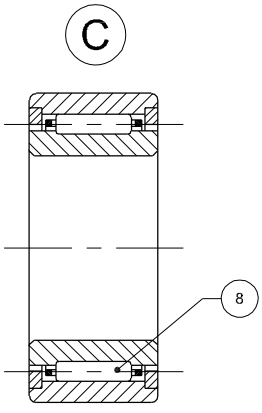
Fig 3

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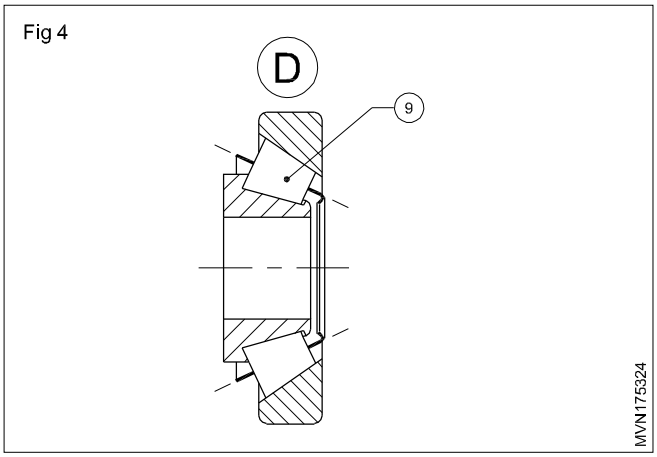
Taper roller bearings (D) (Fig 4) have taper rollers (9) instead of plain rollers. In Automotives, these bearings are generally used in pairs and these can take axial and radial loads. These bearings are used in the differential assembly, wheel hubs etc.

Fig 4




**Details of engine bearings**

**Engine bearings:** These are also called "Shell bearings or sliding function bearings or precision insert bearings. These are largely used for free rotation of crankshaft, connecting rods and camshaft. They provide low frictional areas for these shafts to rotate smoothly under different speeds and loads.

**Shell bearings:** In this lesson, some more useful points are discussed on the shell bearings. They are stated as below:

- Qualities of engine bearings
- Bearing materials
- Bearing spread and crush
- Bearing failures and remedies
- Connecting rod and camshaft bearings
- Load on precision insert bearings
- Advantages of using insert bearings.

## Crankshaft balancing, firing order of the engine

**Objectives:** At the end of this lesson you shall be able to
- **state the types of crankshaft balancing**
- **state the importance of the crankshaft balancing**
- **state the function of firing order.**

**Balancing of crankshaft:** Internal combustion engines have reciprocating parts and they create vibrations, when the engine is running. Every two revolutions of the crankshaft one power impulse in four stroke engine. Balancing of the engine is necessarily required for smooth running of the engine.

The crankshaft is subjected to torsion vibration and engine vibration. Engine vibration is due to the uneven weight distribution on the crankshaft and the unbalanced reciprocating forces of pistons and connecting rods. Balancing is achieved by removing materials (by drilling) in the crank web or by adding weight to the shaft between centres in a special balancing machine.

**Types of balancing:** There are two types engine balance, (i) power balance (ii) mechanical balance

**Power balance:** When the engine power impulses occur at regular intervals with relation to the revolution of the crankshaft and each power of the engine impulse exerts the same force.

**Mechanical balance:** Engine assembling parts of crankshaft connecting rod and pistons are rotating in reciprocating motion, so that crankshaft counter balanced in operation mechanically minimize the vibration of the engine. The rotating parts of an engine can be balance by bringing them into static and dynamic balance.

The main rotating parts are balanced mechanically by crankshaft counter weight and flywheel piston and connecting rods shocks on crankshaft are called primary intertie force. The angularity of the connecting rods produce secondary vibration, it is called secondary intertie force. The perfect static and dynamic balance of crankshaft and flywheel reduce the vibration.

**Firing order:** The sequence of power impulses occur is an engine is called firing order. The firing order in which cylinder deliver their power strokes is selected as a part of the engine design to obtain the best engine performance. The firing order is shown by the sequence of the number of cylinder in which the cylinder deliver their power strokes. Which is the nearest cylinder to radiator is designated as number one cylinder in an inline engine

Three cylinder 1 -3 -2

Four cylinder 1 -3-4-2

Five cylinder 1-3-5-4-2

Six cylinder 1-5-3-6-2-4

Eight cylinder inline engine 1-8-7-3-6-5-4-2

Eight cylinder v8 engine 1-3-2-5-8-6-7-4

# Flywheel

**Objectives:** At the end of this lesson you shall be able to
- **state the function of flywheel**
- **state the construction of flywheel.**

### Function of Flywheel

The flywheel stores energy during the power stroke and supplies it to the crankshaft during the idling stroke i.e. suction, compression and exhaust. In many engines the flywheel also serves as a mounting surface for the clutch.

### Construction

The flywheel Fig 1 is attached to the rear end of the crankshaft (1) by means of bolts (4). A large ring gear (3) is attached to the flywheel. While starting, the engine starter motor 's gear engages with the ring gear (3), and the flywheel (2) rotates to crank the engine. When an automatic transmission is used the torque converter assembly acts as the flywheel. The flywheel also serves as a mounting and frictional surface for the clutch assembly. The size of the flywheel depends upon the number of cylinders and general construction of the engine.

### Timing marks of the flywheel

An engine is provided with timing marks (Fig 2) on a rotating member and a stationary pointer. The timing mark (1) in punched on the circumference of the flywheel / crank pulley. A pointer (2) is fixed on the flywheel housing (3) / timing cover. Timing is adjusted when the pointer (2) coincides with the flywheel mark (1) and at this times distributor contact should just start at open.

Fig 1

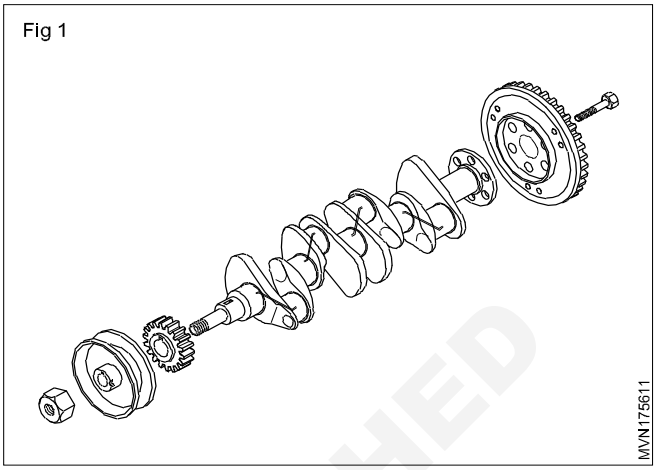
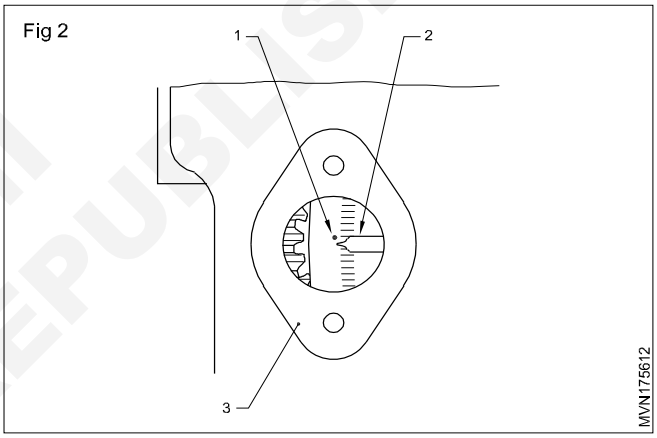



Fig 2






# Vibration damper

**Objective:** At the end of this lesson you shall be able to
- **functions of a vibration damper.**

Vibration dampers are fixed the front end of the crankshaft.

The main function of a vibration damper is to reduce torsional vibrations and stress. It helps in reducing the flywheel weight and increases the crank-shaft life.

### Types and Construction

There are mainly two types of vibration dampers in use.

### Rubber floating type

The damper (Fig 1) is made into two parts, a small inertia ring or damper flywheel (1) and the pulley (2). They are bonded to each other by a rubber insert (3).

As the crankshaft speeds up or slows down, the damper flywheel has a dragging effect. This effect slightly flexes the rubber insert (3) which tends to hold the pulley and crankshaft to a constant speed. This tends to take on the twist and untwist action and torsional vibrations of the crankshaft.

### Clutch and rubber bush dampers

**I**n this type (Fig 2), in between the damper (1) and the pulley (2), two friction facings (3) are provided. A spring (4) and a plate (5) are fixed to control the friction between the damper (1) and the pulley (2).

Fig 1

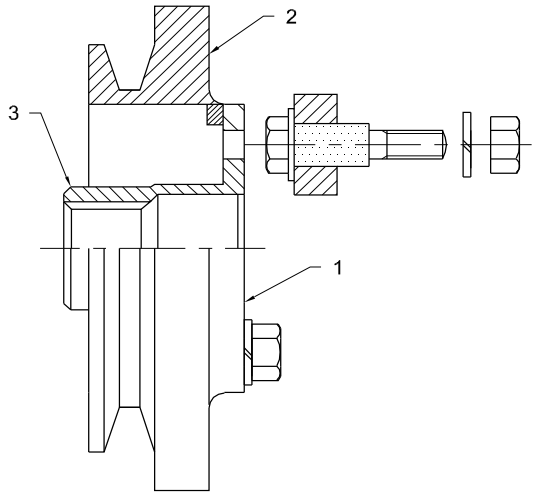



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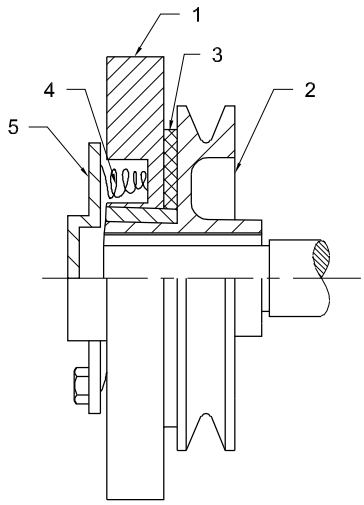
Fig 2

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# Clutch

**Objectives:** At the end of this lesson you shall be able to

- **state the need for a clutch**
- **list out different types of clutch**
- **state the function of the clutch**
- **state the construction of fluid coupling.**

**Need for a clutch:** Expressing different loads in engine requiring change in torque to clutch the rated power available in the engine. This can be achieved by shifting g0ears.

While shifting gears, the speed of the sliding sleeve and the respective gear on the main shaft should be synchronised to avoid gear collision noise. This is achieved by disconnecting the transmission of power from the engine flywheel to the gear box shaft with the help of the clutch. Thus, clutch is used to connect and disconnect transmission of power from the engine flywheel to the gear box drive shaft.

**Function of the clutch**

– The clutch should connect the power from the engine to transmission smoothly gradually without affecting the other components.

– It should damp vibrations and shocks during operation.

– It should not slip under high torque transmission.

Torque transmission by clutch depends upon the:

– contact area of the clutch plate.

– co-efficient of friction of lining material.

– spring pressure.

– number of clutch plate used.

**Different type of clutches:** They are;

– Single plate clutch

– Multi - plate clutch

– Dual clutch

– Dry and wet clutches

– Cone clutch

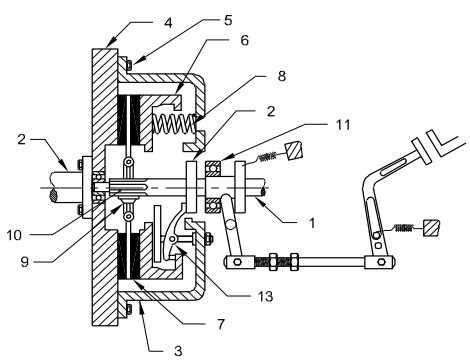
– Dog clutch

– Diaphragm spring type clutch

– Fluid coupling

**Single plate clutch (Fig 1):** A clutch consists of driven (1) and driving shafts (2). A clutch cover (3) is mounted on the flywheel (4) by a set of screws (5). A pressure plate (6) presses the clutch plate (7) against the flywheel by the pressure of springs (8). The clutch plate hub (9) is splined (10) on the gear box drive shaft. The clutch plate rotates along with flywheel and power is transmitted to the drive shaft. When the clutch pedal is pressed, the release bearing (11) pushes the thrust plate (12) through the linkages.

Fig 1




WORKING OF SINGLE PLATE CLUTCH

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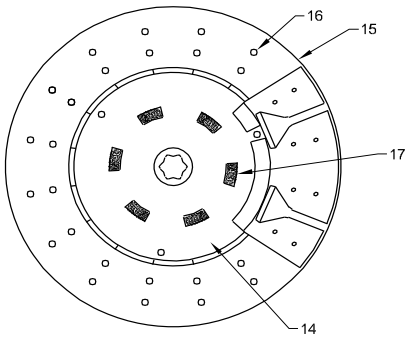
The thrust plate pushes the clutch finger (13), the clutch finger swivels and moves the pressure plate away from the flywheel. When the springs are compressed, the pressure plate does not exert pressure on the clutch plate and in turn

the clutch plate does not transmit power from the flywheel to the drive shaft.

The clutch plate (Fig 2) consists of a torque plate (14) and clutch lining (15) made of frictional material fixed on the torque plate by reverts (16). Damper spring (17) are fixed in the torque plate to dampen shocks and vibrations during clutch operation.

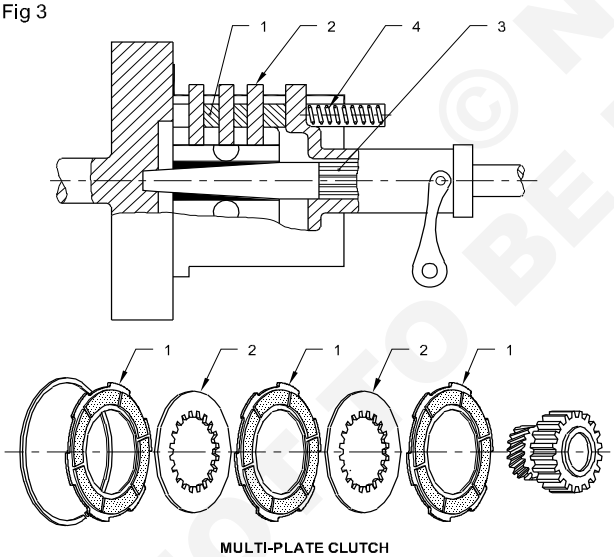
Fig 2




CLUTCH PLATE

**Multi-plate clutch (Fig 3):** To transmit more torque, more contact area is necessary. Instead of using a larger diameter clutch plate, two or three small clutch discs are used to increase in frictional area. The pressure plates (2) and clutch plates (1) are alternatively arranged on the clutch shaft (3) and compressed by a number of pressure springs (4). This type works in the same way as a single plate clutch does.

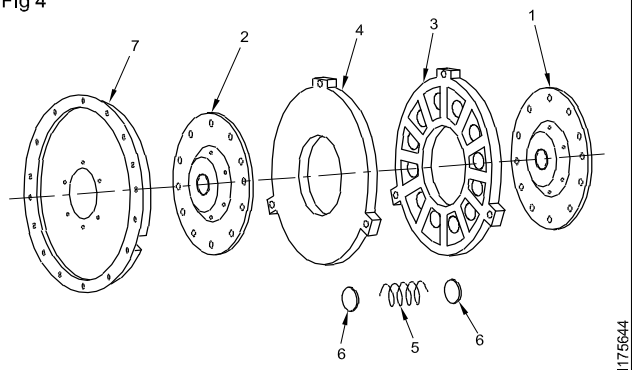
Fig 3




MULTI-PLATE CLUTCH

**Dual clutch (Fig 4):** Dual clutches are combination of the primary master clutch (1) transmitting torque to the driving wheel and secondary P.T.O clutch (2) to drive P.T.O shaft. Dual clutch is mounted into the flywheel with primary pressure ring plate (3) and PTO pressure ring plate (4) (Fig 4) Disc spring (5), inserted in between two pressure rings, through insulating pad (6), pressing on both plates with there outer friction surface is the pressure element. Clutch guard (7) is mounted on the flywheel for safety reason. When clutch pedal is pressed partially, it disengages gearbox, while when pressed completely P.T.O drive is cut off.

Fig 4

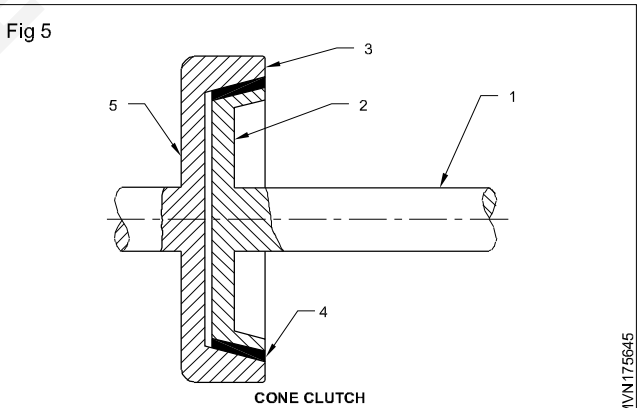



EXPLODED VIEW OF DUAL CLUTCH SYSTEM

**Dry and wet clutches:** These clutches may be dry or wet. When the clutch is operated dry without oil, it is called a dry clutch, but where the oil is used in the clutch it is called a wet clutch. Oil is used to cool the friction plate. The wet clutches are generally used along with or as a part of automatic transmission. These types of clutches are mostly used in heavy tractor and earth moving machineries.

**Cone clutch (Fig 5):** In this case friction plates are in the shape of a cone. When the clutch is engaged the friction surfaces (4) of the male cone (2) on the clutch shaft (1) engage with the female cone (3) on the flywheel (5) due to the force of the spring. When the clutch pedal is pressed the male cone slides on the splines of the clutch shaft against the spring force. It gives more frictional area and is simple in construction. It is practically absolute and the same principle/device is used in the synchroniser unit in a synchro-mesh gear box.

Fig 5

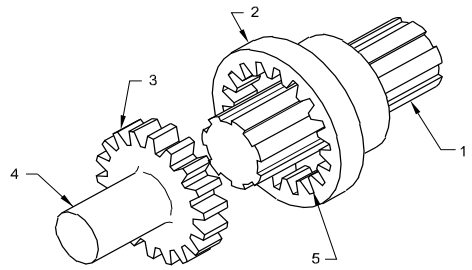



CONE CLUTCH

**Dog clutch (Fig 6):** This type of clutch is used to lock two shafts together or to lock a gear to a shaft. When the sleeve (2) slides on a splined shaft (1) its internal teeth (5) match with the dog clutch (3) teeth of the driving shaft (4) and the clutch is engaged in this type there is no possibility of a slip as both the shafts revolve exactly at the same speed.

**Diaphragm spring type clutch (Fig 7):** In some tractor, instead of using coil spring a conical dish shaped steel plate diaphragm spring (1) is used. It exerts force on the pressure plate (3) to press the clutch plate (4) firmly for engaging the clutch. It does not have release levers. The slots start from the centre of the diaphragm to form a number of release fingers (2). It requires very little pedal effort to disengage the clutch and it works noise free.

Fig 6




DOG CLUTCH

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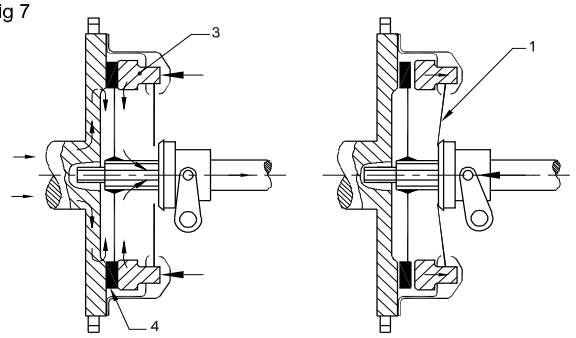
Fig 7




DIAPHRAGM SPRING CLUTCHES

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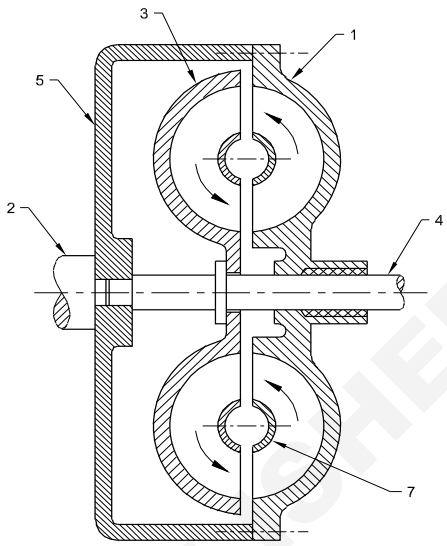
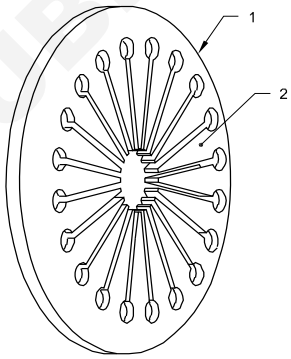
**Fluid coupling (Fig 8):** Fluid coupling consists of two half shells fitted with interior fins (7) which rotate from the hubs. These unit are mounted very close to each other with their open ends. So that they can turn independently without touching each other. A housing (5) surrounds both units to make a complete assembly inside, the assembly is fitted with 80% of fluid. The driving unit impeller (1) is linked to the crankshaft (2) rotates. The driven impeller (3) is mounted on the driven shaft (4) due to the movement of the oil, the impeller (3) rotates and transmits torque to the driven shaft (4).

Fluid coupling enables the driver to use the clutch and gear with less skill and fatigue than the conventional clutch. Wrong clutch engagements or selection of improper gear will not produce any of noise or sound. Any sudden load is also cushioned and absorbed by the fluid coupling. Dynamic stresses or breakages of the gear teeth of the mechanism and final drive are reduced to minimal. Fluid coupling is used with the epicyclic gear box as the output shaft (drive shaft) is always in motion.

Fig 8




FLUID COUPLING




DIAPHRAGM SPRING TYPE CLUTCH

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## Cylinder block

**Objectives:** At the end of this lesson you shall be able to

- **describe the function of the cylinder block**
- **state the constructional features of the cylinder block**
- **state the function of crankcase**
- **state the function of the cylinder liner**
- **list out the various types of cylinder liners**
- **list the material of cylinder liners.**

**Cylinder block:** It forms the base of the engine. Two types of cylinder blocks are used in vehicles.

**Cylinder block construction**

**Single piece casting:** In this the type cylinder block and crankcase are cast as one piece. It gives better rigidity and it is easy to cast, which reduces the cost of manufacturing. (Fig 1)

**Two-piece casting (Fig 2):** In this type the cylinder block and crankcase are cast separately. The crankcase is bolted to the cylinder block. It reduces the problem of lifting the cylinder block from crankcase, during repairing or overhauling. This type of casting is used in heavy generating sets.

The cylinder block is made of cast iron or aluminium alloy. Inside the cylinder block, water jacket passages for the coolant and lubricating oil are provided. The cylinder head along with the valve assembly is fitted on the top of the cylinder block by nuts and bolts. The oil sump is bolted to the cylinder block /crankcase from the bottom. The crankshaft is supported on split type bearings.

Fig 1

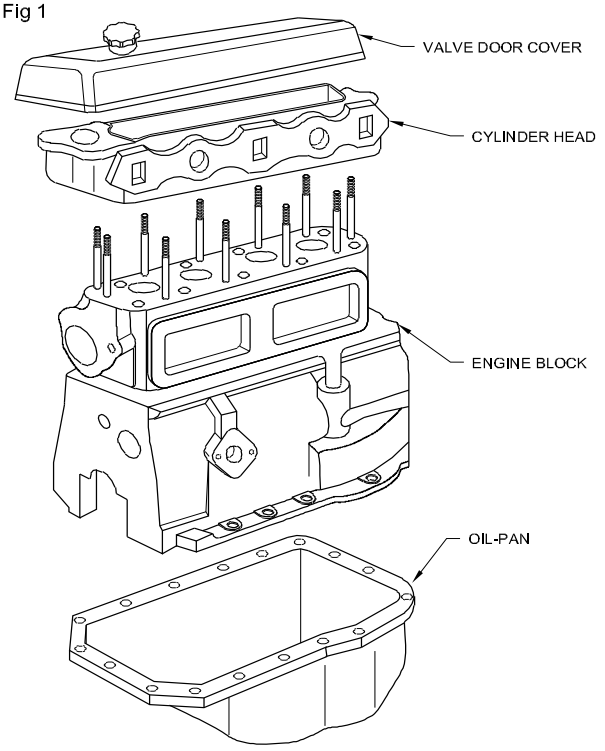
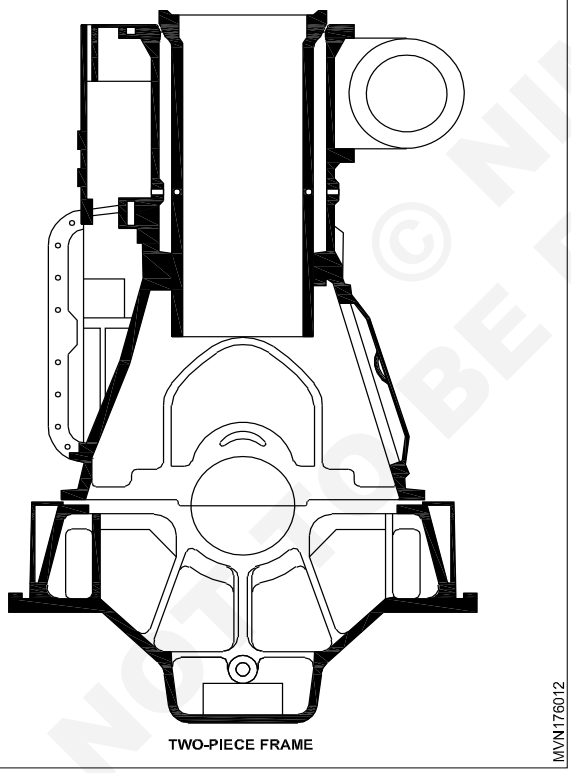



Fig 2




The half bearing is fixed on the web which is cast with the cylinder block, the other half bearing is fixed in the bearing cap. The bearing cap is fastened with the web by nuts and studs. This portion where the crankshaft is fixed is known as the crankcase. In the cylinder block passages are provided for the camshaft and camshaft bearing, push rods, tappets etc.

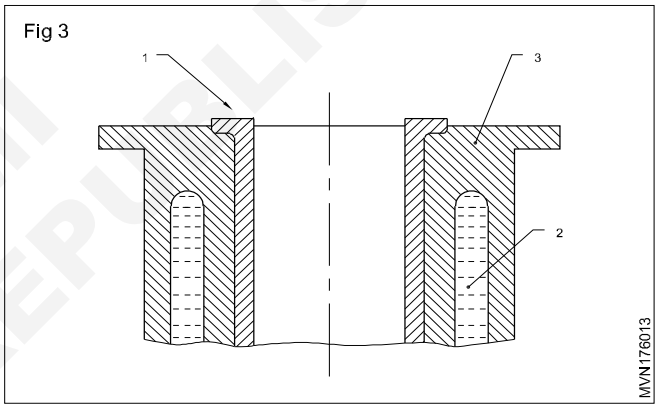
**Crankcase:** Crankcase is attached to the bottom space of the cylinder block. It act as base of the engine and supports the crankshaft oil pan and also provides the arms for supporting the engine of the frame. The oil pan and the lower part of the cylinder block together are called the crank case.

**Crank case material:** The cylinder block and upper half of the crankcase usually made of a ferrous alloy or semi steel to provide a stronger and harder casting. The use of stringer and together materials permits timer casting walls, thus saving weight and improving of cooling effect and good thermal conductivity.

**Liners:** A liner is a thin cast iron circular shell which is centrifugally cast. It contains chromium for hardness. It protects the cylinder block from rapid wear and damage due to combustion. The life of the cylinder block is increased by using a liner, since the block does not bear combustion pressure and temperature directly.

**Dry type:** In the dry type liner (1) the cooling water (2) of the engine does not come in direct contact with the liner. These liners have an interference fit with a cylinder block (3). In the dry type liner a special process is required to insert them into the bores, and to remove them from the bore. (Fig 3)

Fig 3

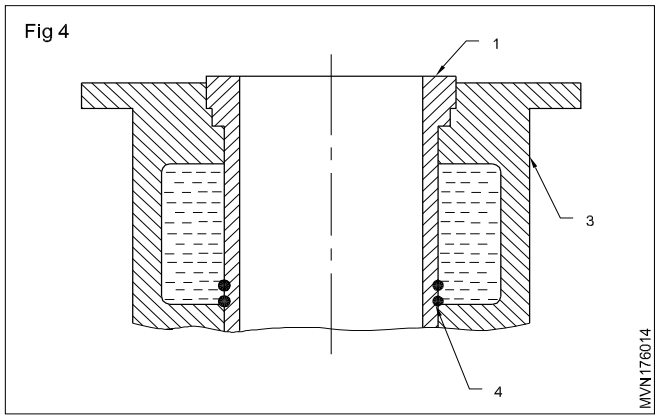



**Wet type:** In a wet type liner (1), the liners are in direct contact with the cooling water. (Fig 4)

Wet type liners are loose in the cylinder block (2) and these are supported between a recess in the block and the cylinder head. Gaskets or sealing 'O' rings (3) are used in liner grooves to seal against gas, oil and water leakage. Removal and fitment of these liners is easier than it is in the case of dry type liner.

**Materials:** Materials used for liners are nitrided steel, nitrided cast iron, chromium-coated alloy steel. Liners are harder than the cylinder blocks.

Fig 4



# Engine cooling system

**Objectives:** At the end of this lesson you shall be able to
- **state the necessity of the cooling system**
- **list out the different types of cooling systems**
- **state the advantages of the forced type of cooling system**
- **draw the water circulation path in an engine block**
- **state the function of the water pump, radiator, temperature indicator, pressure cap**
- **state the need and function of the thermostat valve, recovery system**
- **state the different types of thermostat valves.**

Combustion of fuel inside a cylinder develops a very high temperature (Appx. $2200^0$C). At this temperature the engine parts will expand and tend to seize. Similarly the lubricating oil will loose its property. Therefore it is necessary to keep the engine temperature to operating limits. This is done by the cooling system. Heat is removed from the engine by cooling media (water or air) and is dissipated to the atmosphere.

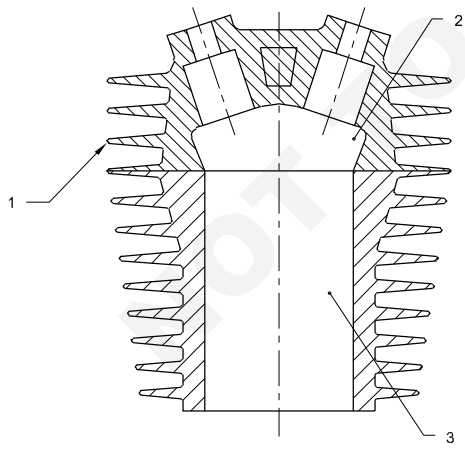
**Types of cooling systems:** There are two types of cooling systems used in engines.

- Direct cooling - air cooling.
- Indirect cooling - water cooling.

**Air-cooled engines**

In air-cooled (Fig 1) engines, cylinders are semi-independent. They are not grouped in a block. Metal fins (1) are provided on the head (2) and cylinder (3), to help dissipate heat from the engine. In some engines fans are also used to improve air circulation around the cylinders and heads. This type of cooling system is employed in two-wheelers and small stationary engines. These are used in both S.I. and C.I. engines.

Fig 1



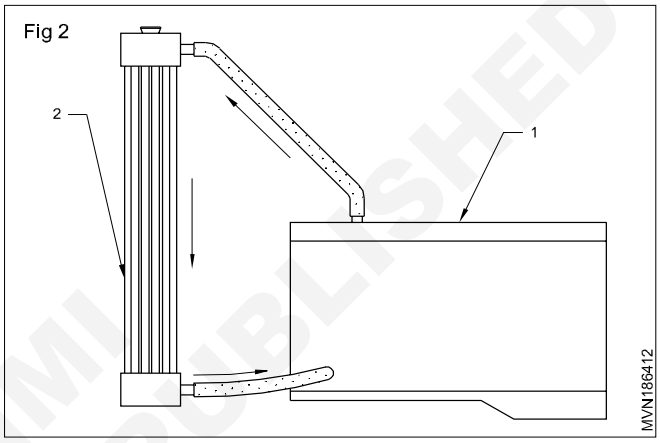

**Water cooling:** Two types of water cooling systems are used.

1 Thermo-syphon system (Fig 2)

2 Forced circulation system (Fig 3)

**Thermo-siphon system (Fig 2)**

Fig 2

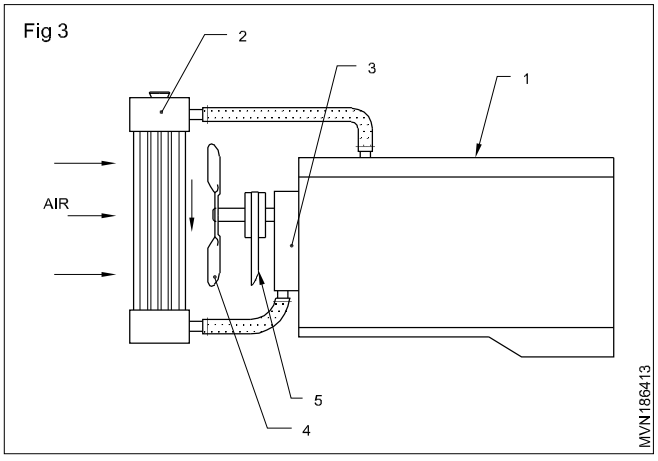



In this system no pump is used for water circulation. Water circulation is obtained due to the difference in the densities of hot and cold water. Water absorbs the heat and rises up in the block (1) and goes to the radiator's (2) top side. Water is cooled in the radiator (2). It again goes to the water jackets in the engine. To maintain a continuous flow of water the level of water is maintained at certain minimum level. If the water level falls down the circulation will discontinue. This system is simple but the rate of cooling is very slow.

**Pump circulation system (Forced feed system) (Fig 3)**

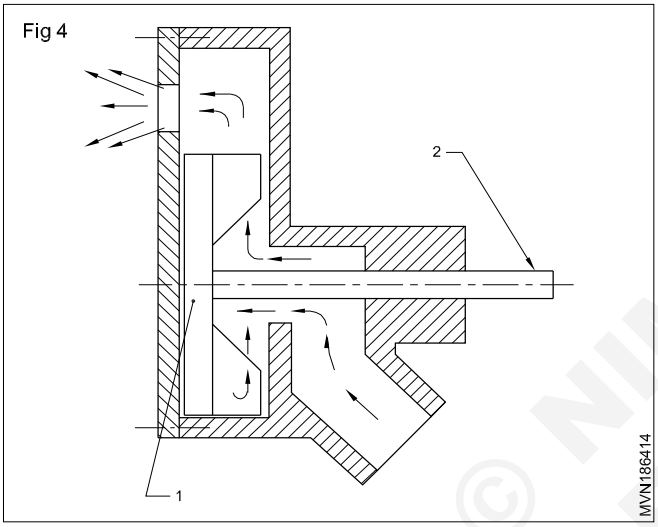
In this system water is circulated by a pump (3). The pump is driven by a belt (5) which is connected with the crankshaft pulley. The circulation depends upon the engine speed. More water is circulated at higher engine speed.

Fig 3



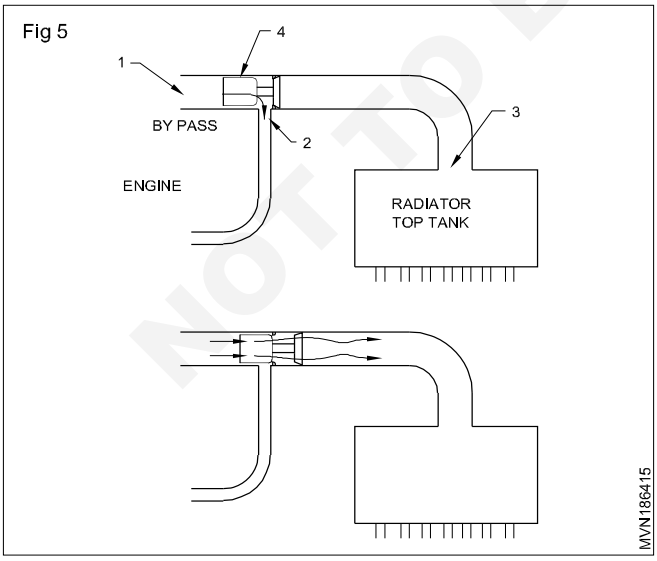
The water absorbs heat from the engine and flows to the radiator's (2) top tank. Water from the top tank of the radiator (2) flows down to the bottom tank. The fan (4) draws the air through the radiator's fins and cools the hot water. Cold water from the bottom tank is again pumped to the engine and the cycle is repeated.

**Water pump:** The centrifugal type water pump (Fig 4) is used in engines. It is mounted on the front side of the cylinder block or head. The water pump is driven by the crankshaft pulley through the fan belt. The impeller (1) is mounted on one end of the water pump shaft (2). The shaft (2) is fitted in the pump housing with bearings. A water seal is provided in the pump to prevent leakage of water and to prevent water entering into the bearings. When the impeller rotates it draws water from the lower tank of radiator, and pumps water to the engine block, by centrifugal force under pressure. The fan is mounted on the water pump pulley.



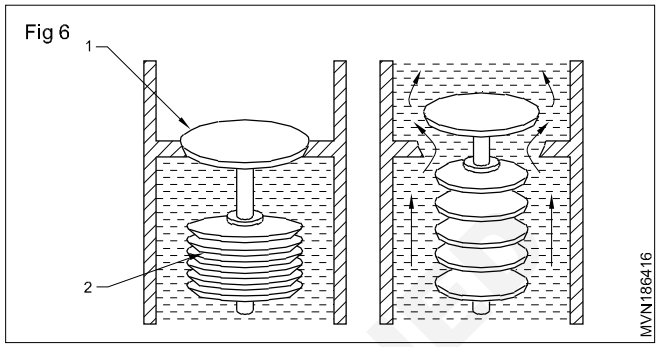

**Thermostat**

The thermostat (Fig 5) helps to bring the cold engine to the operating temperature quickly.

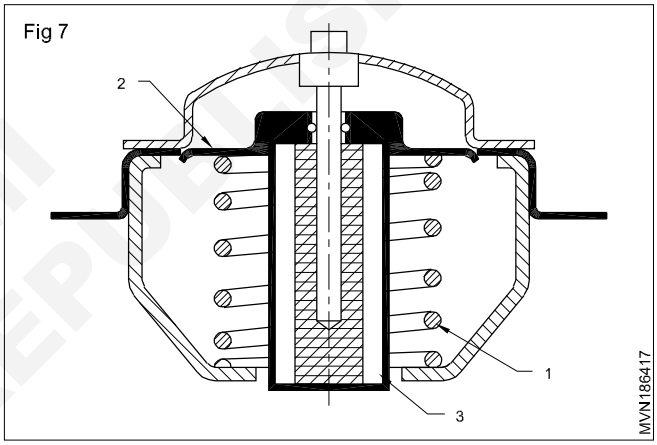



It is fitted in between the water outlet of the cylinder head (1) and the inlet (2) of the radiator in the water cooling system. When the engine is cold, the thermostat (4) is closed. It does not permit water to enter the radiator. Water recirculates in the engine through the bypass hole (2) and the engine reaches the operating temperature quickly. Once the engine has reached the operating temperature the thermostat (4) opens. It closes the bypass hole (2) and now permits water to enter the radiator tank (3). Thermostats are rated to open at different temperatures. Two types of thermostats are used.

- Bellows type (Fig 6)




- Wax type (Fig 7)




**Bellows type**

It has a flexible metal bag closed at both ends. The metal bag is partially filled with ethyl which has a low boiling temperature.

When the engine is cold the valve (1) closes its outlet passage and does not allow water to reach the radiator top tank from the engine, but is circulated through the bypass port to the engine.

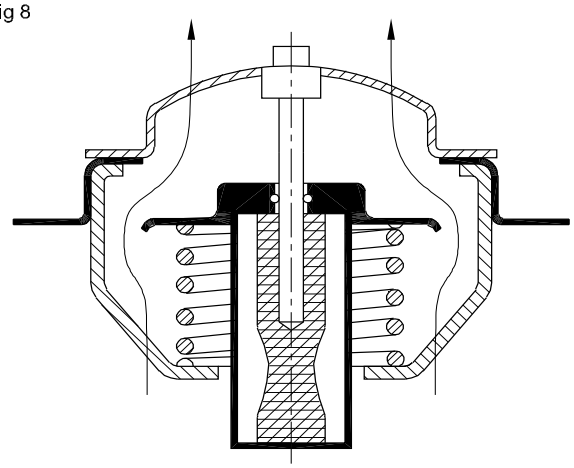
When the water reaches the working temperature, ethyl in the closed bellow (2) expands and opens the valve (1). Now the water reaches the radiator top tank from the engine. In the valve's opened position the bypass passage is closed.

**Wax pellet type**

In this type a wax pellet (3) (Fig 8) is used as a heating element. When the circulating water's temperature is lesser than the operating temperature, the spring (1) keeps the valve (2) in the closed position and the water does not reach the radiator top tank from the engine.

As the water reaches the operating temperature the wax pellet expands and forces the valve (2) to open against the spring tension. Now the water reaches the radiator top tank, from the engine. At this position the bypass port is closed by the valve.

Fig 8



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## Components of water cooling system

**Objectives:** At the end of this lesson you shall be able to
- **state the constructional features of a radiator**
- **state the need of a pressure cap**

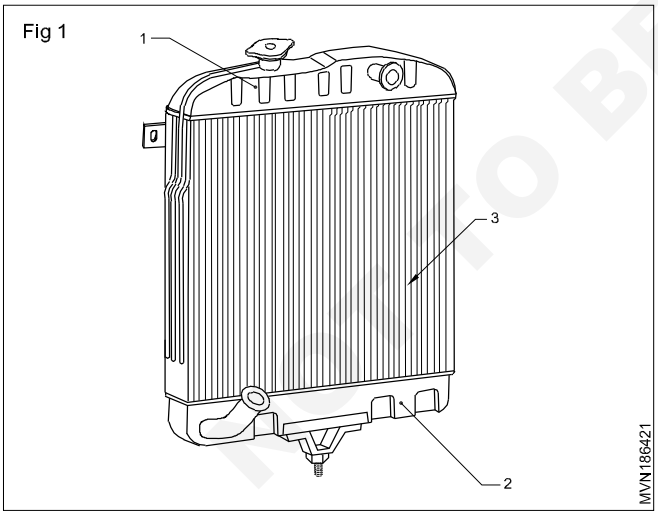
### Radiator

The purpose of a radiator in the cooling system is to cool hot water coming out of engine.

It has a large cooling surface area to allow enough of air to pass through it. Water circulated through it is cooled by the passing air.

The radiator (Fig 1) consists of an upper tank (1),a lower tank (2) and in between the upper and lower tank radiator cores (3) are provided. The upper tank (1) is connected to the water outlet of the engine through a rubber hose. The lower tank (2) is connected to the water pump through rubber hoses.

Fig 1

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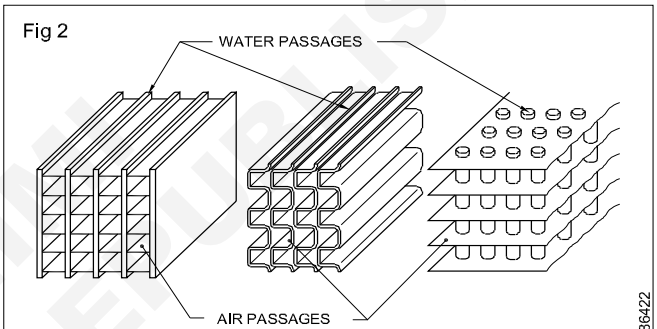
Radiator cores are classified into two types.
- Tubular core (Fig 2)
- Cellular core (Fig 3)

### Tubular core

In a tubular type the upper and lower tanks are connected by tubes. Water passes through these tubes. Cooling fins are provided around the tubes, to absorb and radiate heat to the atmospheric air.

Fig 2




TUBULAR RADIATOR SECTIONS

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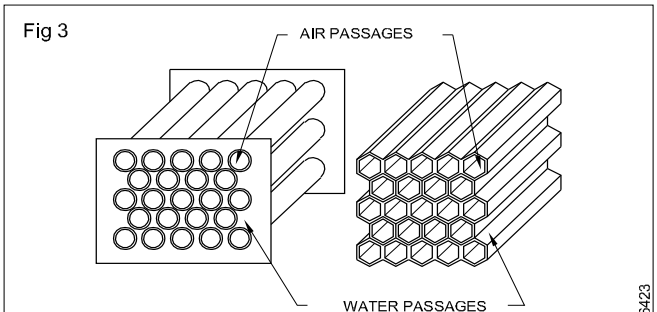
**Cellular cores:** In the cellular type a large number of individual air cells are provided and surrounded by water. Because of its appearance, the cellular type is known as a 'honeycomb' radiator.

The material of the core is of copper and brass. The parts are normally connected together by soldering.

Pressure cap: In normal atmospheric conditions water boils at 100°C. In higher altitude height the atmospheric pressure is low and water boils at a temperature below 100°C. To increase the boiling temperature of water the pressure of the cooling system is increased. This is achieved by providing pressure caps to seal the system. The coolant loss, due to evaporation is also minimized, by using a pressure cap. (Fig 4)

Fig 3




CELLULAR RADIATOR SECTION

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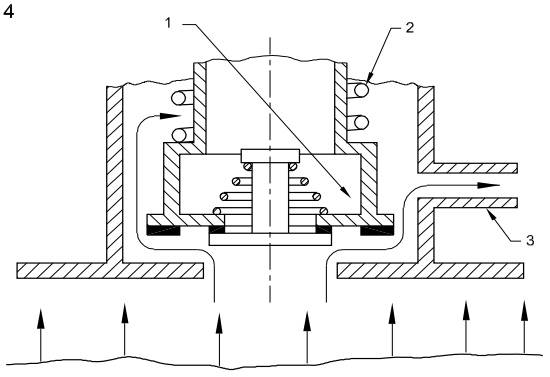
Fig 4




It also permits the engine to operate at a higher temperature so that better efficiency of the engine is achieved.

The pressure cap is fitted in the filler neck portion on the top of the radiator tank. If pressure is increased by 15 P.S.I., the boiling temperature raises to 113°C. The pressure cap has two valves.

- Pressure valve
- Vacuum valve

**Pressure valve**

If the pressure in the system rises it may damage the components. To avoid this a pressure relief valve (1) is used to release the excess pressure. It is a spring- loaded valve. The spring's (2) tension depends on the system's pressure.

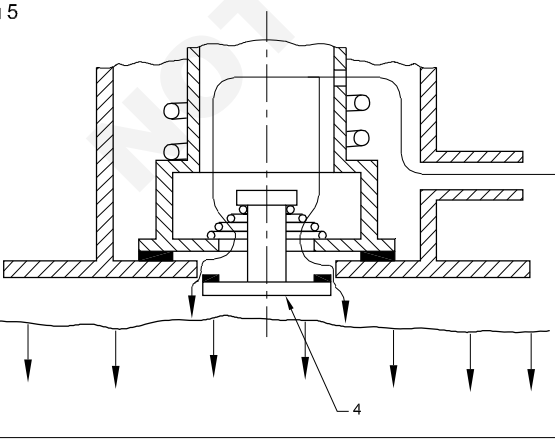
When the cooling water of the engine is heated up it expands which results in high pressure in the system. If the force due to pressure is more than the spring's (2) tension the valve opens and water vapour/steam escapes through the overflow pipe (3) until the pressure is lowered to the preset value.

**Vacuum valve**

When the engine cools down the pressure in the system decreases due to loss of the coolant and a vacuum is created.(This valve is also located in the cap and fitted in the filler neck of the radiator)

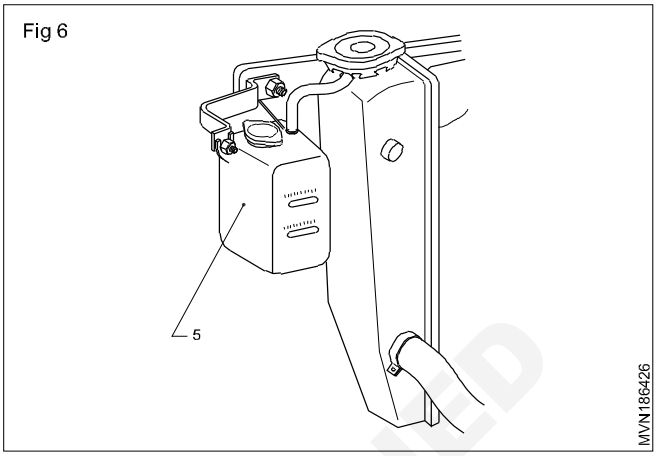
At this time the vacuum valve (4) (Fig 5) opens and air flows into the system until the vacuum is filled up in the system.

Fig 5




In some engines an overflow pipe is connected to an expansion tank (5). The expansion tank (5) (Fig 6) collects the water vapour during the pressure valve operation, and the same vapour, after condensing, goes to the radiator when the vacuum valve is in operation.

Fig 6




**Temperature indicator:** The temperature indicator is fitted on the instrument panel it indicates the temperature of the water in engine water jackets. There are two types of temperature indicator used in an Automotive.

1 Mechanical type

2 Electric type

Mechanical type temperature indicator consists of a sealed bulb that fits in the cylinder head water jacket and connected by a fine tube to temperature pressure gauge on the dash board.

The electric type water temperature sending unit is fitted in the cylinder head water jacket and it is connected through electric wire from ignition switch to temperature use sending units cold terminal through panel indicator bulb, another wire is connected from temperature sending units hot terminal to temperature warning lamp. When the engine temperature reaches normal, the green light circuit is completed by the engine unit and the dial indicates green light. When the engine is over heated the engine unit completes red light circuit and the dial indicates the red light.

In latest vehicle engine coolant temperature (ECT) sensors are using.

**Thermo switch:** This device is prevents the engine from over heating by activating radiator cooling fan, measuring the coolant temperature and controlling the level gauges and warning lights on the engine control unit. This device have upto four terminals and be installed on the radiator, the cooling system tubes or thermostate, so that the coolant flows across the sensing element (bimetal disc or thermistor).

**Function of thermo switch:** Theremo switch operates independent from any current supply, temperature detection is effected by means of a by metal disk switch on temperature. When this fixed switch on temperature is reached this bimetal disk well snap over, closing a contact

the circuit system and there by closing the electric of device to be started. After cooling down and reaching the cut off temperature. The bimetal disk will auto mechanically return into its original position and open the contact. The electric circuit is opened again.

**Coolant properties of an engine:** A efficient cooling system removes 30 to 35% of the heat generated in the combustion chamber.

- Coolant should be remove heat at a fast rate, when the engine is hot.
- Coolant should be remove heat at a slow rate when the engine is started until the engines reaches at its normal operating temperature.
- Coolant should not remove too much heat from the engine. Too much removal of the heat decreases thermal efficiency of the engine.
- It should circulate freely in the coding system.
- It should be prevent frequency and rust formations.
- It should be reasonably cheap.
- It should not waste by vaporisation.
- It should not deposit any foreign mater in the water jackets/radiator.

**Change of engine coolant interval**

1 Coolant should be replace as per specified by the manufacture.

2 Coolant should be replace during major repair in an engine or radiator.

3 Coolant should be replace at dilute (oil mix with water).

**Anti- Freeze mixtures**

1 Wood alcohol

2 Denatured alcohol

3 Glycerine

4 Ethylene glycol

5 Propylene glycol

6 Mixture of alcohol and glycerine

**Fan:** The fan is mounted behind the radiator on the water pump shaft. When engine is running the fan is drawn air through radiator core tubes and fins to cool the water in radiator.

In modern vehicles cooling fan is operated through electric power and it has fun actioning as per sensor base signal delivered by ECU normally it is not operating till water temperature is not reached as specified temperature limit.

## Engine lubricating system

**Objectives:** At the end of this lesson you shall be able to
- **list out the different types of engine lubricating systems**
- **explain the function of each system**
- **draw the oil circulation path in an engine block**
- **state the function of the pressure relief valve**
- **state the types of the pressure relief valve**
- **list out the different types of crankcase ventilation**
- **explain the positive crankcase ventilation.**

**Types of lubricating system:** The following types of lubricating systems are used in engines.

1 Petrol-oil lubrication

2 Dry sump lubrication

3 Splash lubrication

4 Pressurized lubrication

5 Combined lubrication

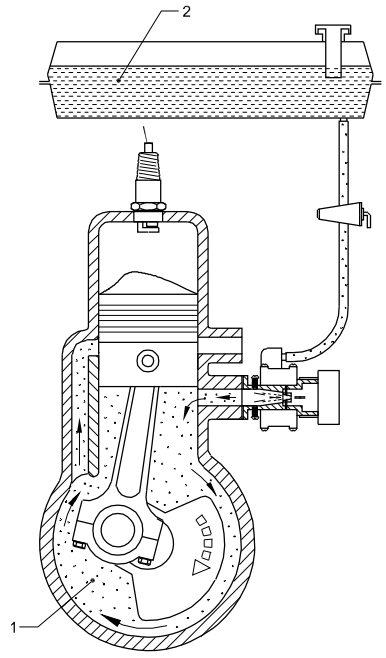
**Petrol-oil lubricating system (Fig 1)**

In this system the lubricating oil is mixed with the petrol(2). The ratio of petrol and oil is 20:1. When fuel goes in the crankcase chamber (1) and crankshaft bearings, the oil mist sticks to the moving parts and gives the lubricating effect. This system is mostly used in two-stroke engines.

**Dry sump lubricating system (Fig 2)**

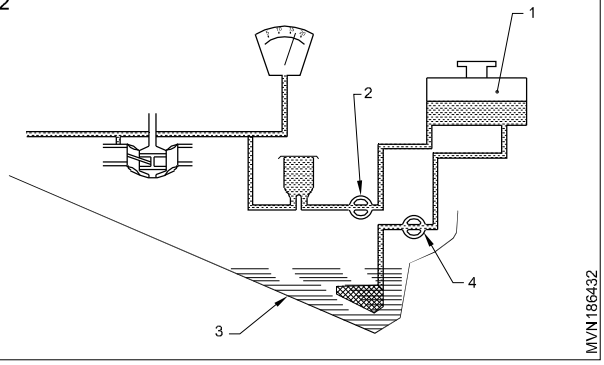
In this system the lubricating oil is delivered from a separate tank (1) to the components by an oil pump (2). The oil lubricates the moving parts and flows back to the oil sump (3). A scavenging pump (4) is provided to pump oil from the sump to the tank.

Fig 1



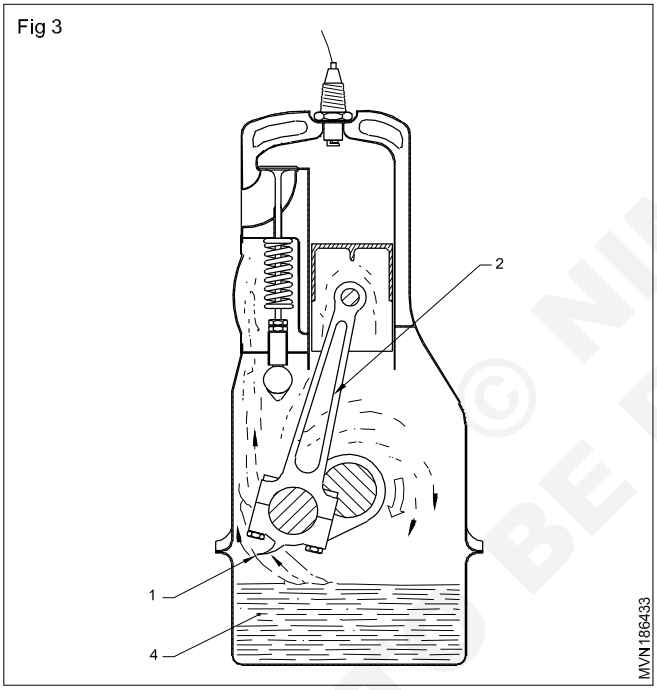
The lubrication effect is not affected when the vehicle is climbing up or moving down.

Fig 2




**Splash type lubricating system (Fig 3):** In this system the lubricating oil is stored in a sump(4). A dipper (1) is made at the lowest part of the connecting rod (2). When the crankshaft rotates the dipper (1) dips in the oil once in every revolution of the crankshaft and splashes oil on the cylinder walls.

Fig 3

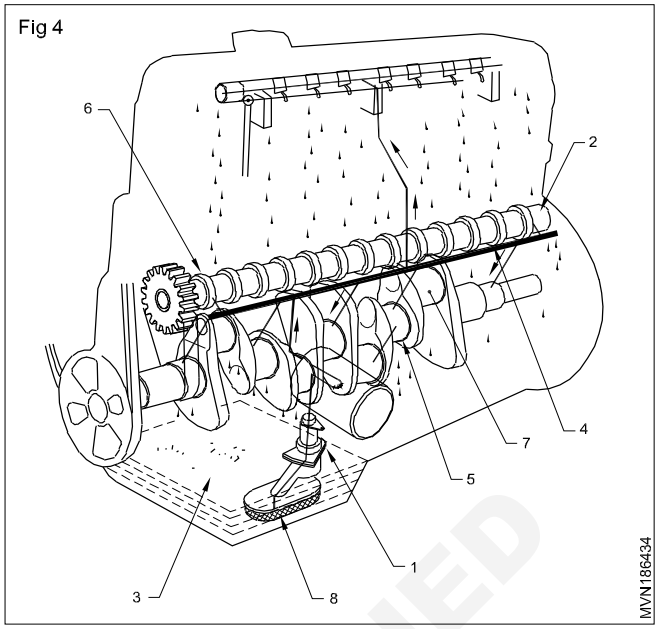



**Pressure lubricating system (Fig 4):** In the system the lubricating oil is circulated to all the moving parts of the engine under pressure, by the oil pump (1) driven by the camshaft (2).

The oil from the sump (3) is sucked by the oil pump (1) through the strainer (8) and suction pipe. The strainer filters the solid dust particles. The oil flows to the main gallery (4) from the filter's outlet. From the main oil gallery (4) the oil flows to the crankshaft main journals (5) and camshaft bushes (6).

From the crankshaft main journal (5) the oil flows to the crankpin (7). From the camshaft bush it flows to the cylinder head and lubricates the rocker bushes. When the crankshaft rotates the oil splashes from the connecting rod bearings and lubricates the piston rings and liner. In some engines an oil hole is drilled from the connecting rod big end to the small end to lubricate the gudgeon pin bush.

Fig 4



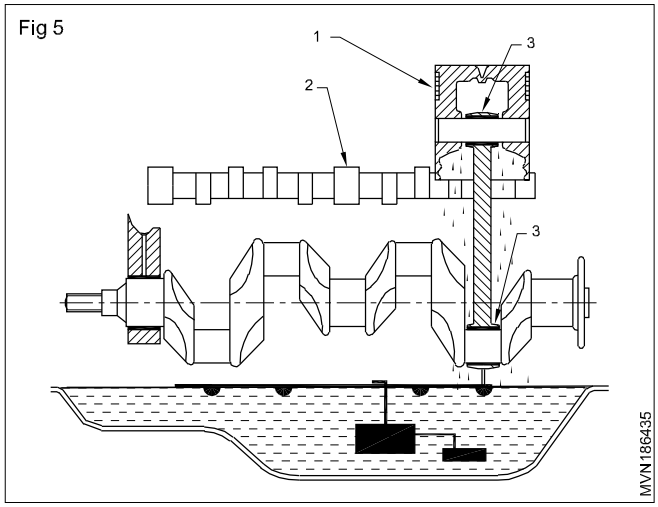

A relief valve is provided in the path between the oil pump and the filter. The relief valve limits the maximum pressure of the oil in the system. An oil pressure gauge or indicating lamp is provided to indicate the oil pressure.

After lubricating the various parts of the engine, the oil reaches the oil sump.Combined lubricating system

**Combined lubricating system (Fig 5)**

It is a combination of splash lubricating system and pressure lubricating system. Some parts are lubricated by the splash lubricating system - such as the cylinder wall (1), camshaft bearings (2), connecting rod bearing (3) and the remaining parts are lubricated by pressure lubricating system.

Fig 5

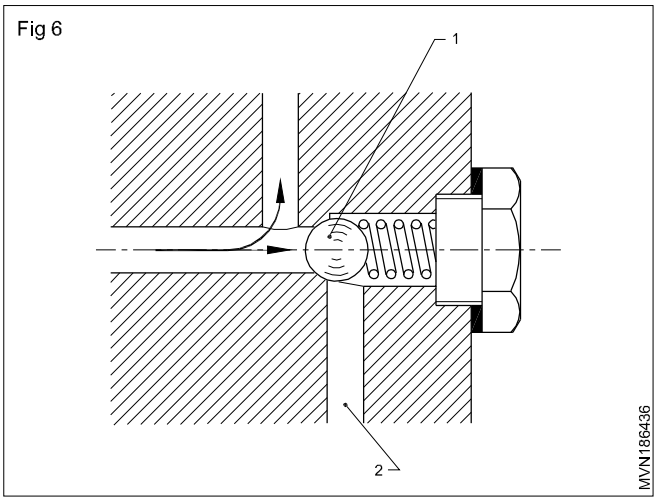



**Pressure relief valve**

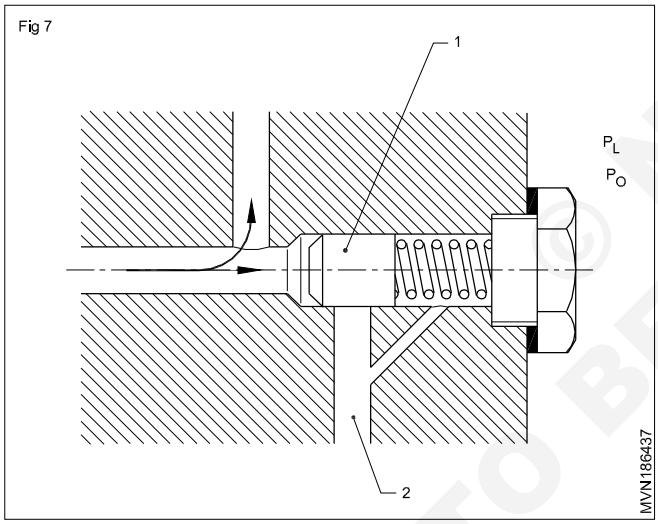
The pressure relief valve is used to limit the maximum pressure of the oil. When the oil pressure increases more than the prescribed limit, the relief valve opens and allows oil to return back to the oil sump directly. Following types of relief valves are used.

- Ball type
- Plunger type

**Ball type (Fig 6):** In this type of relief valve a spring-loaded ball (1) opens the connection to the return channel (2) when the oil pressure over comes the spring force. The oil flows through the return channel back to the oil sump.



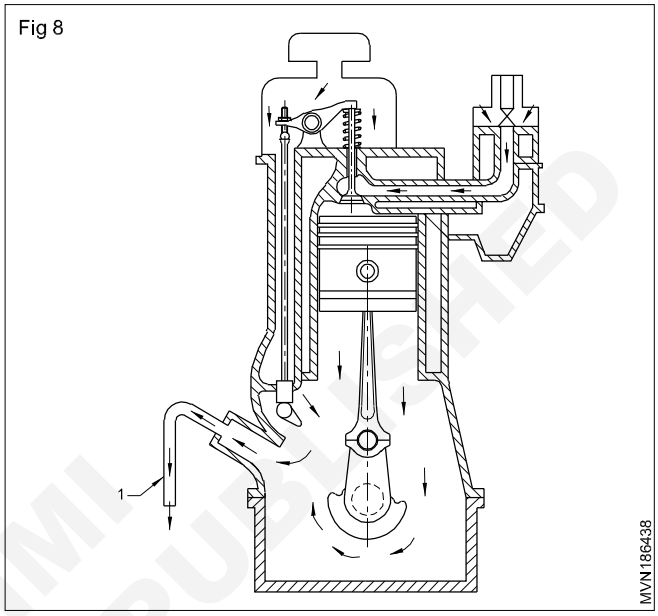

**Plunger type relief valve (Fig 7):** This type of relief valve is similar to that of the ball type except that a plunger (1) is used instead of a ball. A leakage oil relurn passage is provided to allow oil to return to the oil sump which has passed through the plunger (1).




**Crankcase ventilation (Fig 8):** In the crankcase oil gets diluted due to the mixture of blow by gases, carbon particles, metallic particles, sand, dust, dirt and the acids formed out of the exhaust gas condensation such as sulphuric acid and phosphoric acid. This affects lubrication and forms a sludge (accumulation of dirty oil). Frequent cleaning and change of oil is needed. To overcome this problem, crankcase ventilation is provided. Fresh air is allowed in the crankcase which passes out after circulation through a breather pipe (1) in the rear. This arrangement is known as OPEN TYPE CRANKCASE VENTILATION.

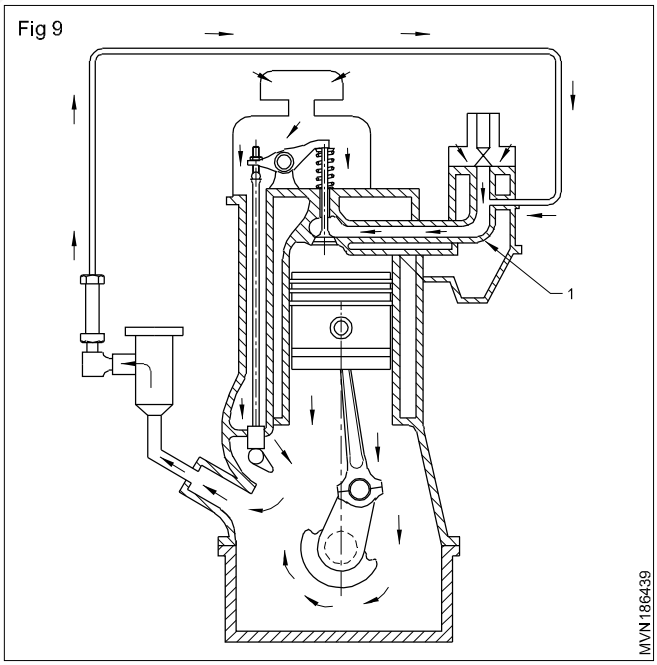
**Positive crankcase ventilation (Fig 9):** The exhaust gases and other particles going out of the engine are toxic and injurious to public health. To overcome this positive crankcase ventilation or closed type ventilation is provided. In this arrangement all air flowing out of the engine crankcase is drawn back into the inlet manifold (1) and fed into the engine. This prevents the flow of gases outside the engine.

**Function of sump:** Oil sump is the lowest part of the crank case (Engine). It provides a covering for the crankshaft and contains oil in it. In wet sump lubricating system, the oil is taken out from the sump and after lubricating different parts of engine again oil drops in to oil sump. It is made of steel pressing/aluminium/east iron. It contains drain plug at its lowest part to drawn out the oil. In dry sump lubricating system the oil is stored drain in a separate oil tank.




**Oil collection pan**

Oil pan is the lowest part of the engine. In dry sump lubricating system oil pan is collect the oil after lubricating different parts the engine oil drops in an engine and then oil is sent back to the oil tank by a separate delivery pump.



### Oil tank

In dry sump lubrication system, two oil pumps are used one for feed the oil from tank to lubricating system and another pump scavenging pump is sent oil from dry sump to oil tank. In this system oil is not stored in oil sump.

**Oil pick up tube:** The oil pick up tube is located in oil pump and it is connected from oil strainer to oil pump in wet sump lubrication system.

In dry lubrication system two pick up tube is used to pick up oil from oil tank to engine main gallory and oil drop sump to oil tank through suction pump and scavenging oil pump.

**Pick up tube:** In dry sump lubricating system pick up tube is connected between delivery pump and oil tank, to pick up the oil from sump to oil tank. In wet sump system pick up tube is connect the stainer and oil pump.

## Oil pump and Filter

**Objectives:** At the end of this lesson you shall be able to
- **state function of oil level and pressure indicator**
- **list out the types of oil pump**
- **list out the type of oil flow system**
- **purpose of the oil cooler.**

### Oil level indicator

It is a steel stick graduated at the front end for measuring the level (amount) of oil in the sump. The graduations are “Full” , “Half”, “Low” marks are provided on the bottom end of the dip stick. These marks show whether the oil is up to the required full or half level or the level is so low. The low oil level may cause danger to engine life.

For measuring oil level, remove the stick from the engine, clean and dipped into the oil sump and again taken out to see graduation oil has sticked.

### Oil pressure indicator

Oil pressure gauge or oil waring light is provided on the dash board to indicate the lubrication.Oil pressure during engine running.

### Oil pressure gauge

It is equipped with pressure lubricating system to warn the engine operator, what is the oil pressure is in the engine. The oil pressures are following types

1 Pressure expansion type

2 Electric type

a Balancing type

b Bimetal thermal type

### Oil pressure indicating light

The light comes when the ignition switch is turned on and the oil pressure is low. The circuit uses four stage diaphragm switch, which operates a warning lamp according to the pressure required for different engine speeds. The switch is located at the oil main gallery. Its connection with the warning light is through the ignition switch.

### Components of the lubrication system

### Oil pumps

The oil pump is used to pump oil from the oil sump to the oil galleries at a certain pressure.

It is located in the crankcase and is driven by the camshaft.

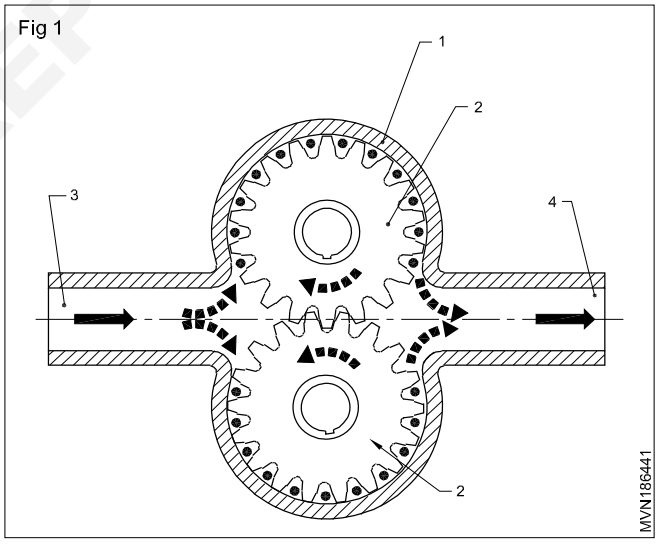
Four types of oil pumps are used.

- Gear type oil pump
- Rotor type oil pump
- Vane type oil pump
- Plunger type oil pump

### Gear type oil pump (Fig 1)

In this type two gears are fixed in the pump housing (1). The gears (2) have little clearance with the pump housing (1). When the gears rotate a vacuum is created in the casing.

Fig 1



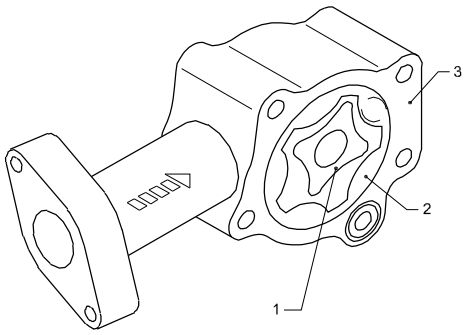

Oil is sucked through the inlet (3) and pumped to the oil gallery through the outlet (4).

### Rotor type oil pump (Fig 2)

The rotor type oil pump consists of an inner driving rotor (1), and an outer drive rotor (2) which rotates freely in the pump housing (3) and runs eccentrically in relation to the inner rotor.

The oil is sucked into the pump in the side where the volume between the rotor teeth increases and is pumped out on the side where the volume decreases.

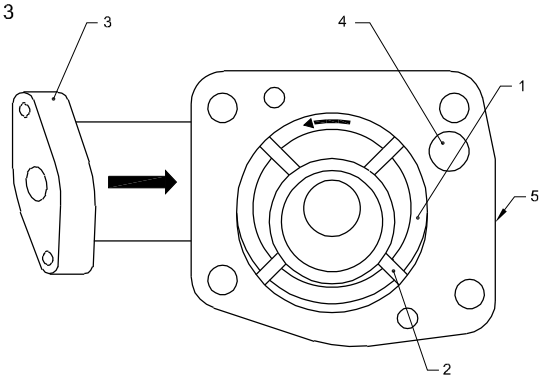
Fig 2




**Vane pump (Fig 3)**

In the vane type pump the rotor (1) runs eccentrically in the pump housing (5). Spring- loaded vanes (2) slide against the pump housing walls. Suction us created by the vanes (2) when the rotor (1) rotates. Oil is sucked through the inlet duct (3) and discharged through the discharge duct (4).

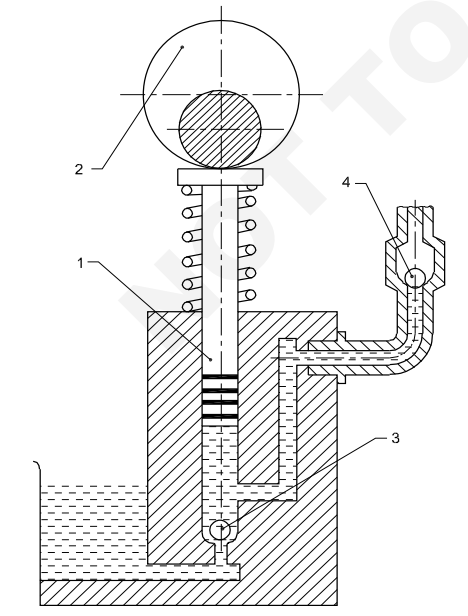
Fig 3




**Plunger type oil pump (Fig 4)**

In this type of plunger (1) moves up and down in the cylinder. It is operated by a special eccentric cam (2). This pump has two non-return ball valves (3) & (4). These valves are spring-loaded balls. One of these is on the suction side (3).

Fig 4

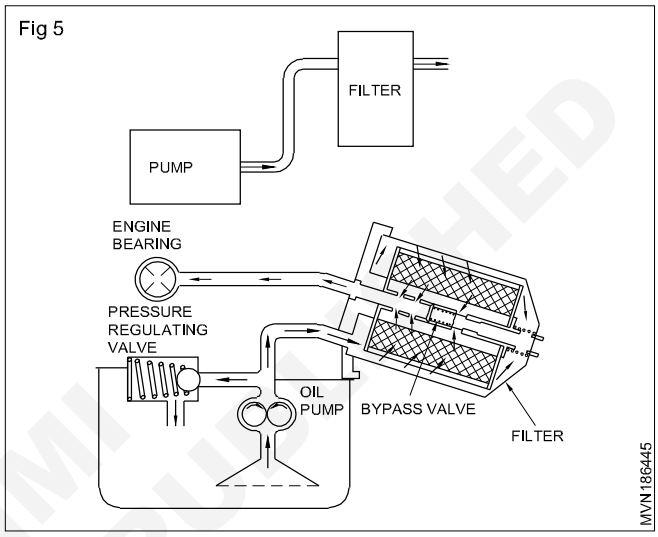



During the upward stroke the oil is sucked through the valve (3). During the downward stroke the non-return valve (3) closes. The other non-return valve (4) which is on the delivery side opens and permits the oil to flow out from the pump. This type of plunger pump is used in medium and high pressure lubricating systems.

**Oil filter**

**Full flow oil filter system (Fig 5):** In this system all the oil passes through the filter before reaching the main oil gallery. One bypass valve is provided in the filter which allows oil to reach the main oil gallery directly if the filter is choked.

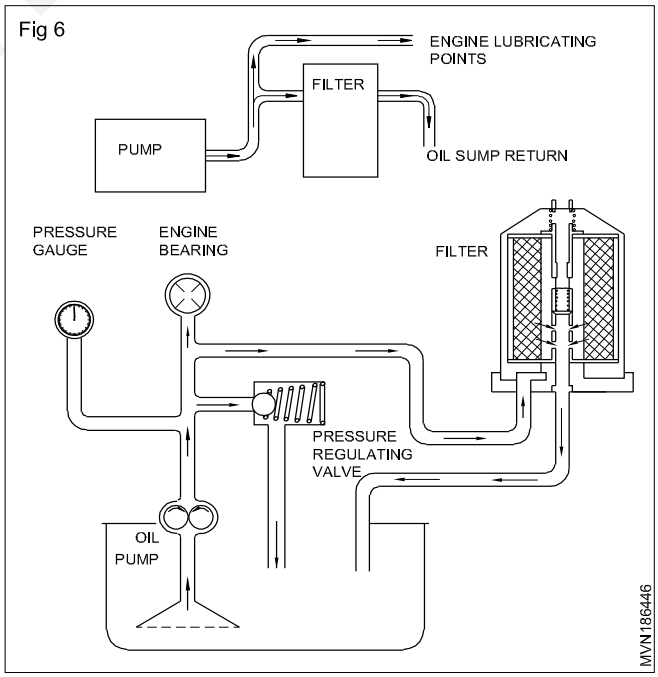
Fig 5




**Bypass oil filter system (Fig 6)**

In this system only a part of the engine oil enters the filter. After filtering, the oil goes to the oil sump. The remaining oil goes directly to the main oil gallery.

Fig 6

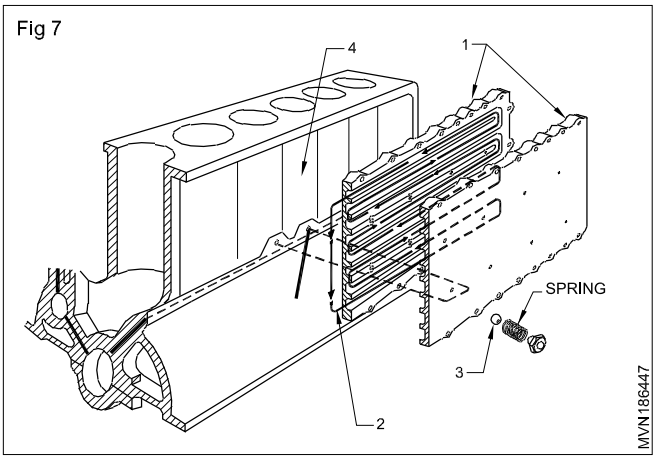



**Filter element**

Filter elements are made of felt, cotton waste, cloth and paper. Oil filters are replaced after certain kilometres of running of the engine as specified by the manufacturer.

**Oil coolers (Fig 7)**

Fig 7



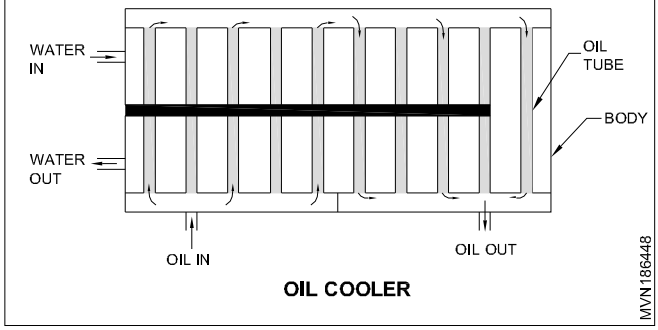

Oil cooler consists of two halves (1). Passages (2) are provided in between the cooler's halves for oil circulation. A ball valve (3) is provided to maintain the required oil pressure. This is made of cast iron. The purpose of the oil cooler is to transfer the heat from engine oil to cooling water and cool the engine oil.

The inner wall of the oil cooler is in contact with cooling water. The engine oil which is made to circulate through the passages provided in the oil cooler, transfers its heat to the cooling water circulating in engine block (4), and the inner wall of oil cooler. This maintains the temperature of the engine.

**Oil cooler purpose (Fig 8)**

The purpose of an oil cooler us to cool the lubricating oil in heavy duty engines where the oil temperature become quite high the oil must be kept cold in the lubricating system.

Fig 8




An oil cooler is just like a simple heat exchanger. The oil may be cooled in it either by cold water from the radiator. At the time of starting when the water is hotter that the oil, the oil is heated to provide complete circulation in the system. At higher temperatures, when the oil becomes hotter than water, the water cools the oil.

A water type oil cooler, simply consists of tubes in which oil circulates. The water circulates outside the tubes in the casing of the cooler. The heat of the oil is carries away by the circulating water.

**Spurt holes and maingallory**

The engine parts are lubricated under pressure feed. The oil pump takes the oil through oil strainer and delivers it at pressure of 2.4 kg/cm$^2$ to main gallory. Further the pressurised oil goes through different size of spurt holes to main bearing camshaft bearing cranks pin, rocker arm and valves, main gallory is act as hub for oil distribution to engine moveable working parts.

## Lubricant

**Objectives:** At the end of this lesson you shall be able to
- **state the need of lubricating an engine**
- **list out the properties of lubricating oils**

**Functions of a lubricant:** The main function of a lubricant is to minimise the friction between two moving surfaces which are in contact with each other.

**It also helps to**

- absorb heat from the moving parts due to friction.
- Minimise wear and tear of the components.
- Provide a cushioning effect between the moving parts.
- Clean the parts by carrying away metal chips with it.
- Protect parts from corrosion.
- Prevent blow-by of gases by providing an oil film between the rings and the liner/bore.

**Properties of a lubricant**

- It should have viscosity to suit the operating conditions.
- The viscosity should remain the same in both hot and cold conditions.
- Its boiling temperature should be high.
- It should be corrosion-resistant.
- It should not develop foam.
- It should withstand critical operating pressure.

**Viscosity**

It is most important properties of lubricating oils for it determines their ability to flow. An oil with excessively high viscosity is very thick, and it is difficult for penetrate the clearance between the rubbing engine parts, while an oil with too low viscosity flows easily and does not stay in the clearances. So that the engine oil should be used as particular engine specifications and the season (plain area or high attitude area).

**Oil additives:** Any mineral oil by it self does not posses all the properties. The oil companies add a number of additives into the oil during the manufacturing process main oil additives

- Pour point depressants
- Oxidation inhibitors
- Corrosion and rust inhibitors
- Foaming resistance
- Detergents depressants
- Extreme pressure resistance

**Synthetic oil**

- Synthetic oils are made from substances other than crude oil
- They can be made from vegetable oils

**Types**

1 Polyalkylene glycols and their derived

2 Silicon which are manufactured from coal and sand

**Application**

a This oil can provide longer service life, less friction and improved fuel economy than convention oil.

b It, costs is more than regular SAE graded oils.

**SAE oil grade**

| When expected atmospheric temperature are- | Single viscosity graded oil | Multi viscosity graded oil |
|---|---|---|
| Below minus 10° F | SAE5W | SAEFW-20 |
| Above minus 10° F | SAE10W | SAE10W-20, or SAE10W-30 |
| Above plus 10° F | SAE20W | SAE 20W-30 or SAE10W-30 |
| Above 32° F | SAE20 or 20 W<br>SAE 30 Some manufacturers | SAE 20W-30 or SAE10W-30 |
| Above 90° F | SAE 30<br>SAE 30 Some manufacturers | SAE 20W-30 or SAE 10W -30 |

## Description of induction and exhaust system

**Objectives:** At the end of this lesson you shall be able to
- **state the function of induction system**
- **state the function of exhaust system**

**Induction system**

In diesel engine only air is drawn into the cylinder from atmosphere through air cleaner, turbocharger, induction manifold, intake port and inlet valve. The induction manifold provides passage for the flow of fresh air from air cleaner via turbo charger towards the engine cylinder. The intake value provides entrance for the fresh air charge into the combustion chamber and cylinder. The following air flow system is used in diesel induction system.

Air cleaner → Turbo charger → Induction manifold → Intake port → Inlet value → Combustion chamber and cylinder

**Exhaust system**

The diesel engine used gases go out of the cylinder and combustion chamber through exhaust valve, which act as gate to provide exit for the burnt gases. The gases flow out through exhaust valve mouth space to the connecting passage of exhaust port into the exhaust manifold. The used exhaust gases from the manifold are let out into the atmosphere through catalytic converter muffler and tail pipe. The catalytic converter reduced the emission from the exhaust gases and muffler silence the noise of exhaust gases by reducing the pressure of the exhaust gases by slow expansion and cooling.

Further exhaust gases used for exhaust brake system to control the vehicle speed and to drive the turbo charge's turbine unit. The flow of exhaust gases.

Engine cylinder → used exhaust gases → exhaust port-exhaust manifold → exhaust brake → Turbim → catalytic converter → muffler → tail pipe → atmosphere.

## Air compressor, exhauster and super charger

**Objectives:** At the end of this lesson you shall be able to
- **explain constructional features of an air compressor**
- **explain operation of an air compressor**
- **explain constructional features of an exhauster**
- **explain operation of an exhauster**
- **explain constructional features of a supercharger**
- **explain operation of a supercharger.**

**Air Compressor:** An air compressor is part of an engine. It is driven either from the timing gear or from the camshaft to maintain air pressure for different purposes.

Normally, it is of a single cylinder type consisting of a piston assembly, connected to the crankshaft by means of a connecting rod. It has an inlet valve and a delivery valve. An air compressor is having an inbuilt air cooling system with fins on its head. Valves are automatic in action and consist of hardened and lapped spring loaded steel discs against removable seats. Engine lubricating oil is circulated to lubricate the parts of air compressor

**Operation:** During the downward stroke of piston partial vacuum is created in cylinder which opens the inlet valve, air to enter into the cylinder. During the upward stroke, the pressure closes the inlet valve. So air is compressed in the cylinder which opens the delivery valve sending compressed air to the reservoir.

**Exhauster**

**Vane type exhauster**

Exhausters are fitted on diesel engine to develop vacuum to assist the pneumatic governor of F.I.P. A vane type exhauster is held by bolt over an opening in the engine and consists of a rotor, keyed to a shaft. The rotor is mounted eccentrically to the barrel (body) of the exhauster. Vanes are fitted with sliding fit in the slots of the rotor. A shift valve fitted on the exhauster, limits the vacuum to a predetermined pressure.

**Impeller type exhauster**

The impeller type exhauster has two spindles. One has an impeller. It is driven by auxiliary driving shaft and the other spindle has rotor whose vanes engage with those on the driven rotor.

**Operation of exhauster**

The vane type exhauster unit works on the principle of centrifugal force. When the engine is running due to centrifugal action, the vanes which have a sliding fit, fit into the slots in the rotor, which come out to the interior surface of the body (barrel). Air is thus evacuated through out the section and is discharged into the crank case. Lubrication for vanes is provided by splash of oil from the crank case.

**Supercharger:** A supercharger is a device which increase the pressure of the airfuel mixture from the carburettor before it enters the engine. It is connected between the carburettor and the cylinder in the way of intake manifold. It is usually driven by the engine through suitable gears and shafts. There are three general types of superchargers:

1 Centrifugal type

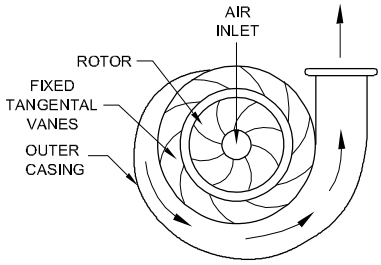
2 Vane type

3 Roots air-blower type

**Centrifugal type supercharger (Fig 1)**

It consists of an impeller which rotates at a very high speed, about 10,000 r.p.m. The air-fuel mixture enters the impeller at the centre and after passing through the impeller and diffuser vanes goes out of the casing to the engine cylinder. Due to the high speed of the impeller, the mixture is forced into the cylinder at a high pressure.

Fig 1

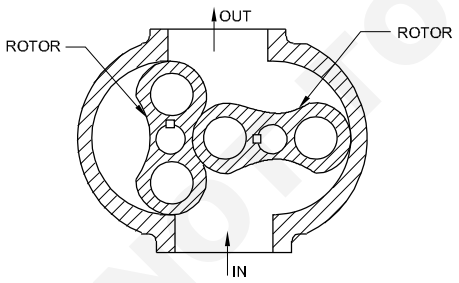



**CENTRIFUGAL TYPE SUPERCHARGER**

**Roots air-blower type supercharger (Fig 2)**

It consists of two rotors of epicycloid shape. Each rotor is fixed to a shaft by a key. The two shafts are connected whether by means of gears of equal size the two rotors rotate at the same speed. The working action of such a supercharger is just like a gear pump, so that the mixture at outlet side is at a high pressure.

Fig 2



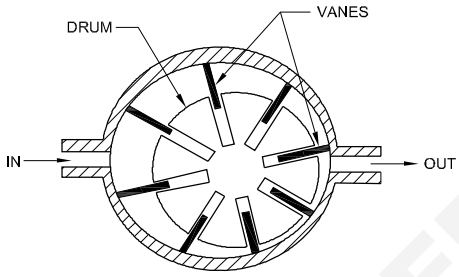

**ROOTS AIR-BLOWER TYPE SUPERCHARGE**

**Vane type supercharger (Fig 3)**

It consists of a drum on which a number of vanes are mounted in such a manner that they can slide in or out against some spring force, so that all the times they are in contact with the inner surface of the supercharger body. The space between the body and the drum goes on decreasing from the inlet to the outlet side. Thus, the air-fuel mixture entrapped between any two vane at inlet goes on decreasing in volume and increasing in pressure as in reaches the outlet.

The roots supercharger is simpler in construction and requires least maintenance. It has comparatively long life. It works well even at lower speed ranges. Centrifugal type supercharger has poor working characteristics at lower speeds. Vane type supercharger has the problem of wear of vane tips.

Fig 3

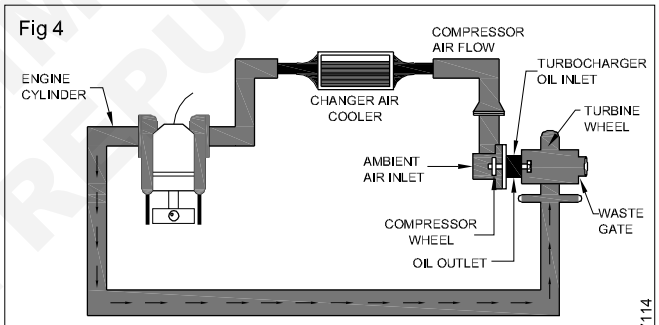



**VANE TYPE SUPERCHARGER**

Turbo charger passes compressed hot air into inter cooler and it heats up expands air the pressure increase from a turbocharger is the result of heating the air before it goes into the engine. In order to increase the power of the engine and get more air molecules into the cylinder.

**Intercooler (Fig 4)**

Fig 4




**INTERCOOLER**

The intercooler (Fig 4) is an additional component that looks like a radiator, except that air passes through the inside as well as the outside of the intercooler. The intake air passes through sealed passageways inside the cooler, while cooler air from outside is blown across fins by the engine cooling fan.

**Charge air cooler and turbo charger**

Charge air cooler and turbo charge are part of a high tech induction system that increases engine combustion efficiency. The turbo charger uses exhaust gases to compress air before it entire the charge - air cooler.

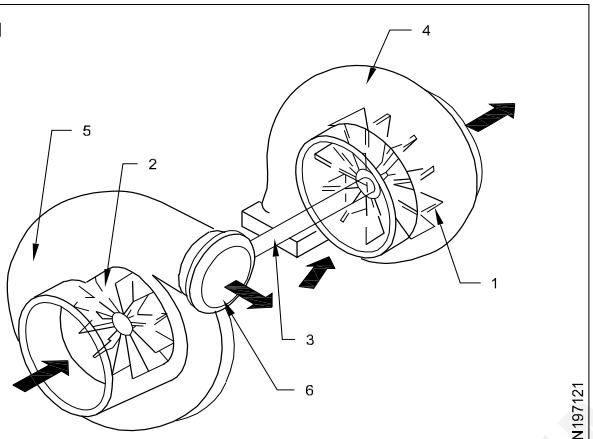
The compressed air going through the charge-air cooler is then cooled by the ambient air flowing across the cooler fins. The cooled air is more dense than warm air. So when it flow into the intake side of the engine, the increased density improves horse power, fuel economy and reduce the emissions.

# Turbocharger

**Objectives:** At the end of this lesson you shall be able to
- **explain constructional features of a turbocharger**
- **explain operation of turbo charger**
- **explain types of turbocharger.**

**Turbocharger (Fig 1):** Turbo charger is mounted on the engine. It increases the amount of air delivered to the engine cylinder, thereby more fuel can be burnt which increases engine power. Whenever the density of air is less than the density at atmospheric pressure specially at higher altitudes, turbo charges helps the engine to get the sufficient air. An engine may have one or more turbo chargers.

Fig 1



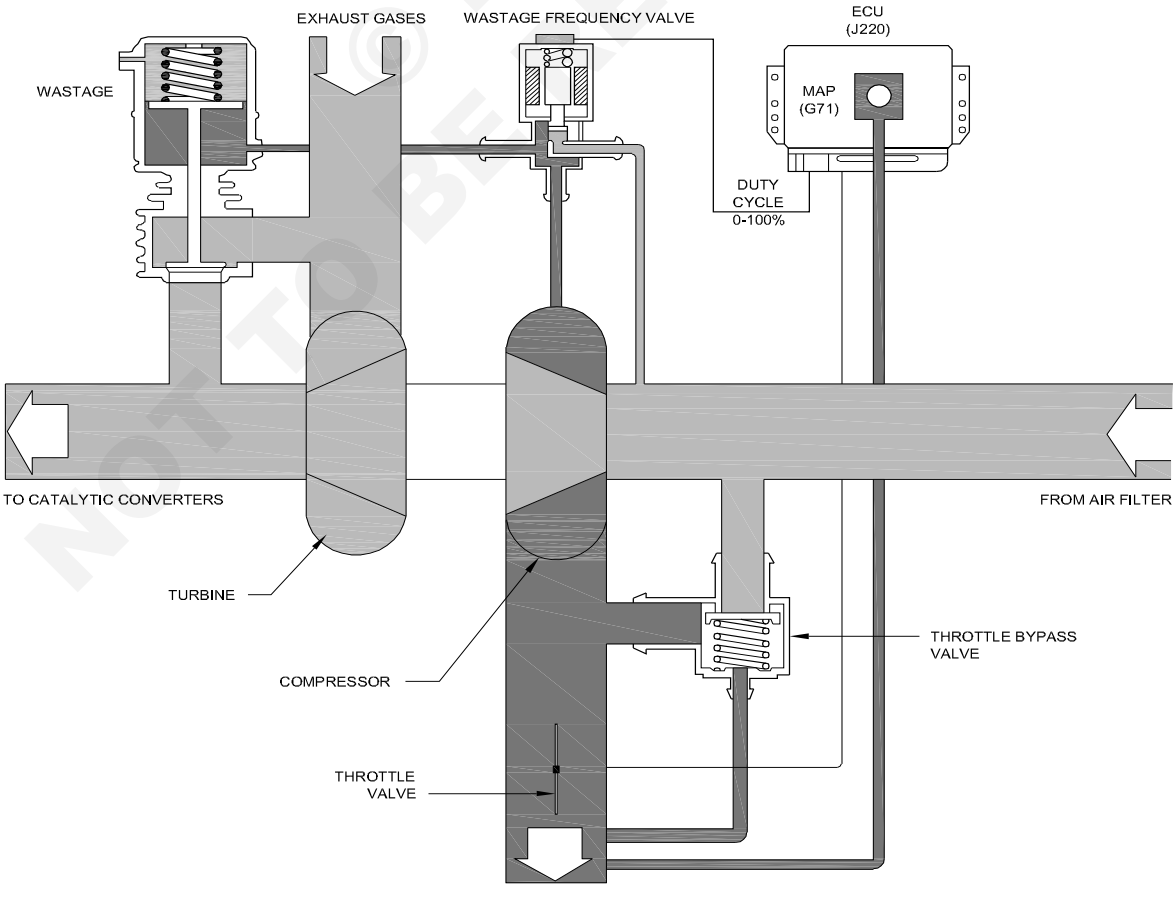

A turbocharger is mounted on the exhaust manifold. It has a turbine wheel (1) and a compressor wheel (2) on the same shaft (3). Exhaust gases enter in turbine housing (4) and rotate the turbine wheel (1). Compressor housing's (5) inlet is connected to the air cleaner and compressed air is discharged to inlet manifold through the outlet (6).

### Turbocharger

### Fixed Geometry Turbochargers (FGT)

A turbocharger consists of a turbine and a compressor linked by a shared axle. The turbine inlet receives exhaust gases from the engine exhaust manifold causing the turbine wheel to rotate. This rotation drives the compressor, compressing ambient air and delivering it to the air intake manifold of the engine at higher pressure, resulting in a greater amount of the air and fuel entering the cylinder. In FGT, (Fig 2) the amount of compressed air which has to be entered in the engine is controlled by a waste gate valve which regulates the turbo output depending on engine's speed.

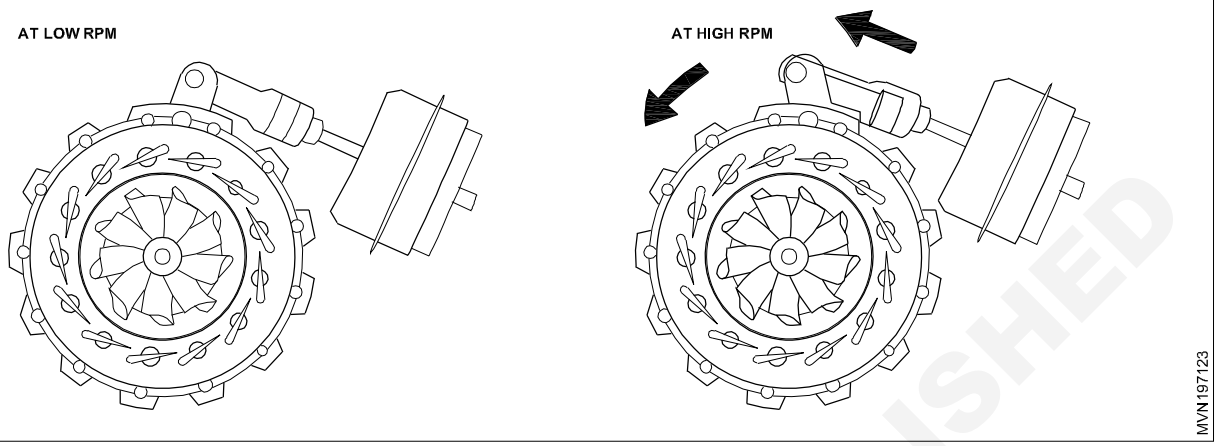
Fig 2



### Variable Geometry Turbochargers (VGT)

Variable geometry turbochargers (VGTs) (Fig 3) are a family of turbochargers, usually designed to allow the effective aspect ratio of the turbo to be altered as conditions change. This is done because optimum aspect ratio at low engine speeds is very different from that at high engine speeds. If the aspect ratio is too large, the turbo will fall to create boost at low speeds; if the aspect ratio is too small, the turbo will choke the engine at high speeds, leading to high exhaust manifold pressures, high pumping losses and ultimately lower power output. By altering the geometry of the turbine housing as the engine accelerates, the turbo's aspect ratio can be maintained at its optimum. Because of this, VGTs have a minimal amount of lag, have a low boost threshold, and are very efficient at higher engine speeds.

Fig 3




## Air cleaner and air cooler

**Objectives :** At the end of this lesson you shall be able to
- **state the need of an air cleaner**
- **state the different types of air cleaners**
- **state the function of induction manifold**
- **state the function of an air cleaner.**

Atmospheric air consists of a large quantity of dirt and dust. Uncleaned air will cause faster wear of and damage to the engine parts, so air is filtered before entering inside the cylinder bore.

### Purpose of air cleaner

- It cleans the intake air.
- It reduces the noise of the intake air.
- It acts as a flame arrester during engine backfire.

### Location

It is mounted on the top of the air inlet manifold.

### Types

- Wet-type (Fig 1)
- Dry-type (Fig 2)

### Wet type air cleaner

The atmospheric air enters the air cleaner through the side passage (1) and strikes on the surface of the oil (2). Heavy dust particles are absorbed by the oil. The partially filtered air, along with oil particles, moves upward through the filter element (3). Fine particles and oil particles are collected by the filtering element (3). Cleaned air then passes through the passage to the inlet manifold.

Fig 1

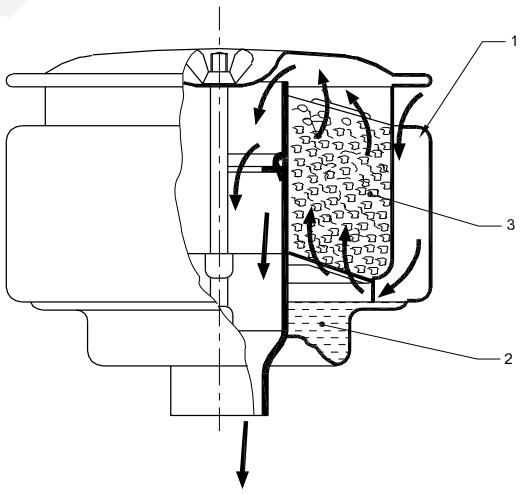
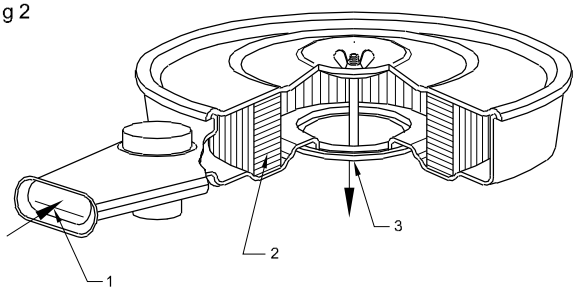



Fig 2

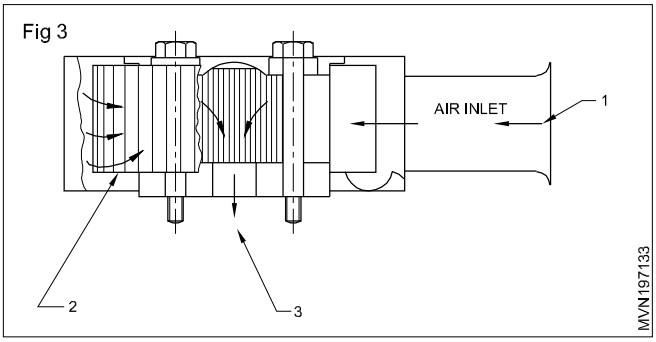


**Dry type air cleaner:** In this type of air cleaner, a specially treated paper element is used to filter the intake air.

**Function:** The atmospheric air enters the air cleaner (Fig 3) through the air entrance (1) and passes through the paper element (2). The filtered clean air goes to the intake manifold entrance (3).

**Intake manifold:** The intake manifold is connected with air cleaner and cylinder head intake port of the cylinder head. It is allow the fresh air to flow from air cleaner to cylinder through inlet valve. The intake manifold is made of a cast iron or aluminium.

Fig 3



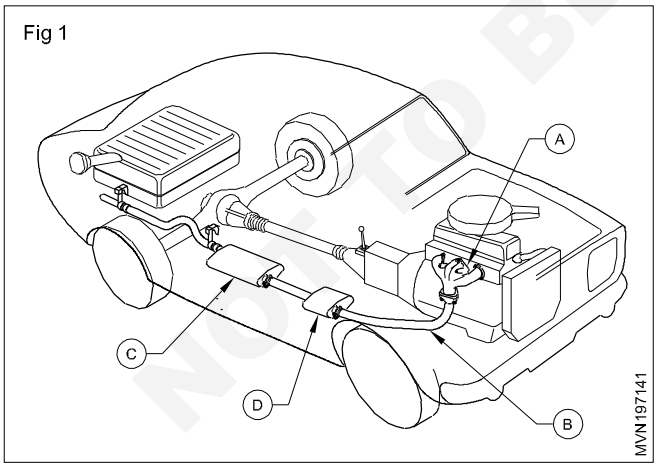

## Manifolds and silencer

**Objectives:** At the end of this lesson you shall be able to
- **explain the purpose of the inlet manifold**
- **explain the purpose of the exhaust manifold**
- **explain the purpose of the muffler and tail pipe**
- **explain the constructional features of the mufflers**
- **list out the different types of mufflers.**

**Manifolds and silencer:** The inlet manifold is used to supply the air-through from the carburettor to the intake ports in the cylinder head. The inlet manifold is generally made of aluminium alloy or cast iron.

The exhaust manifold (A) (Fig 1) is used to collect the exhaust gases from the different cylinders and send them to the silencer. The exhaust manifold is generally made of cast iron. The exhaust manifold may include a heat control valve (Fig 2) or a heat riser which has a thermostatically operated butterfly valve (2) fitted in exhaust manifold. (Fig 2) When the engine is cold, the valve is closed and hot gases are directed around the inlet manifold. When the engine attains operating temperature the valve opens and the exhaust gases are directly sent to the muffler.

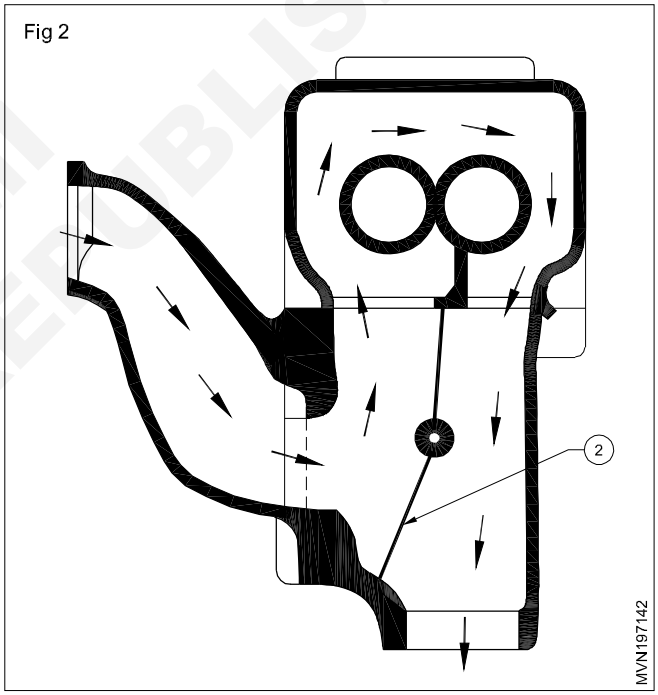
Fig 1




### Exhaust pipes

The exhaust pipe takes the burnt gases from the manifold to the muffler. The pipes are steel tubes, suitably shaped and routed below the chassis to lead the gases away from the vehicle at the rear and to direct the gases down and under the vehicle. It is kept in place by flanges or clamps at either end. In some vehicles, a flexible mounting to the body or chassis is used.

Fig 2




### Muffler

The muffler (C) (Fig 1) is normally located under the body of the vehicle and attached to the body or chassis with flexible mountings. In some trucks in which exhaust gases are directed upward, the muffler is mounted at the rear end of the cab and surrounded with a guard to prevent accidental touching. The muffler reduces the engine exhaust noise. It is a large cylindrical shaped container, fitted with passages and chambers that absorb and dampen the noise of the exhaust gases. Often a small or pre-muffler (D) is fitted in the exhaust system between the manifold and the main muffler.

### Types of mufflers

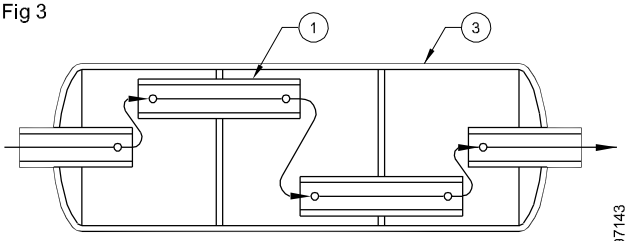
i **Reverse flow muffler (Fig 3):** In this type, small pipes (1) (Fig 3) are placed in the housing (3) of the muffler.

Exhaust gases flow in a zigzag way, thus reducing the sound, by travelling through a longer length.

ii **Straight through muffler:** In this type a straight perforated tube (1) (Fig 4) is placed throughout the length of the muffler. Glass wool or steel wool (2) is filled in between the perforated tube and the muffler housing, which acts as a sound absorbent.

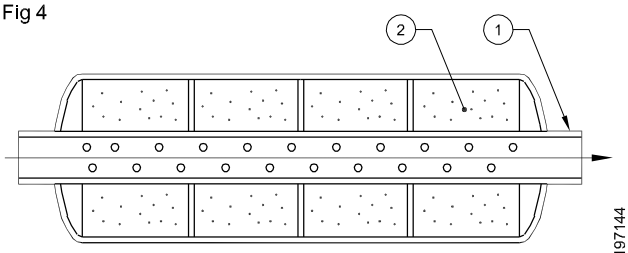
iii **Baffle type:** In this type, a series of baffles (1) (Fig 5) are placed in the muffler which causes restriction and back pressure to the exhaust gases, thereby reducing the sound of the exhaust gases.

Fig 3



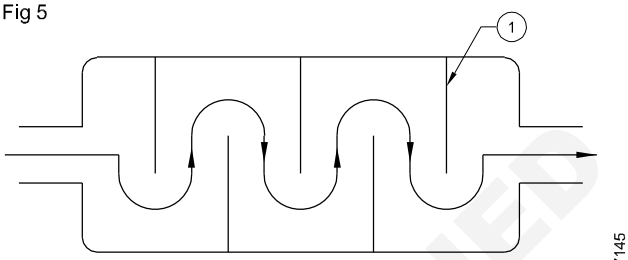

REVERSE-FLOW MUFFLER

Fig 4




STRAIGHT-THROUGH MUFFLER

Fig 5




BAFFLE TYPE MUFFER

## Mufflers

**Objectives:** At the end of this lesson you shall be able to
- **describe the back pressure**
- **describe the back pressure muffler**
- **describe the electronic muffler.**

### Back pressure

Any restriction to exhaust flow in the exhaust system creates back-pressure. Some back-pressure can be beneficial, excessive back-pressure reduces volumetric efficiency and reduces engine efficiency.

### Variable flow exhaust/Back pressure muffler

A movable valve fitted within the exhaust system is used to change the amount of exhaust back-pressure. At higher engine speeds when exhaust noise levels are unacceptable, the valve is closed, thus reducing the bore of the exhaust. This enables greater back-pressure and noise reduction is the result. The valve can be operated by

- Pneumatics - exhaust gas pressure
- Electronics - a computer

When a variable flow exhaust is added to the baffle and chamber system, quieter noise emissions are the result. This is because the system can partially respond to changes in engine speed and load.

### Electronic mufflers

Electronic mufflers are designed to produce anti noise without restricting exhaust flow. This computer-controlled system uses a microphone to detect the sound waves produced within the exhaust system. As the exhaust gas leaves the tail pipe, computer driven loudspeakers are operated to generate the correct amount of anti-noise.

The result is virtually silent exhaust without generating additional and unwanted back-pressure across all engine operating conditions. This increases fuel economy and reduces exhaust emissions.

Sensors and microphones pick up the pattern of the pressure waves an engine emits from its exhaust pipe (Fig 1 & 2). This data is analyzed by a computer. A mirror-image pattern of pulses is instantly produced and sent to speakers mounted near the exhaust outlet. Opposite waves are created that cancel out the noise. Noise is removed without creating back pressure in the muffler. Electronic mufflers can be designed to emit certain sounds or no sound at all.

Fig 1

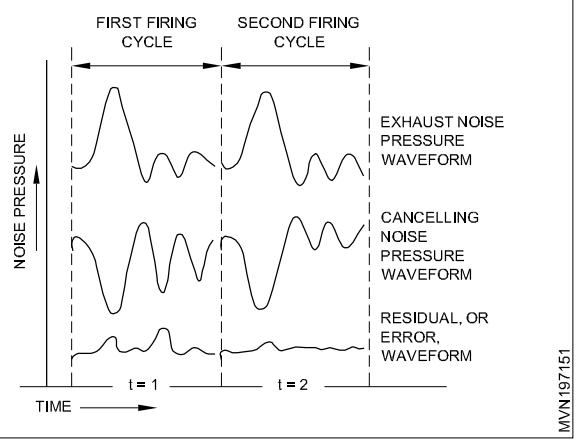
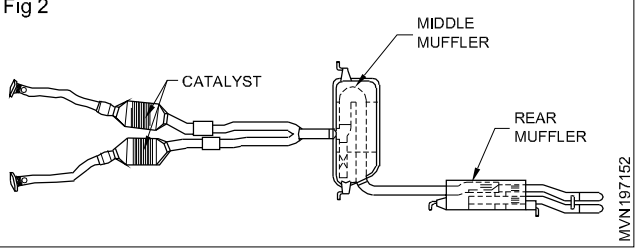


Fig 2




**Catalytic converter**

**Extractor manifolds**

The extractor exhaust manifold system for an internal combustion engine, which improves its efficiency by using precise geometry to reflect the pressure waves form the exhaust valve at a particular time in the cycle.

**Advantages of extractor manifold**

- Separating the gas flow from the individual cylinders.
- Avoid the inter cylinder gas interference
- Maintaining an optimum gas velocity by chosen tube diameter
- Allowing the individual cylinders to assist one to another where the individual exhausts merge.

This type of exhaust system can be used with or without a muffler and so can be used on both race car and road vehicles.

**Absorption mufflers in exhaust system:** This type of mufflers are almost indispensable element of modern exhaust systems. The absorption material is just modern exhaust systems. The absorption material is just as important as a calculation method for designing the mufflers in order to ensure that they are optimally used.

**Absorption:** Automotive exhaust noise can be attenuated is several ways. A distinction is generally made between active and passive attenuation. The modern engine exhaust system consist of more than one absorption muffler to reduce the noise and pollution. The absorption mufflers are dissipating the sound energy through the use of porous materials.

**Noise absorption components:** Reactive / absorption silencers in single package unit

**Flexible connection:** The exhaust pipe takes the burning gases from the exhaust manifold. The silencer pipes are fitted under the chassis body to lead the exhaust gases away from the manifold. The silencer pipes are mounting with flexible connection to the chassis or body of the vehicle. The flexible connections are prevent the damages by heavy jerks or rough up and down movement of the vehicles.

**Ceramic coatings:** Ceramic coating is capable of with standing of high temperature and it has very good chemical and corrosion resistance and possess excellent thermal barrier characteristics, providing a dramatic reduction in radiated heat. It is self-cleaning properties.

Ceramic coatings contain the gaseous heat with in exhaust pipes. This causes the gasses to heat up and expand as a result exhaust flow is boosted.

**Catalytic converter:** The catalytic converter looks like a muffler. It is located in the exhaust system a head of the muffler. Inside convertor are pellets or a honeycomb made of platinum or palladium The platinum or palladium are used as a catalyst (a catalyst is a substance used to speed up a chemical process). Catalyst is chemically oxidized or converted to carbon dioxide and water. This converter works to clean the (exhaust) unburnt hydrocarbons before they fly out the tail pipe.

# Diesel fuel

**Objective:** At the end of this lesson you shall be able to
- **state the concept of quiet diesel technology**
- **state the fuel requirement**
- **explain fuel specification and characteristics of fuel.**

**Function of fuel injection system**

In this system diesel fuel is injected into the combustion chamber at the end of compression stroke in diesel engine.

If the amount and rate of fuel being injected is not measured, will result in uneven running of engine and it leading to vibrations and loss of power. The diesel fuel injection should be fully atomized into fine particles for it spreads one immediately in the combustion chamber to mix up with hot compressed air for high combustion. The injection should take place at the correct time, according firing order of the engine.

Fuel system must fulfil the following requirement

- Time the fuel injection and distribute the fuel properly in the combustion chamber.
- Measure the correct quantity of fuel injected.
- Control the rate of fuel injection.
- Fully atomize the fuel.
- Develop pressures well in excess of the combustion chamber pressure.

An engine converts heat energy of fuel into mechanical energy. The engine fuel may be solid, liquid or gas. Solid fuel (coal) is used in external combustion engine. e.g. steam engine. Liquid gases and fuel are used in internal combustion Engines.

**Specification and characteristics of fuel**

**Octane number:** It is a measure to determine the burning quality of the gasoline. It has the tendency to resist knocking in an engine. The higher the octane number the lesser the tendency to knock.

**Volatility:** Volatility is the ability of the gasoline to evaporate, so that its vapour will adequately mix with air for combustion. Vapourised fuel will burn easily.

**Viscosity:** This indicates quality of fuel to flow. Lower viscosity fuel will flow more easily than that of higher viscosity.

**Sulphur content:** Gasoline contains some sulphur. Sulphur present in fuel increases corrosion of engine and therefore it is reduced at the refinery to the maximum possible extent.

**Additives:** Several additives are put in gasoline to control harmful deposit and to increase anti-freezing quality of the engine.

Detergents are also added to clean certain critical components inside the engine

**Diesel fuel:** Diesel engine fuel is a highly refined distillate fuel obtained from fractional distillation of crude oils

There are light medium and heavy diesel fuel available in the market, which are used as per the recommendations of engine manufacturers.

**Cetane number:** Cetane number (cetane rating) is an indicator of the combustion speed of diesel fuel and compression needed for ignition. It is an inverse of the similar octane rating for gasoline. The CN is an important factor in determining the quality of diesel fuel, but not the only one; other measurements of diesel's quality include energy content, density, lubricity, cold-flow properties and sulphur content.

**Concept of quiet diesel technology:** Technology for quieter, smoother diesel

The combustion pressure in diesel engine cylinder rises intensely and the maximum pressure is extremely high compared with a petrol engine, because of the differences in the combustion method. As a result, diesel engines generally produce more noise, vibration and harshness than petrol engines, and this is a major complaint among diesel users. Efforts to reduce the NVH to the level of petrol engines by making full use of the latest technology.

**Pilot injection system to reduce combustion pressure**

The sudden rise in combustion pressure is a major source of diesel engine noise. By the development of the common rail high-pressure injection system and electronic fuel injection, flexible and precise control over the injection timing and amount made possible. The fuel pressure rise controlled by smoothing the combustion process by pilot injection, a method in which a small amount of fuel is injected and ignited just before the main fuel injection process. This is known as pilot injection control process.

**Increased rigidity of engine structure**

The maximum cylinder pressure in diesel engine is considerably high and the pressure rise during combustion is very rapid, causing the engine vibration and noise. Also, diesel engine components such as the piston are solidly built in order to endure the high pressure and pressure increase ratio. The extra weight of these components translates into increased inertia, the scale of vibration. it is possible to control noise generation by reforming the engine structure to absorb vibration and to reduce the

overall level of vibration. Moreover, vibration travels from the piston to the connecting rod, crankshaft and engine block. This form of vibration attenuated by employing a ladder frame structure with a more rigid crankshaft bearing.

**Other technologies used to reduce NVH (Noise vibration and harshness)**

A secondary balancer is use to help smooth out the vibrations characteristic of four-cylinder engines.

pairs of gears or scissors gears, working side by side with the same numbers of teeth, help to reduce mechanical engine noise by reducing the gear play.

The two sides of the flywheel, which face the engine and the transmission respectively, are each fitted with a spring and damper to absorb vibration caused during changes in speed.

**Clean diesel technology**

Clean diesel is a new generation of diesel made up of a three part system.

1 Advanced engines
   - Highly efficient diesel engines

2 Cleaner diesel fuel
   - Ultra-low sulfur diesel

3 Effective emissions controls
   - Advanced emissions control

This new system ensures that advanced diesel engines will continue to play an important role in the transport of people and goods in the future, while helping meet greenhouse gas and clean air objectives in the world.

Technical innovation has helped progressively to lower vehicle emissions - over the last 15 years, nitrogen oxides (NOx) limits for diesel car engines have been reduced by 84% and particulates (PM) by 90%.

15% less $CO_2$ Emissions than equivalent petrol-powered vehicles. Diesel vehicles contribute to reducing $CO_2$ emissions from road transport and therefore to reduce climate change. Clean diesel fuel technology is involved with diesel fuel, engine & emission control.

## Fuel tank and fuel pipes

**Objectives:** At the end of this lesson you shall be able to
- **explain the function of the fuel tank**
- **explain the function of each part of fuel tank**
- **explain the function of fuel pipes.**

**Fuel tank**

The Fuel tank is provided for storing diesel required for running the engine. It is constructed of either pressed sheet metal with welded seams and special coating to prevent corrosion or fiber glass reinforced plastic materials.

It may be round or rectangular in shape. It is mounted above the engine assembly.

**Parts of the fuel tank**

Filler neck and cap

Baffle

Fuel gauge sensing unit (Float)

Filter

Sediment bowl and drain plug

Filler neck is provided for pumping diesel into the fuel tank. A cap is provided for closing the tank tightly. A vent hole is provided either in filler neck or in cap to maintain atmospheric pressure in the tank above the fuel.

Baffles are provided in the fuel tank to minimize the slushing of fuel due to movement inside the tank.

Fuel gauge sensing unit is provided to know the level of fuel available in tank. It consists of a float resting on the surface of the diesel in the tank. The float with the help of the electrical sensing system indicates the level of the fuel available in the tank, on the dash board fuel-gauge.

Filter is provided at the lower end of the suction pipe. It filters heavy foreign particles.

At the bottom of the fuel tank a drain plug is provided to collect sediments and drain it out of the tank.

**Fuel pipe**

Fuel pipe between the fuel tank and the feed pump is called suction pipe, the pipes between F.I.P. and the injectors are called high pressure pipes. An over flow pipe is provided on fuel filter bowl and injectors to supply excess fuel back to fuel tank.

# Fuel filter

**Objectives:** At the end of this lesson you shall be able to
- **state the need of a fuel filter**
- **explain the types of fuel filter systems**
- **explain the need for bleeding the fuel system**
- **state the function of water separator.**

### Need of fuel filter

Effective filtering of fuel, oil is most important for long trouble free functioning of the engine. Diesel fuel while transporting and handling has chances of getting contaminated by water, dirt, bacteria and wax crystals. Dirt is the worst enemy of the fuel injection equipment. Dirt contamination can be the result of careless filling of the fuel tank. When fuel tank is not filled, moist air condenses inside the metal wall of the fuel tank resulting in water contamination of the fuel.

For these reasons a very efficient filtering system is required to remove these impurities.

### Types of fuel filter system

There are two types of fuel filtering system.

Single filter system

Two stage filter system

In a single filtering system one single filter assembly is used in between feed pump and fuel pump. The single filter in this system is capable of separating dirt from fuel. It should be replaced periodically as per the recommendations of the manufacturers.

In a two stage filter system, primary filter (1) (Fig 1) is used for filtering large solid contaminants and most of the water in the fuel is also removed by this filter. The secondary filter (2) is made of a paper element. This filter controls the size of the particles allowed to pass into the fuel injectors. It also separates any water that might have passed through the primary filter. An overflow valve assembly (3) is used to send back excess fuel to fuel tank. A bleeding screw (4) is provided to bleed the air from fuel system.

### Fuel filter element

A paper element is most suitable because important properties which determine filter quality such as pore size and pore distribution can be effectively maintained. Generally paper filter elements are used at the secondary stage filtration process.

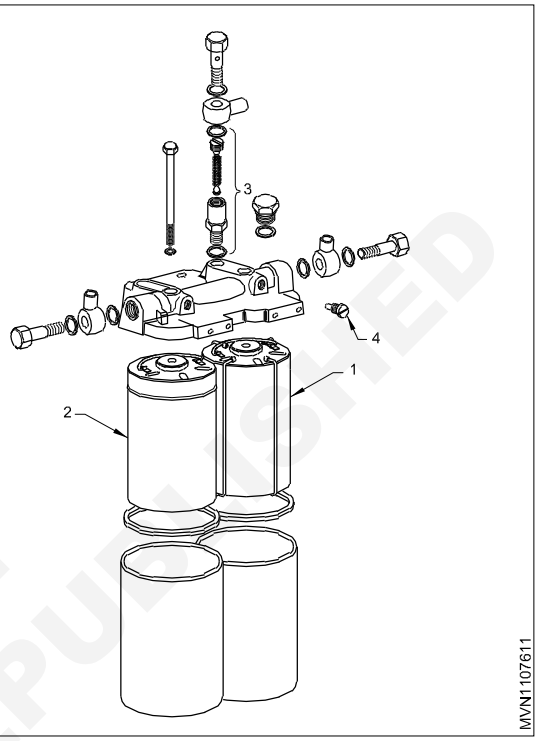
Coil type paper filter inserts are wound around a tube and neighbouring layers are glued together at the top and bottom. This forms a pocket with the openings at the top.

In the star type paper filter inserts, the fuel flows radially from outside to inside. The paper folds are sealed at the top and bottom by end covers.

Cloth type filter inserts are used for primary stage filtration. In this the fuel flows radially from outside to inside. The cloth is wound over a perforated tube whose ends are sealed at the top and bottom by end covers.

### Bleeding of the fuel system

Fig 1




Bleeding is the process by which air, which is present in the fuel system, is removed. Air locking in the fuel system will result in erratic running of the engine and may result in stopping of the engine. Bleeding is carried out by priming the filter. A slight loosening of the bleeding screw allows locked air to escape as bubbles along with the fuel. When locked air escapes and the system is free of air, the screw is tightened finally.

### Diesel fuel water separator

A fuel water seperator is device that works to ensure clean fuel is delivered to the engine.

The fuel water seperator is a small filtering device used to remove water from the diesel fuel before it reaches to the sensitive parts of the engine. Water and contaminants have a direct impact on the service life and performance of diesel engines.

Besides being abrasive to engine components and cylinder walls, water and combination displaces diesel fuels lubricative coating on precision injector components, causing tolerance erosion, surface fitting, fuel loss and poor performance.

The first stage of the fuel water separator uses a plated paper element to change water particles into large enough droplets that will fall by gravity to a water sump at bottom of the filter. The second stage is made of silicone treated nylon that acts as a safety device to prevent small particles

of water that avoid the first stage from passing into the engine. To remove the water from the fuel water separator, open the valve to drain the water from filter if the water separator fails, water in the fuel can wear away lubricants on the diesel fuel injectors, so that fuel water separator is important part of fuel system.

**Components of Fuel water separator filter (FWSF) components:** Fuel water, separater filter provide a better way to filter fuel and it have twist fuel filter water seperating system.

- Filter
- Water collection bowl
- Water drain valve with WIF sensor or threaded port

**Benefits**

- Protect the engine components
- Extend the equipments life

**Features**

- It is easy to switch over water from fuel
- Water separating fuel filter with standard twist & drain.
- Water collection bowel for easy visual inspection.
- Alternative twist and drain valve with water in fuel (WIF) sensor or threaded port.

## Fuel feed pump

**Objectives:** At the end of this lesson you shall be able to
- **explain the function of a feed pump**
- **explain the construction of a feed pump**
- **explain the working of a feed pump.**

**Function**

A feed pump is usually mounted on the F.I.P. and is driven by the camshaft of F.I.P. It sucks fuel from fuel tank and supplies it to fuel filters.

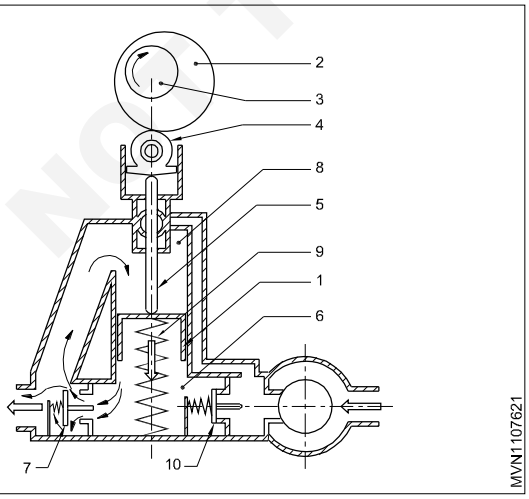
**Construction**

The fuel feed pump consists of a barrel, a plunger, a plunger return spring, spindle, roller tappet, suction and delivery valves, hand primer and pre-filter.

**Working**

The feed pump plunger (1) (Fig 1 & Fig 2) is driven by the cam (2) provided on the F.I.P. camshaft (3). When the plunger moves "downwards" by means of roller tappet (4) and pressure spindle (5) a portion of the fuel present in the suction chamber (6) is delivered through the pressure valve (7) to the pressure chamber (8) and the plunger spring (9) compressed in an intermediate stroke. Towards the end of this stroke the spring loaded pressure valve closes again.

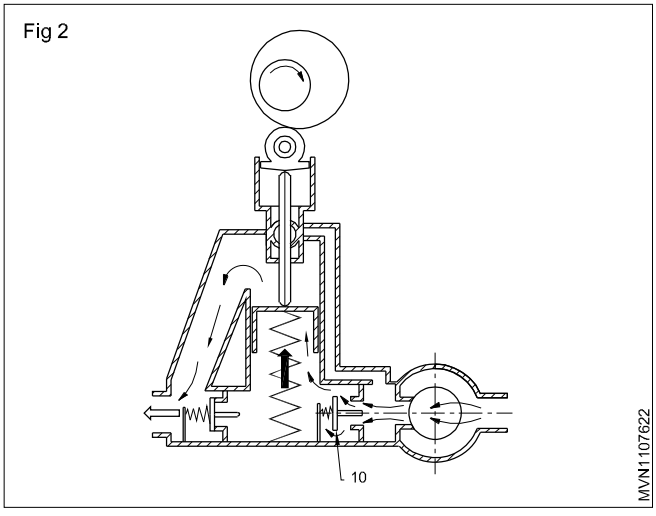
Fig 1




As soon as the cam or eccentric has passed its maximum stroke, plunger, pressure spindle and roller tappet move "upward" due to the pressure exercised by the plunger spring. A portion of the fuel present in the pressure chamber is thereby delivered to the fuel injection pump through filter. However, fuel is sucked simultaneously from the fuel tank to the suction chamber through the primary filter provided in the feed pump and suction valve (10).

When the pressure in the feed pipe exceeds a specified, pressure the plunger spring lifts the plunger only partially. The quantity of fuel delivered per stroke in this is comparatively smaller. When the fuel pipe line is full and the F.I.P. does not need further fuel the feed pump should be put out of action. Due to the excess fuel in the fuel outlet line the pressure in the pressure chamber, holds the plunger in the top position putting the feed pump out of action. During this period only spindle works. The moment the pressure falls down the spring forces the plunger down and the pumping action is resumed. This action during which fuel is not supplied by feed pump is known as idling of feed pump.

Fig 2



**Hand priming device**

The hand priming device is screwed into the feed pump above the suction valve. When the engine is at rest, with the aid of the hand priming device fuel can be pumped from the fuel tank through the filter to the F.I.P. In order to operate the primer the knurled knob is screwed out until the plunger can be pulled upwards causing the suction valve to open for fuel to flow into the suction chamber.

When the plunger is pressed down the suction valve closes while the pressure valve opens and fuel flows through the feed pipe and the filter to the F.I.P. After the use it is essential to screw the knob again in its original position.

**Preliminary strainer:** The preliminary strainer is usually attached to the feed pump. The function of the preliminary strainer is to prevent the coarser impurities at a very early stage. It consists of a housing with a nylon/wire gauge insert or a wire mesh sieve.

## Fuel injection pump

**Objectives:** At the end of this lesson you shall be able to
- **explain function of F.I.P**
- **explain constructional features of F.I.P**
- **state the need of calibration**
- **list out types of fuel injection system**
- **explain air injection and airless injection**
- **state the need of a governor**
- **list out different types of governors**
- **explain constructional features of governors**
- **explain operation of governor.**

**Function of the F.I.P:** Fuel Injection Pumps are designed to deliver specific quantity of fuel to the combustion chamber through an injector at a specific time.

**Types of F.I.P:** There are two types of F.I.P;

**Inline pump**

**Distributor or rotary type pump**

The inline pump has a plunger and barrel assembly for each cylinder of the engine. The assemblies are grouped together in one housing that resembles cylinders of an engine block.

Distributor or rotary type of fuel injection pump has a single pumping element, which supplies fuel to all the cylinders. Distribution to the individual injector is effected by a rotor having a single inlet and delivery, in turn to the appropriate number of outlets. This is done with the help of rotor. Cylindrical plungers and drilled holes in the bore.

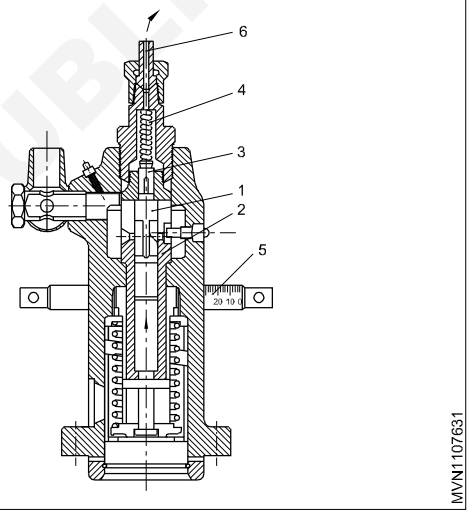
**Working of a F.I.P**

When the plunger (1) (Fig 1) is at its bottom position fuel enters through the barrel's (2) inlet port from the feed pump, fills the space above the plunger in the barrel and excess fuel flows out through the spill port. In a primed system, the barrel(2), all the pipes and the entire system is filled with the fuel.

As the plunger rises up due to cam operation, certain amount of fuel is pushed out of the barrel through the ports. As soon as the ports are closed by the plunger, the flow of fuel is stopped and the fuel above the plunger in the barrel is trapped and is pressurized. The pressure increases to as high as 400 to 700 bar (kgf/cm²) .

This pressure lifts the fuel delivery valve (3) and the fuel enters the fuel line (6) which is connected to the injector. As the pipe is already full of fuel the extra fuel which is being pumped causes a rise in the pressure throughout the line and lifts the injector valve.

Fig 1

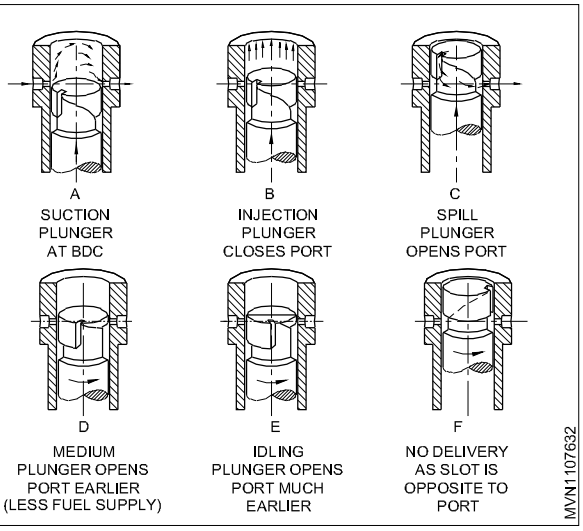



This permits the fuel to be sprayed into the combustion chamber in a fine mist form. It continues until the lower edge of the helical groove in the plunger uncovers the port in the barrel. As soon as the port is uncovered, the fuel by passes downwards through the vertical slot and flows to the port. This causes a drop in pressure and delivery valve closes under its springs (4) pressure. With the consequent drop in the fuel line the injector valve also closes and cuts off the fuel injection.

The plunger stroke is always constant. But by rotation of the plunger in the barrel, it is possible to deliver the fuel earlier or later in the stroke and control the quantity of fuel sprayed. (Fig 2) The rotation of the plunger is obtained by operating the control rack (5), which is in turn connected to the governor.

The governor controls all engine speeds upto a maximum, according to pedal pressed by driver. Different positions of the plunger and the fuel flow is given in the figure.

Fig 2

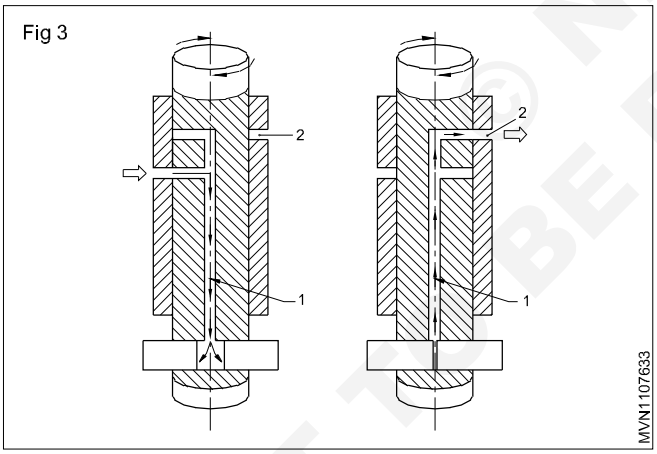



**Constructional features of distributor type F.I.P**

It has a single pumping element which supplies fuel to all cylinders. The distribution to the individual injector is effected by a rotor having a single inlet and delivery equal to the number of cylinders. This ensures in built and uniform delivery to all injectors.

The pumping element consists of two plain opposed cylindrical plungers in a diametrical hole in the rotor head, an extension of which forms the distributor. An axial hole (1) (Fig 3) drilled in this extension connects the pumping chamber with a racked hole which registers in turn with racked delivery ports (2) due for each cylinder of the engine.

Fig 3




**Need for calibration**

In a multi cylinder engine it is necessary that equal and specified quantity of fuel is supplied to each cylinder by fuel injection pump at specified time. The measurement of fuel delivered by each plunger with the control rod in a fixed position and its comparison is called calibration of F.I.P. The adjustment for varying the fuel delivery can be done by altering the position of the control sleeve of each plunger. It is achieved by calibrating the F.I.P. on a test bench by a correct chart as recommended by the manufacturer.

Phasing is the process of testing the pump for the accuracy of their supplying fuel at correct intervals.

**Cooling and lubrication:** The single-plunger injection pump can be mounted in any position. In operation, its interior is completely filled with Diesel fuel under slight pressure in order to prevent intrusion of air and dust; and also to prevent rust formation caused by condensation. Excess fuel is recirculated within the pump to provide adequate cooling and lubrication.

**Types of fuel injection system:** There are two types of fuel injection system for diesel engines.

1 **Air blast injection:** In the air blast injection system, a high pressure air blast drives the fuel at a very high velocity into the cylinder where it is mixed with the compressed air in the cylinder and ignites.

2 **Mechanical injection:** In mechanical fuel injection system, fuel is forced in from a mechanical fuel injection pump through injectors. These are of two types -

- Low pressure fuel supply system.
- Metering injection system.

All fuel supply systems use the same components, although the components vary in size and location within the system.

**Low pressure fuel supply system:** The low pressure fuel supply system consists of one or more fuel tanks, a feed pump, fuel filters, hand priming pump, overflow valve and a return orifice.

**Metering injection system:** It consists primarily of injection pump and injector and categorized as below, depending on the metering system.

i **Pump controlled system:** This is operated with a high pressure plunger and metering mechanism.

ii **Unit injectors system:** This system is similar to the pump controlled system except that the high pressure pumping and metering mechanism are an integral part of the fuel injector.

iii **Common rail system:** This type of system uses a high pressure fuel pump that is connected to a common fuel rail. Each cylinder's fuel injector is connected to the common fuel rail.

**Governors:** The governor is a device for holding any speed steady between idling and maximum speed. The fuel injection pump operates in conjunction with a governor, which is required to control the injected quantity of fuel so that the engine neither stalls when idling nor exceeds the maximum speed for which it is designed.

**Following types of governors are used**

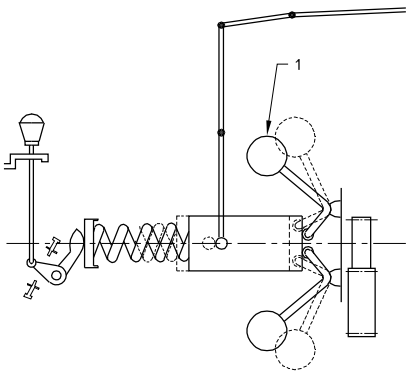
- Mechanical
- Pneumatic
- Servo
- Hydraulic

**Mechanical governor**

Mechanical governors have speed measuring mechanism and fuel controlling mechanism actuated by mechanical arrangement. Two fly weights (Fig 4) (1) are mounted to the

governor's drive gear or directly fastened to the camshaft. The centrifugal force of the fly weights actuates the fuel control mechanism.

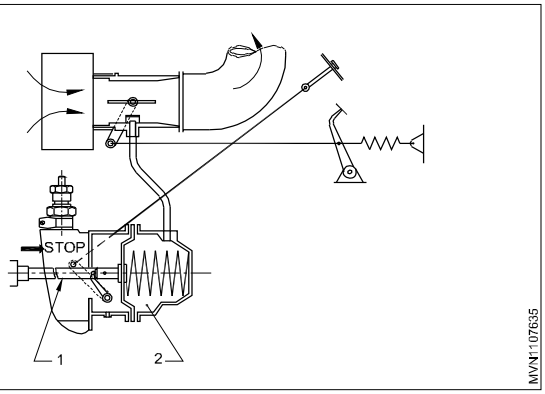
Fig 4




**Pneumatic Governor**

In this type of governors the fuel control rack (1) (Fig 5) is actuated by joint effort of the atmospheric pressure, governor spring and allow pressure chamber (2) connected through a tube to the auxiliary venturi.

Fig 5




**Servo Governor:** In servo type of Governors the fuel controlling mechanism is actuated by hydraulication. This of governor reduced the effort required to move the fuel control device since a small force is necessary to move governor control mechanism.

**Hydraulic Governor:** In this type of Governors the fuel controlling mechanism is actuated by hydraulic action. This of governor reduces the effort required to move the fuel control device since a small force is necessary to move governor control mechanism.

## Electronic Diesel Control (EDC) system

**Objective:** At the end of this lesson you shall be able to
- **state the function of electronic diesel control system.**

**EDC system**

Electronic diesel control (Fig 1 to 2) is a diesel engine fuel injection control system for the precise metering and delivery of fuel into the combustion chamber of modern diesel engines used in trucks and cars.

Fig 1


ELECTRONIC DIESEL CONTROL DEVICE

The electronic control, the system which provides greater ability for precise measuring, data processing environment flexibility and analysis to ensure efficient diesel engine operation.

- It receives the information from sensor, analyze/ calculate it and sends the instructions to the acturators.
- It converts information from analog to digital.
- It consists of microprocessors to process the information from sensor to ECM and ECM to actuators.
- Number of microprocessors are depends upon the number of sensors and actuators.
- It also consists of memory to store the data.
- Speed is in the form of 8 Bit, 16 Bit, 32 Bit, 64 Bit etc., to pass the information from sensor to ECM, ECM to actuator and also in networking system.
- Individual programmes have to be made for each sensor and actuator.

**Move the below figure under the common rail direct injection system (Fig 2)**

**Main control systems in diesel engine**

- It controls the fuel for idling.
- It controls the fuel for high speed.
- It controls the fuel according to the speed and load conditions.
- It controls the exhaust gas recirculation (EGR) valve.

**Working**

It gets the input from the different sensors named are as follows.

1 Throttle position **TP** (Drivers demand on power)
2 Cam position **CMP** (For valve timing)

3 Crank positon **CKP** (For injection & ingnition timing and RPM)

4 Engine coolant temperature **ECT** (For engine temperature)

5 Inlet air temperature **IAT** (temperature of inlet air)

6 Manifold absolute pressure **MAP** (inlet air pressure)

7 Oxygen $\mathbf{O_2}$ (percentage of oxygen in exhaust gas)

After receiving the above inputs, it analyzes/calculates the amount of fuel is required for the cylinder, accordingly it supplies the voltage to the injector solenoid. The solenoid will open the injector to supply the fuel into the combustion chamber. The minimum injector opening period is $1/10^{th}$ second.

Minimum 3 important sensors (TP, CKP & CMP) inputs are required at the time of starting, if any one of the sensor fails, engine does not start.

Rest of the sensors (IAT, ECT, MAP, and O2) fails; engine will start but the performance of the engine will affect.

- **In a vehicle minimum one EDC/ECM is required**
- **More than one EDC/ECM are used depends on number of controls.**

**Example of control units EDC/ECM in a vehicle**

1 Engine management

2 Automatic transmission

3 Power steering

4 SRS (Air Bag) supplemental restraint system

5 ABS (Antilock braking system)

Exhaust gas recirculation (EGR) EGR valve allows the exhaust gases into the inlet manifold, to burn the unburn gases to reduce the emission.

The opening angle of the valve is controlled by the EDC, depending upon the amount - (%) of oxygen passing through exhaust gases.

EDC gets the percentage of oxygen from the oxygen sensor.

**Sensor:** It senses the information in the form of physical or chemical variables and sends that information to the ECM in the form of voltage i.e. between 0-6 volts or 0-12 volts.

Ex: Throttle valve opening position (angle) information sends to the ECM in the form of voltage.

**ECM:** It analyzes or calculates the information which have come from the sensors and gives the instruction to the actuators.

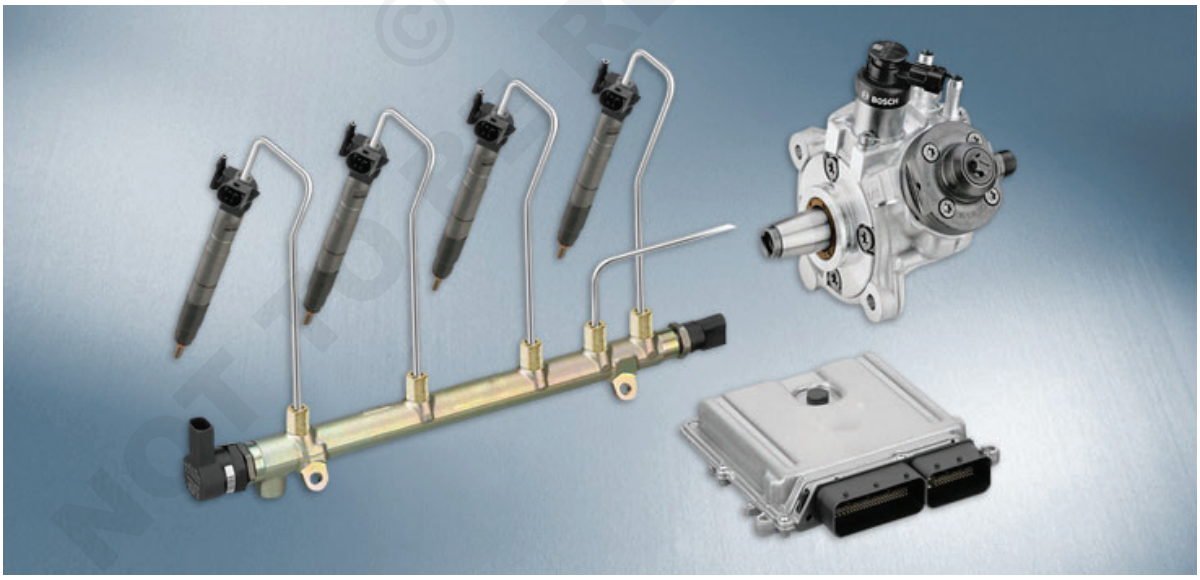
Ex: It supplies the current to the solenoid to open the injector opening duration depends on Inputs

**Actuators**

Based on instructions from the ECM, it does the mechanical work.

Ex: Injector open duration depends on ECM instruction.

Fig 2



COMMON RAIL WITH FUEL INJECTORS

MDN2511412

**Schematic layout system components**

| Input from senders & switches |
|---|
| Engine speed sender CKP |
| Hall sender CMP |
| Accelerator pedal position APP |
| Air mass meter HFM |
| Intake air temperature IAT |
| Coolant temperature ECT |
| Radiator outlet coolant temperature |
| Charge pressure sender G31 |
| Fuel temperature sender |
| Fuel pressure sender |
| Exhaust gas recirculation potentiometer |
| Lambda probe |
| Exhaust pressure sender |
| Cutch position |
| Throttle valve potentiometer |
| Brake light switch |

→ ECU →

| Output from ECU |
|---|
| Fuel pump relay |
| Fuel pump for pre-supply |
| Injection valves |
| Valve for fuel dosage |
| Fuel pressure regulating valve |
| Solenoid valve for charge pressure control |
| Intake manifold flap motor |
| Throttle valve module |
| Exhaust gas recirculation valve |
| Radiator Fan |
| Automatic glow period control unit |
| Lambda probe heater |



## Electronic Control Module (or) system (ECM)

**Objectives:** At the end of this lesson you shall be able to
- **describe E.C.M Electronic control module (or) system**
- **state the various control system**
- **explain the fuel injection control system**
- **explain the fuel pump control system**
- **explain the injection control system**
- **explain the radiator fan control system.**

### Electronic control system

The electronic control system consist of various sensors which detect the state of engine and driving conditions, ECM which controls various devices according to the signals from the sensors and Various controlled devices.

The control systems are as follows

- Fuel injection control system
- Idle speed control system
- Fuel pump control system
- Radiator fan control system

### Idle speed control system

This system controls the bypass airflow by means of ECM & IAC valve for the following purposes. To keep the engine idle speed as specified at all times. The engine idle speed can vary due to load applied to engine, to improve starting performance of the engine to compensate air fuel mixture ratio when -decelerating, to improve drivability while engine is warmed up. IAC valve operates according to duty signal sent from ECM. ECM detects the engine condition by using the signals from various signals and switches and controls the bypass airflow by changing IAC valve opening. When the vehicle is at a stop, the throttle valve is at the idle position and the engine is running, the engine speed is kept at a specified idle speed.

**Fuel pump control system:** ECM controls ON/OFF operation of the fuel pump by turning it ON, the fuel pump relay under any of the conditions. For two seconds after ignition switch ON. While cranking engine (while engine start signal is inputted to ECM). While crankshaft position sensor or camshaft - position sensor signal is inputted to ECM.

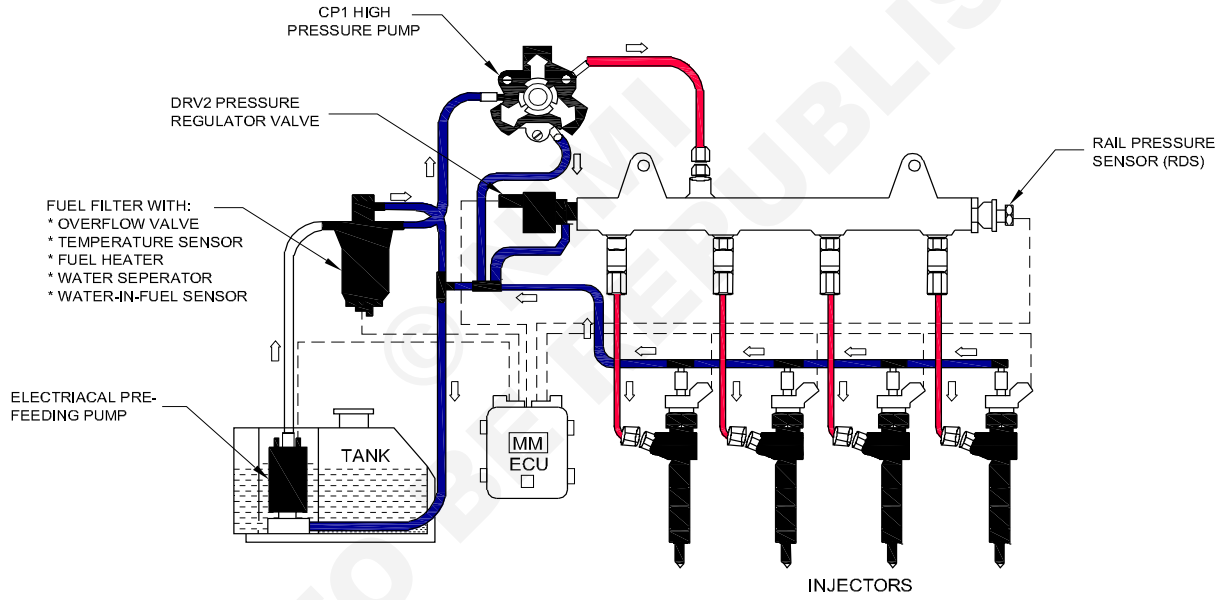
## Common Rail Direct Injection (CRDI)

**Objectives:** At the end of this lesson you shall be able to
- **describe the construction of CRDI**
- **explain the working of the CRDI**
- **list out the merits and demerits of the CRDI.**

**Construction and working of CRDI system (Figs 1&2)**

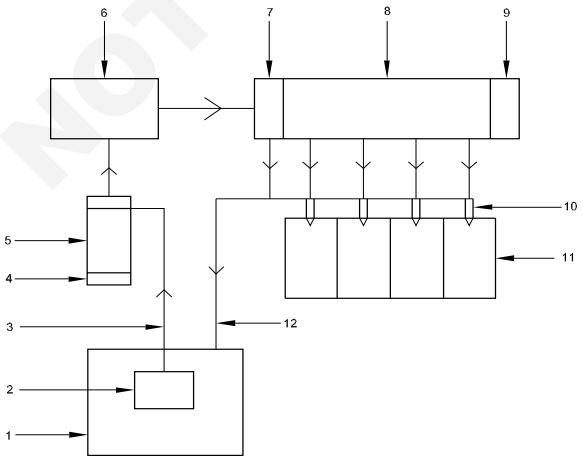
The common rail fuel system consists of fuel tanks fuel pump, common rail, pressure regulator, injectors and sensors. The electrical fuel pump (low pressure) in placed inside the fuel tank, It develops pressure upto 6 bar and supplies to the high pressure fuel pump (CRDI) through fuel filter and water separator. The high pressure fuel pump develops pressure 200 to 2000 bar and supplies to the common rail and common rail to fuel injectors inject fuel into the combustion chamber. Fuel injector are operator by ECM through solenoid valve. Common rail consists of fuel pressure regulator rail pressure sensor and fuel pressure regulator supplies the excess amount of fuel to the fuel tank (≤ 1 bar pressure). The common rail pressure sensor send information to ECM/EDC, the existing pressure in the common rail will control the RPM of the fuel pump. Common rail will distribute the fuel to all the cylinder with equal pressure, then all cylinders will develop uniform power, which will reduce vibration and noise of the engine.

Fig 1




**DIESEL DIRECT INJECTION SUSTEM (DDIS) -- FUEL SYSTEM LAYOUT**

Fig 2




1. FUEL TANK
2. ELECTRICAL FUEL PUMP
3. FUEL SUPPLY LINE
4. WATER SEPARATOR
5. FUEL FILTER
6. HIGH PRESSURE FUEL PUMP (CRDI PUMP)
7. FUEL PRESSURE REGULATOR
8. COMMON RAIL
9. FUEL RAIL PRESSURE SENSOR
10. FUEL INJECTOR
11. ENGINE
12. FUEL RETURN LINE

**COMMON RAIL DIRECT INJECTION SYSTEM (CRDI) FUEL SUPPLY SYSTEM**

**Diesel Direct injection system (Fig 1)**

**Sensors:** Types of sensors

1 Engine coolant temperature (ECT)

2 Manifold absolute pressure (MAP)

3 Inlet air temperature (IAT)

4 Oxygen ($O_2$)

5 Throttle position sensor (TP)

6 Cam position (CMP)

7 Crank position (CKP)

8 Anti-lock braking system (ABS)

The above sensors are being used for the engine management system.

Recently one more sensor is added i.e ABS

Apart from the above so many other sensors are using in the vehicle. In modern vehicles 10 to 100 plus sensors are using.

Classification & working principle of sensors

Switches

Resistive sensor

Current generating sensor

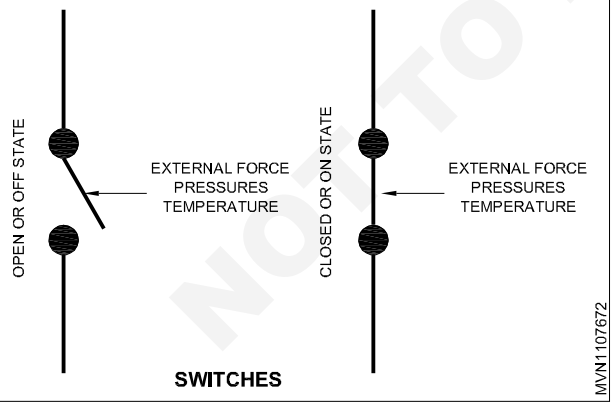
Hall effect sensor

Hot film air mass meter

Lambda sensor

**Switches (Fig 3):** Switches are basically on-off sensors & the input given to ECU is normally in two states i.e either "ON" or "OFF" physical position of the switch can be change by operating condition like temperature, pressure, external force etc.

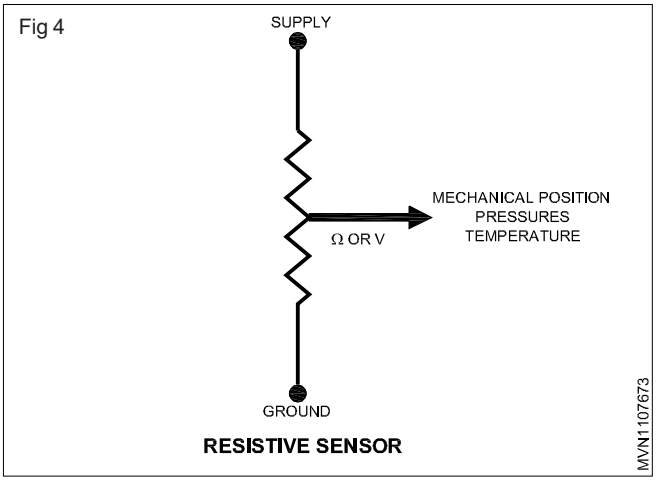
Fig 3




SWITCHES

**Resistive sensor (Fig 4):** In resistive sensor the variation is resistance happens due to change in input data like position, temperature pressure etc. Input to the control unit is not necessarily the resistance but can be the voltage also.

Fig 4

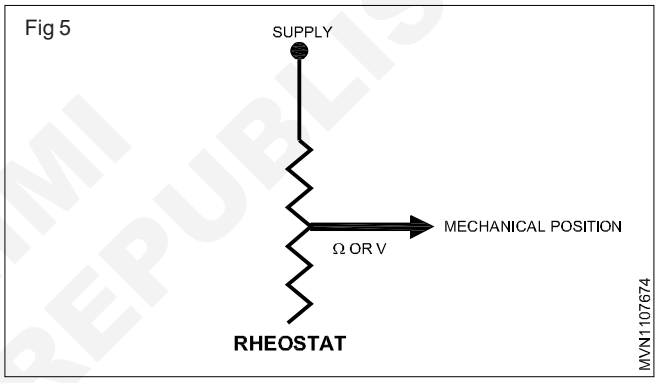



RESISTIVE SENSOR

**Types of resistive sensor**

1 **Rheostat (Fig 5):** Generally 2 wire sensor. Change is resistance happen due to change in mechanical position. Value of resistance or voltage is interpreted by ECU for calculation. Measurement of value happen inside the control unit.

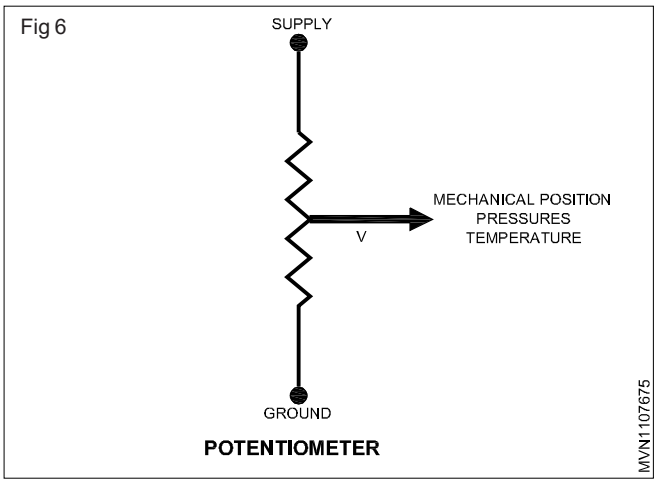
Fig 5




RHEOSTAT

2 **Potentiometer (Fig 6):** Generally 3 wire sensor. Change is resistance happen due to change in mechanical position. Value of voltage is interpreted by ECU for calculation. Measurement of value happen outside the control unit.

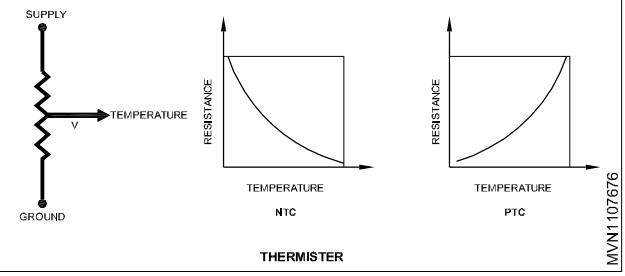
Fig 6




POTENTIOMETER

3 **Thermistor (Fig 7):** Thermistor are those sensors whose resistance value changes due to change in temperature. Thermistor are supplied with constant voltage. Out put voltage changes due to change in resistance which is continuously monitor by control unit to decide the temperature value. Thermistor can have either negative temperature co efficient [NTC] or positive temperature co-efficient [PTC].

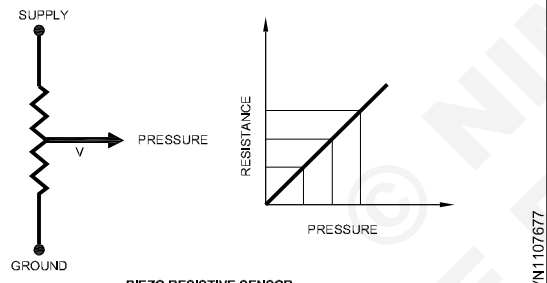
Fig 7




THERMISTER

4 **Piezo resistive sensor (Fig 8):** Piezo resistive sensors are those whose resistance changes die to change in pressure. They are subjected to external pressure which causes change in resistance. Constant voltage is supplied & out put voltage changes due to change in pressure which is interpreted by control unit to decide the pressure value.

Fig 8



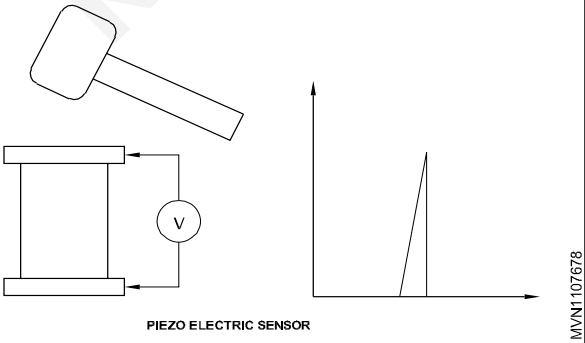

PIEZO RESISTIVE SENSOR

5 **Current generating sensor:** Certain sensors generate the voltage when subjected to change is physical phenomenon such as pressure, position etc. They are mainly classified as follows.

- Piezo electric sensor
- Magnetic induction sensor

6 **Piezo electric sensor (Fig 9):** Certain crystal such as quartz when subjected to a pressure generate potential difference on its surface. The phenomenon is reversible.

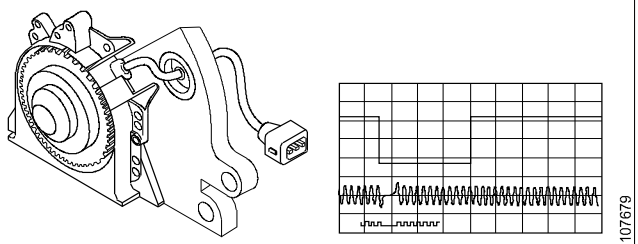
Fig 9




PIEZO ELECTRIC SENSOR

7 **Magnetic inductive sensor (Fig 10):** This kind of sensor are consist of coil would around the permanent magnet. When the magnetic filed is disturb by external means current is generated inside the coil terminals. The pattern of current obtained is depends on the kind of disturbance produce.

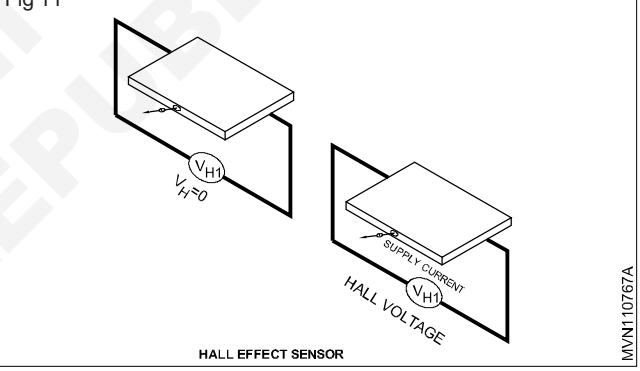
Fig 10




MAGNETIC INDUCTIVE SENSOR

8 **Hall effect sensor (Fig 11):** When a current passes through the semiconductor plate there is no current develop at right angles to the direction of current. However when this plate is subjected to a magnetic filed, voltage is developed at right angles to the direction of current. The magnitude of this voltage is proportionate to the magnetic field through the semi-conductor.

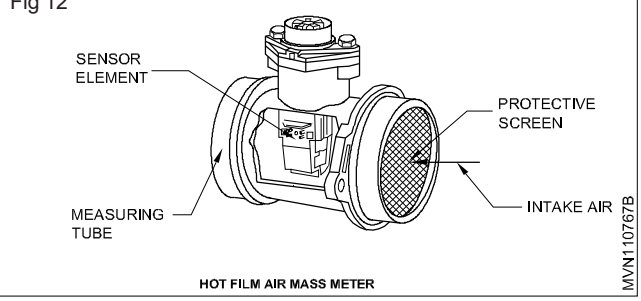
Fig 11




HALL EFFECT SENSOR

9 **Hot film air mass meter (Fig 12):** This sensor is used to measure the air flow in engine management system. It consist of measuring tube & sensor electronic with sensor element. The sensor element consist of heating resistors, two thermistor R1&R2 & intake air temperature sensor.

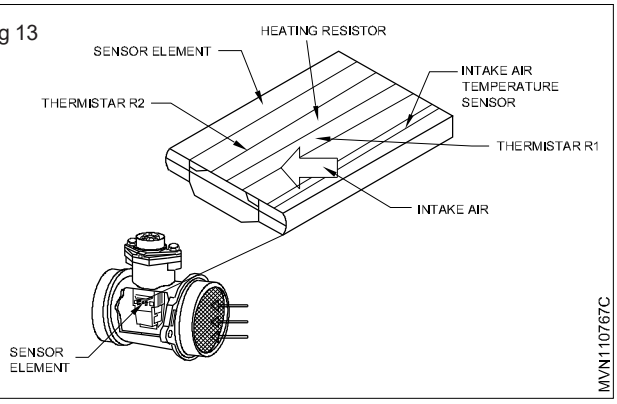
Fig 12




HOT FILM AIR MASS METER

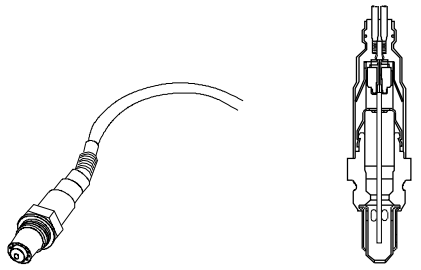
10 **Sensors & actuators (Fig 13):** Sensors element is heated at constant temperature appr. 120°C above intake air temperature. Due to air flow there is a temperature difference at R1 & R2. This difference is recognized by electronic module & the intake air mass is calculated. This also decide the direction of air flow.

Fig 13



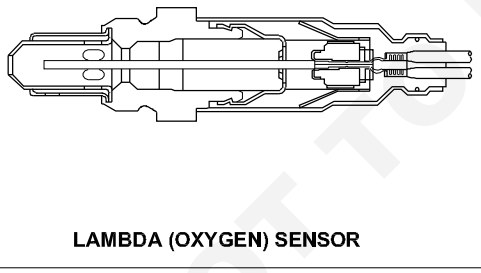

**11 Lambda (oxygen) sensor (Fig 14):** This sensor is normally used in petrol engine to decide the oxygen content in exhaust gas. Based on the input from this sensor the ECU do minor correction to the amount of fuel being metered.

Fig 14




**12 Lambda (oxygen) sensor (Fig 15):** The difference in oxygen content between the exhaust gas & ambient air causes a change in the electrical voltage within the probe. A change in the composition of the air fuel mixture produces a sudden voltage change by which $\lambda = 1$ can be identified.

Fig 15




**13 Sensors & actuators (Fig 16):** In connection with OBD II, second lambda sensor is connected after catalytic converter. It test correct functioning of the catalytic converter.

**Actuators**

1 Injectors

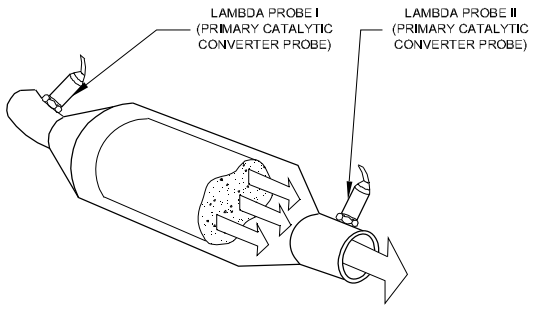
2 Power windows

3 Wiper motors

4 Relays etc

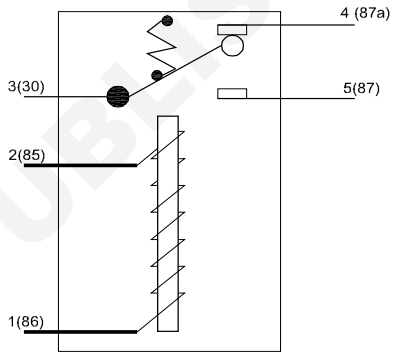
Number of actuators depends upon the devices to be operated.

Fig 16




**14 Relay (Fig 17):** A relay is an electrically operated switch. many relays use an electromagnet to operate a switching mechanism mechanically, but other operating principles are also used. Relays are used where it is necessary to control a circuit by a low-power signal (with compete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal.

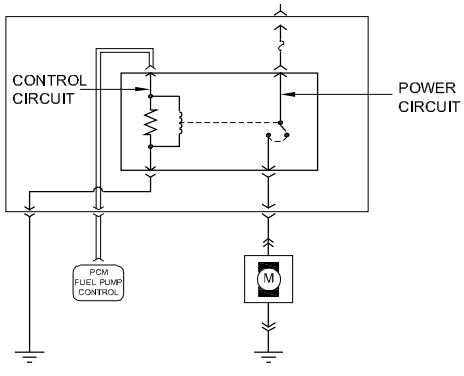
Fig 17




1 **Control circuit:** Control the operation which are activated by control unit or switch. It required very less power to activate. (Fig 18)

2 **Power circuit:** Connected to the load. Main current flows through this circuit. (Fig 18)

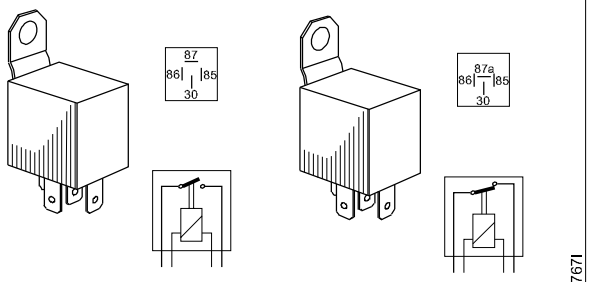
Fig 18




1 **Normally open relay [NO]: (Fig 19)** Power circuit is in open position. Circuit closes when control circuit is activated.

2 **Normally close relay [NC]: (Fig 19)** Power circuit is in close position. Circuit opens when control circuit is activated.

Fig 19

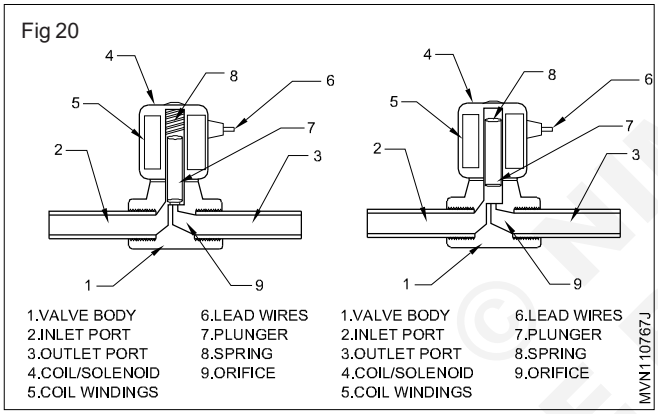



**Working principles of actuators**

**DC Motors**

**Solenoid (Fig 20):** A solenoid is an electromechanical switch/ valve that is controlled by an electric current. The electric current runs through a solenoid, which is a wire coil wrapped around a metallic core. A solenoid creates a controlled magnetic field when an electrical current is passed through it. This magnetic field affects the state of the solenoid valve, causing the valve to open or close.

Fig 20

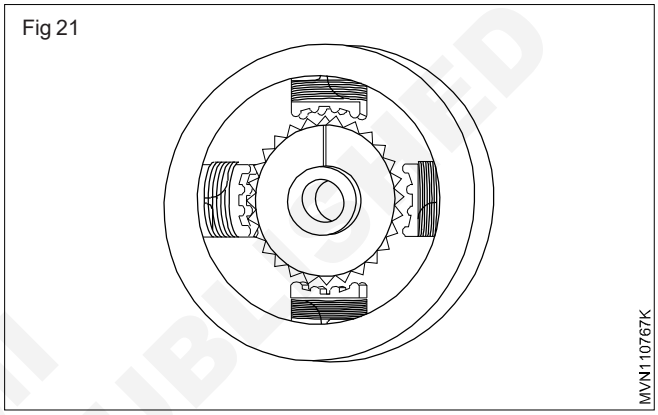



**Stepper motor (Fig 21):** Stepper motors provide a means for precise positioning and speed control without the use of feedback sensors. The basic operation of a stepper motor allows the shaft to move a precise number of degrees each time a pulse of electricity is sent to the motor.

Since the shaft of the motor moves only the number of degrees that it was designed for when each pulse is delivered, you can control the pulses that are sent and control the positioning and speed. The rotor of the motor produces torque from the interaction between the magnetic field in the stator and rotor.

The strength of the magnetic fields is proportional to the amount of current send to the stator and the number of turns in the windings.

Fig 21



# Engine assembling special tools

**Objective:** At the end of this lesson you shall be able to
- **use of special tools.**

**Engine assembling**

Place the crankshaft in position on the crankcase and useof the following special tools for assembling the engine parts.

| Engine Assembling | Special Tools |
|---|---|
| 1.Refitting of liner | Hydraulic press |
| 2 Bearing oil - clearance check | Plastic gauge |
| 3 **Piston assembly** | |
| (a) piston clearance | Feeler gauge |
| (b) Piston pin assembling | Copper Drift, circlip plier |
| (c) Piston ring removing and refitting | Piston ring expander |
| (d) Piston ring groove cleaning | Piston ring groover cleaning tool |
| 4 Inserting of piston into cylinder block | Piston ring compressor |
| 5 **Connecting rod** | Connecting rod alignment fixture |
| 6 **Crankshaft checking** | Crankshaft balancer , Dial gauge, Feeler gauge, Out side micrometer. |
| 7 **Cylinder bore ovality and taper** | Bore dial gauge |
| 8 **Connecting rod bearing diameter** | Telescopic gauge |

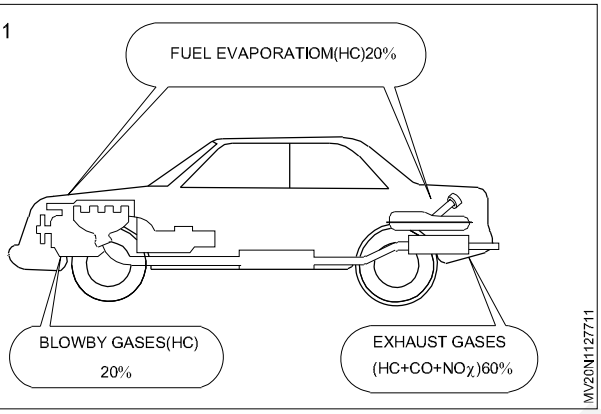
| Cylinder Head | Special Tools |
|---|---|
| Valve assembly | Valve spring compressor |
| Valve measurement | Vernier caliper, bevel protractor, valve guide gauge |
| Valve Reconditioning | Valve refacing m/c (machine) |
| Valve seat reconditing | Valve seat grinding m/c , valve seat cutter |
| Valve spring | Valve spring tester |
| Valve leakage checking | Valve leakage Tester |
| Fly wheel | Surface plate |
| Warpage checking | Straight edge, Feeler gauge |
| Cyliner block crack | Ultrasonic tester , megnetic particle inspection test |
| Cylinder head | Torque wrench |
| Cylinder compression test | Compression gauge |
| Cylinder vacuum test | Vacuum gauge |

## Sources of emission

**Objectives:** At the end of this lesson you shall be able to
- **state sources of emission**
- **state different type of emission.**

The power to move a motor vehicle comes from burning fuel in an engine. Emissions from vehicles are the by-products of this combustion process. Emissions from a motor vehicle generally come from four sources

Fig 1




1 The fuel tank

2 The crankcase

3 The exhaust system

**Evaporative Emissions:** The fuel tank and carburetor allow fuel to evaporate and escape to the atmosphere. These are called evaporative emissions

**Exhaust Emissions:** The crankcase and exhaust system (Fig 1) emit pollutants directly from the engine into the atmosphere. They are caused when hydrocarbons, lead compounds, and oxygen and nitrogen from the air, are burned in the combustion chamber.

In a compression-ignition engine, emissions originate from the engine, and escape to the atmosphere from the exhaust, and the crankcase breather.

## Vehicle emissions standards - Euro and Bharat

**Objectives:** At the end of this lesson you shall be able to
- **follow the European emission standards for gasoline of diesel passenger vehicle, light vehicle and heavy vehicle**
- **follow the bharat emission standards for gasoline passenger vehicle, light vehicle and heavy vehicle.**

Emission requirements for light road vehicles have existed in the European emission standards (EU) since the early 1970s, while the first requirements for heavy vehicles came in at the end of the 1980s. Today, vehicle emissions are controlled under two basic frameworks: the "Euro standards" and the regulation on carbon dioxide emissions.

Currently, emissions of nitrogen oxides (NOx), total hydrocarbon (THC), non-methane hydrocarbons (NMHC), carbon monoxide (CO) and particulate matter (PM) are regulated for most vehicle types, including cars, lorries, trains, tractors.

While the norms help in bringing down pollution levels, it invariably results in increased vehicle cost due to the improved technology & higher fuel prices. However, this increase in private cost is offset by savings in health costs for the public, as there is lesser amount of disease causing particulate matter and pollution in the air.

Exposure to air pollution can lead to respiratory and cardiovascular diseases, which caused 620,000 early deaths in 2010, and the health cost of air pollution in India has been assessed at 3 per cent of its GDP.

European emission standards define the acceptable limits for exhaust emissions of new vehicles sold in EU member states.

Emission standards for passenger cars and light commercial vehicles are summarised in the following tables.

European emission standards for passenger cars (Category M*), g/km.

| Tier | Date | CO | THC | NMHC | NOx | HC+NOx | PM | P*** |
|---|---|---|---|---|---|---|---|---|
| Diesel | | | | | | | | |
| Euro 1† | July 1992 | 2.72 (3.16) | - | - | - | 0.97 (1.13) | 0.14 (0.18) | - |
| Euro 2 | January 1996 | 1.0 | - | - | - | 0.7 | 0.08 | - |
| Euro 3 | January 2000 | 0.64 | - | - | 0.50 | 0.56 | 0.05 | - |
| Euro 4 | January 2005 | 0.50 | - | - | 0.25 | 0.30 | 0.025 | - |
| Euro 5 | September 2009 | 0.50 | - | - | 0.180 | 0.230 | 0.005 | - |
| Euro 6 | September 2014 | 0.50 | - | - | 0.080 | 0.170 | 0.005 | - |
| Petrol (Gasoline) | | | | | | | | |
| Euro 1† | July 1992 | 2.72 (3.16) | - | - | - | 0.97 (1.13) | - | - |
| Euro 2 | January 1996 | 2.2 | - | - | - | 0.5 | - | - |
| Euro 3 | January 2000 | 2.3 | 0.20 | - | 0.15 | - | - | - |
| Euro 4 | January 2005 | 1.0 | 0.10 | - | 0.08 | - | - | - |
| Euro 5 | September 2009 | 1.0 | 0.10 | 0.068 | 0.060 | - | 0.005** | - |
| Euro 6(future) | September 2014 | 1.0 | 0.10 | 0.068 | 0.060 | - | 0.005** | - |

* Before Euro 5, passenger vehicles > 2500 kg were type approved as light commercial vehicles N1-I

** Applies only to vehicles with direct injection engines

*** A number standard is to be defined as soon as possible and at the latest upon entry into force of Euro 6

† Values in brackets are conformity of production (COP) limits

Emission standards for light commercial vehicles

European emission standards for light commercial vehicles ≦ 1305 kg (Category N1-I), g/km.

**Emission standards for light commercial vehicles**

**European emission standards for light commercial vehicles≤ 1305 kg (category $N_1$ - I), g/km**

| Tier | Date | CO | THC | NMHC | NOx | HC+NOx | PM | P |
|---|---|---|---|---|---|---|---|---|
| Diesel | | | | | | | | |
| Euro 1 | October 1994 | 2.72 | - | - | - | 0.97 | 0.14 | - |
| Euro 2 | January 1998 | 1.0 | - | - | - | 0.7 | 0.08 | - |
| Euro 3 | January 2000 | 0.64 | - | - | 0.50 | 0.56 | 0.05 | - |
| Euro 4 | January 2005 | 0.50 | - | - | 0.25 | 0.30 | 0.025 | - |
| Euro 5 | September 2009 | 0.500 | - | - | 0.180 | 0.230 | 0.005 | - |
| Euro 6 | September 2014 | 0.500 | - | - | 0.080 | 0.170 | 0.005 | - |
| Petrol (Gasoline) | | | | | | | | |
| Euro 1 | October 1994 | 2.72 | - | - | - | 0.97 | - | - |
| Euro 2 | January 1998 | 2.2 | - | - | - | 0.5 | - | - |
| Euro 3 | January 2000 | 2.3 | 0.20 | - | 0.15 | - | - | - |
| Euro 4 | January 2005 | 1.0 | 0.10 | - | 0.08 | - | - | - |
| Euro 5 | September 2009 | 1.000 | 0.100 | 0.068 | 0.060 | - | 0.005* | - |
| Euro 6 | September 2014 | 1.000 | 0.100 | 0.068 | 0.060 | - | 0.005* | - |

* Applies only to vehicles with direct injection engines

**European emission standards for light commercial vehicles 1305 kg - 1760 kg (Category N1-II), g/km**

| Tier | Date | CO | THC | NMHC | NOx | HC+NOx | PM | P |
|---|---|---|---|---|---|---|---|---|
| Diesel | | | | | | | | |
| Euro 1 | October 1994 | 5.17 | - | - | - | 1.4 | 0.19 | - |
| Euro 2 | January 1998 | 1.25 | - | - | - | 1.0 | 0.12 | - |
| Euro 3 | January 2001 | 0.80 | - | - | 0.65 | 0.72 | 0.07 | - |
| Euro 4 | January 2006 | 0.63 | - | - | 0.33 | 0.39 | 0.04 | - |
| Euro 5 | September 2010 | 0.630 | - | - | 0.235 | 0.295 | 0.005 | - |
| Euro 6 | September 2015 | 0.630 | - | - | 0.105 | 0.195 | 0.005 | - |
| Petrol (Gasoline) | | | | | | | | |
| Euro 1 | October 1994 | 5.17 | - | - | - | 1.4 | - | - |
| Euro 2 | January 1998 | 4.0 | - | - | - | 0.6 | - | - |
| Euro 3 | January 2001 | 4.17 | 0.25 | - | 0.18 | - | - | - |
| Euro 4 | January 2006 | 1.81 | 0.13 | - | 0.10 | - | - | - |
| Euro 5 | September 2010 | 1.810 | 0.130 | 0.090 | 0.075 | - | 0.005* | - |
| Euro 6 | September 2015 | 1.810 | 0.130 | 0.090 | 0.075 | - | 0.005* | - |

* Applies only to vehicles with direct injection engines

**$N_1$ - III & $N_2$, g/Km**

| Tier | Date | CO | THC | NMHC | NOx | HC+NOx | PM | P |
|---|---|---|---|---|---|---|---|---|
| Diesel | | | | | | | | |
| Euro 1 | October 1994 | 6.9 | - | - | - | 1.7 | 0.25 | - |
| Euro 2 | January 1998 | 1.5 | - | - | - | 1.2 | 0.17 | - |
| Euro 3 | January 2001 | 0.95 | - | - | 0.78 | 0.86 | 0.10 | - |
| Euro 4 | January 2006 | 0.74 | - | - | 0.39 | 0.46 | 0.06 | - |
| Euro 5 | September 2010 | 0.740 | - | - | 0.280 | 0.350 | 0.005 | - |
| Euro 6 | September 2015 | 0.740 | - | - | 0.125 | 0.215 | 0.005 | - |
| Petrol (Gasoline) | | | | | | | | |
| Euro 1 | October 1994 | 6.9 | - | - | - | 1.7 | - | - |
| Euro 2 | January 1998 | 5.0 | - | - | - | 0.7 | - | - |
| Euro 3 | January 2001 | 5.22 | 0.29 | - | 0.21 | - | - | - |
| Euro 4 | January 2006 | 2.27 | 0.16 | - | 0.11 | - | - | - |
| Euro 5 | September 2010 | 2.270 | 0.160 | 0.108 | 0.082 | - | 0.005* | - |
| Euro 6 | September 2015 | 2.270 | 0.160 | 0.108 | 0.082 | - | 0.005* | - |

* Applies only to vehicles with direct injection engines

Whereas for passenger cars, the standards are defined by vehicle driving distance, g/km, for lorries (trucks) they are defined by engine energy output, g/kWh, and are therefore in no way comparable. The official category name is heavy-duty diesel engines, which generally includes lorries and buses.

**EU Emission Standards for HD Diesel Engines, g/k wh (smoke in m $^{-1}$)**

| Tier | Date | Test cycle | CO | HC | NOx | PM | Smoke |
|---|---|---|---|---|---|---|---|
| Euro I | 1992, < 85 kW<br>1992, > 85 kW | ECE R-49 | 4.5<br>4.5 | 1.1<br>1.1 | 8.0<br>8.0 | 0.612<br>0.36 | |
| Euro II | October 1996<br>October 1998 | | 4.0<br>4.0 | 1.1<br>1.1 | 7.0<br>7.0 | 0.25<br>0.15 | |
| Euro III | October 1999 EEVs only | ESC & ELR | 1.0 | 0.25 | 2.0 | 0.02 | 0.15 |
| | October 2000 | ESC & ELR | 2.1 | 0.66 | 5.0 | 0.10<br>0.13* | 0.8 |
| Euro IV | October 2005 | | 1.5 | 0.46 | 3.5 | 0.02 | 0.5 |
| Euro V<br>Euro VI | October 2008<br>31 December 2013[15] | | 1.5<br>1.5 | 0.46<br>0.13 | 2.0<br>0.4 | 0.02<br>0.01 | 0.5 |

* for engines of less than 0.75 $dm^3$ swept volume per cylinder and a rated power speed of more than 3,000 per minute.

EEV is "Enhanced environmentally friendly vehicle".

Bharat stage emission standards are emission standards instituted by the Government of India to regulate the output of air pollutants from internal combustion engine equipment, including motor vehicles. The standards and the timeline for implementation are set by the Central Pollution Control Board under the Ministry of Environment & Forests.

The standards, based on European regulations were first introduced in 2000. Progressively stringent norms have been rolled out since then. All new vehicles manufactured after the implementation of the norms have to be compliant with the regulations. Since October 2010, Bharat stage III norms have been enforced across the country. In 13 major cities, Bharat stage IV emission norms have been in place since April 2010.

The phasing out of 2 stroke engine for two wheelers, the stoppage of production of Maruti 800 & introduction of electronic controls have been due to the regulations related to vehicular emissions.

**Table 1: Indian Emission Standards (4-Wheel Vehicles)**

| Standard | Reference | Date | Region |
|---|---|---|---|
| India 2000 | Euro 1 | 2000 | Nationwide |
| Bharat Stage II | Euro 2 | 2001<br>2003.04<br>2005.04 | NCR*, Mumbai, Kolkata, Chennai<br>NCR*, 13 Cities†<br>Nationwide |
| Bharat Stage III | Euro 3 | 2005.04<br>2010.04 | NCR*, 13 Cities†<br>Nationwide |
| Bharat Stage IV | Euro 4 | 2010.04 | NCR*, 13 Cities† |
| Bharat Stage V | Euro 5 | 2020 (proposed) | Entire country |

* National Capital Region (Delhi)

† Mumbai, Kolkata, Chennai, Bengaluru, Hyderabad, Ahmedabad, Pune, Surat, Kanpur, Lucknow, Sholapur, Jamshedpur and Agra

The above standards apply to all new 4-wheel vehicles sold and registered in the respective regions. In addition, the National Auto Fuel Policy introduces certain emission requirements for interstate buses with routes originating or terminating in Delhi or the other 10 cities.

**Emission standards for 2-and 3-wheelers**

**Table 2: Indian Emission Standards (2 and 3 wheelers)**

| Standard | Reference | Date |
|---|---|---|
| Bharat Stage II | Euro 2 | 1 April 2005 |
| Bharat Stage III | Euro 3 | 1 April 2010 |
| Bharat Stage IV | Euro 4 | 1 April 2016 (proposed) |
| Bharat Stage V | Euro 5 | 1 April 2020 (proposed) |

In order to comply with the BSIV norms, 2 and 3 wheeler manufacturers will have to fit an evaporative emission control unit, which should lower the amount of fuel that is evaporated when the motorcycle is parked.

**Trucks and buses**

Emission standards for new heavy-duty diesel engines-applicable to vehicles of GVW > 3,500 kg-are listed in Table 3.

**Table 3: Emission Standards for Diesel Truck and Bus Engines, g/kWh**

| Year | Reference | Test | CO | HC | NOx | PM |
|---|---|---|---|---|---|---|
| 1992 | - | ECE R49 | 17.3-32.6 | 2.7-3.7 | - | - |
| 1996 | - | ECE R49 | 11.20 | 2.40 | 14.4 | - |
| 2000 | Euro I | ECE R49 | 4.5 | 1.1 | 8.0 | 0.36* |
| 2005† | Euro II | ECE R49 | 4.0 | 1.1 | 7.0 | 0.15 |
| 2010† | Euro III | ESC<br>ETC | 2.1<br>5.45 | 0.66<br>0.78 | 5.0<br>5.0 | 0.10<br>0.16 |
| 2010‡ | Euro IV | ESC<br>ETC | 1.5<br>4.0 | 0.46<br>0.55 | 3.5<br>3.5 | 0.02<br>0.03 |

* 0.612 for engines below 85 kW
† earlier introduction in selected regions, see Table 1 ‡ only in selected regions, see Table 1

Emission standards for light-duty diesel vehicles (GVW ? 3,500 kg) are summarised in Table 4. Ranges of emission limits refer to different classes (by reference mass) of light commercial vehicles; compare the EU light-duty vehicle emission standards for details on the Euro 1 and later standards. The lowest limit in each range applies to passenger cars (GVW ? 2,500 kg; up to 6 seats).

**Table 4: Emission Standards for Light-Duty Diesel Vehicles, g/km**

| Year | Reference | CO | HC | HC+NOx | NOx | PM |
|---|---|---|---|---|---|---|
| 1992 | - | 17.3-32.6 | 2.7-3.7 | - | - | - |
| 1996 | - | 5.0-9.0 | - | 2.0-4.0 | - | - |
| 2000 | Euro 1 | 2.72-6.90 | - | 0.97-1.70 | 0.14-0.25 | - |
| 2005† | Euro 2 | 1.0-1.5 | - | 0.7-1.2 | 0.08-0.17 | - |
| 2010† | Euro III | 0.64<br>0.80<br>0.95 | - | 0.56<br>0.72<br>0.86 | 0.50<br>0.65<br>0.78 | 0.05<br>0.07<br>0.10 |
| 2010‡ | Euro 4 | 0.50<br>0.63<br>0.74 | - | 0.30<br>0.39<br>0.46 | 0.25<br>0.33<br>0.39 | 0.025<br>0.04<br>0.06 |

† earlier introduction in selected regions, see Table 1
‡ only in selected regions, see Table 1

The test cycle has been the ECE + EUDC for low power vehicles ( with maximum speed limited to 90 km/h).

Before 2000,emissions were measured over an Indian test cycle.

**Engines for use in light-duty vehicles can be also emission tested using an engine dynamometer. The respective emission standards are listed in table 5.**

**Table 5: Emission Standards for Light-Duty Diesel Engines, g/kWh**

| Year | Reference | CO | HC | NOx | PM |
|---|---|---|---|---|---|
| 1992 | - | 14.0 | 3.5 | 18.0 | - |
| 1996 | - | 11.20 | 2.40 | 14.4 | - |
| 2000 | Euro I | 4.5 | 1.1 | 8.0 | 0.36* |
| 2005† | Euro II | 4.0 | 1.1 | 7.0 | 0.15 |

* 0.612 for engines below 85 kW
† earlier introduction in selected regions, see Table 1

**Table 6: Emission Standards for Gasoline Vehicles (GVW 3,500 kg), g/km**

| Year | Reference | CO | HC | HC+NOx | NOx |
|---|---|---|---|---|---|
| 1991 | - | 14.3-27.1 | 2.0-2.9 | - | |
| 1996 | - | 8.68-12.4 | - | 3.00-4.36 | |
| 1998* | - | 4.34-6.20 | - | 1.50-2.18 | |
| 2000 | Euro 1 | 2.72-6.90 | - | 0.97-1.70 | |
| 2005† | Euro 2 | 2.2-5.0 | - | 0.5-0.7 | |
| 2010† | Euro 3 | 2.3<br>4.17<br>5.22 | 0.20<br>0.25<br>0.29 | - | 0.15<br>0.18<br>0.21 |
| 2010‡ | Euro 4 | 1.0<br>1.81<br>2.27 | - | 0.1<br>0.13<br>0.16 | 0.08<br>0.10<br>0.11 |

* for catalytic converter fitted vehicles
† earlier introduction in selected regions, see Table 1 ‡ only in selected regions, see Table 1

Gasoline vehicles must also meet an evaporative (SHED) limit of 2g/test (effective 2000).

Emission standards for 3- and 2- wheel gasoline vehicles are listed in the following tables.

**Table 7: Emission Standards for 3-Wheel Gasoline Vehicles, g/km**

| Year | CO | HC | HC+NOx |
|---|---|---|---|
| 1991 | 12-30 | 8-12 | - |
| 1996 | 6.75 | - | 5.40 |
| 2000 | 4.00 | - | 2.00 |
| 2005 (BS II) | 2.25 | - | 2.00 |
| 2010.04 (BS III) | 1.25 | - | 1.25 |

**Table 8: Emission Standards for 2-Wheel Gasoline Vehicles, g/km**

| Year | CO | HC | HC+NOx |
|---|---|---|---|
| 1991 | 12-30 | 8-12 | - |
| 1996 | 5.50 | - | 3.60 |
| 2000 | 2.00 | - | 2.00 |
| 2005 (BS II) | 1.5 | - | 1.5 |
| 2010.04 (BS III) | 1.0 | - | 1.0 |

**Table 9: Emission Standards for 2- And 3-Wheel Diesel Vehicles, g/km**

| Year | CO | HC+NOx | PM |
|---|---|---|---|
| 2005.04 | 1.00 | 0.85 | 0.10 |
| 2010.04 | 0.50 | 0.50 | 0.05 |

# Evaporation emission control

**Objectives :** At the end of this lesson you shall be able to
- **state the purpose of Evaporation emission control (EVAP) systems.**
- **Explain the working principle of evaporation emission control (EVAP) systems**
- **describe the EVAP system components.**

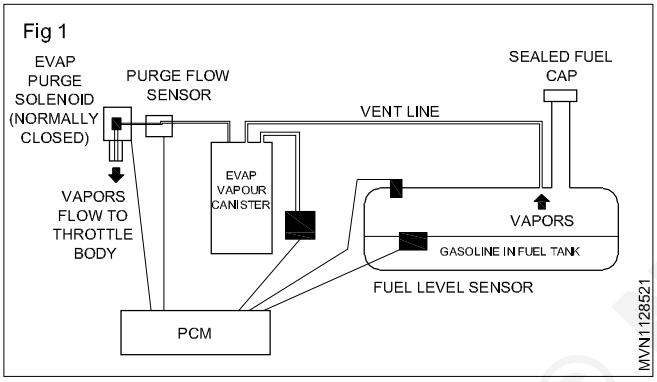
### Purpose of Evaporation emission control (EVAP) systems

The Evaporation emission control (EVAP) systems totally eliminate fuel vapours going into the atmosphere.

Vent lines from the fuel tank and carburetor bowl route vapors to the EVAP storage canister, where they are trapped and stored until the engine is started.

When the engine is warm and the vehicle is going down the road, the PCM/ECU then opens a purge valve allowing the vapors to be drain off from the storage canister into the intake manifold. The fuel vapors are then burned in the engine (Fig 1)

Fig 1




### Evap system components

The major components of the evaporative emission control system include

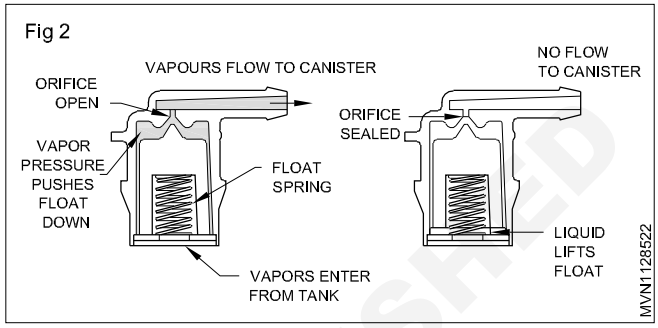
Fuel tank- This has some expansion space at the top so fuel can expand on a hot day without overflowing or forcing the EVAP system to leak.

Gas cap - This contains pressure/vacuum relief valve for venting on older vehicles (pre-OBD II), but is sealed completely (no vents) on newer vehicles (1996 & newer).

Liquid-Vapor Separator - This is located on top of the fuel tank or part of the expansion overflow tank. This device prevents liquid gasoline from entering the vent line to the EVAP canister.

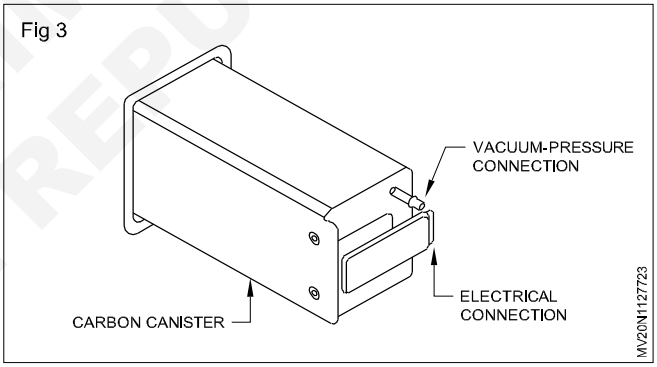
Some liquid-vapor separators use a slightly different approach to keeping liquid fuel out of the canister vent line. A float and needle assembly is mounted inside the separator. If liquid enters the unit, the float rises and seats the needle valve to close the tank vent. (Fig 2)

Fig 2




EVAP Canister - This is a small round or rectangular plastic or steel container mounted somewhere in the vehicle. It is usually hidden from view and may be located in a corner of the engine compartment or inside a rear quarter panel. (Fig 3)

Fig 3




The canister is filled with about a kg of activated charcoal. The charcoal acts like a sponge and absorbs and stores fuel vapors. The vapors are stored in the canister until the engine is started, is warm and is being driven. The PCM then opens the canister purge valve, which allows intake vacuum to drain off the fuel vapors into the engine. The charcoal canister is connected to the fuel tank via the tank vent line.

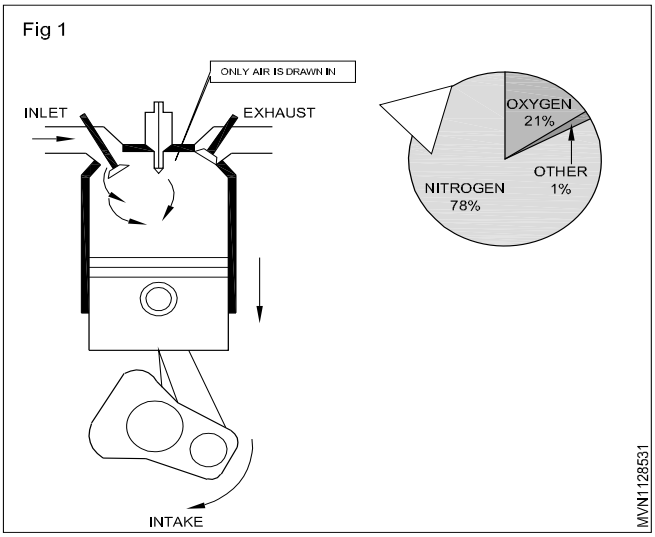
# Source of pollutants

**Objectives:** At the end of this lesson you shall be able to
- **state the characteristics of Oxides of nitrogen**
- **state the characteristics of Particulates**
- **state the characteristics of Carbon monoxide**
- **state the characteristics of Carbon dioxide ($CO_2$)**
- **state the characteristics of Sulfur content in fuels.**

### Oxides of nitrogen

Air contains almost 78% Nitrogen (Fig 1). Under the high temperatures and pressure of combustion, this nitrogen combines with oxygen to produce oxides of nitrogen. Almost all internal combustion engine exhaust gases contains these chemicals.

Fig 1




If a lean mixture is used, formation of hydrocarbons and carbon monoxide is reduced, but for oxides of nitrogen, it is increased. This is due to the high temperature, and the increase in available oxygen.

Compression-ignition engines can produce high levels of oxides of nitrogen.

**Particulates:** Particulates from modern engines are usually carbon-based. Older vehicles may produce lead-based particulates. This is caused by lead compounds used in the fuel to raise its octane rating.

In spark ignition engines, particulates are caused by incomplete combustion of rich air-fuel mixtures.

In compression-ignition engines, they are caused by a lack of turbulence and lack of oxygen. Burning of lubricating oil inside combustar chamber leaves particulates in CI engine.

**Carbon monoxide:** Carbon monoxide is a colorless, odorless, tasteless, flammable, and highly toxic gas.

Carbon monoxide is a product of incomplete combustion and occurs when carbon in the fuel is partially oxidized rather than fully oxidized to carbon dioxide.

Carbon monoxide reduces the flow of oxygen in the bloodstream and is particularly dangerous to persons with heart disease.

**Carbon dioxide ($CO_2$)**

Carbon dioxide is produced, with water, when complete combustion of air and fuel occurs.

Catalytic converters in gasoline-engined vehicles convert carbon monoxide to carbon dioxide.

**Carbon dioxide is also produced by diesel and LPG-fueled vehicles.**

Carbon dioxide does not directly impair human health, but it is considered a "greenhouse gas". In other words, as it accumulates in the atmosphere, it is believed to trap the earth's heat and contribute to the potential for climate change.

**Sulfur content in fuels**

Gasoline and diesel fuels contain sulfur as part of their chemical composition.

Sulfuric acid is produced when sulfur combines with water vapor formed during the combustion process, and some of this corrosive compound is emitted into the atmosphere through the exhaust.

High sulfur levels in fuel, when combined with water vapor, can also cause corrosive wear on valve guides and cylinder liners, which can lead to premature engine failure. The use of proper lubricants and correct oil drain intervals helps combat this effect and reduces the degree of corrosive damage.

Although regulations have reduced the permissible levels of sulfur in fuel, there are some side effects from using low sulfur diesel fuel.

The refining process used to reduce the sulfur level can reduce the natural lubricating properties of the diesel fuel, which is essential for the lubrication and operation of fuel system components such as fuel pumps and injectors.

## Characteristics and effect of hydrocarbons

**Objectives:** At the end of this lesson you shall be able to
- **state the of different type Hydrocarbon compounds**
- **state the Characteristics of Hydrocarbons**
- **state the Effect of Hydrocarbons.**

- Hydrocarbons are a major source of motor vehicle emissions.
- Gasoline, diesel, LP and natural gas are all hydro carbon compounds.
- Hydrocarbon emissions react with other compounds in the atmosphere to produce photo-chemical smog.
- Gasoline needs to evaporate easily to burn properly in an internal combustion engine.
- But this property also means it evaporates easily into the atmosphere at ordinary temperatures and pressures.
- When a vehicle is being refueled, hydrocarbon vapors can escape from the filler neck into the atmosphere.
- When the vehicle is left in the sun, its temperature increases, and fuel evaporates from the tank.

## Hydrocarbons in exhaust gases

**Objective:** At the end of this lesson you shall be able to
- **state the release of Hydrocarbon compounds in produced during combustion.**

In a 4-stroke gasoline engine, during valve overlap at top dead centre (TDC), some intake charge is drawn out of the combustion chamber into the exhaust port. Raw fuel, a mixture of hydrocarbons and air, is released into the atmosphere.

When combustion occurs in the cylinder, the walls, piston and piston rings are slightly cooler than points closer to the burning mixture. Some of the air and fuel molecules come in contact with these cooler parts, and they cool down, until their temperature becomes too low for combustion to occur. They are left unburned, and when the exhaust port opens, they leave the cylinder.

Misfiring of the ignition can result in unburned fuel leaving the cylinder when the exhaust port opens.

If an excessively rich air-fuel mixture is used, there is too much fuel for the quantity of air. Combustion will be incomplete, and any unburned fuel will leave the cylinder through the exhaust port.

If an excessively lean mixture is used, then combustion takes longer, and the flame may extinguish before it is complete. When the exhaust port opens, unburned hydrocarbons will be exhausted from the cylinder.

## Diesel Particulate Filters (DPF)

**Objectives:** At the end of this lesson you shall be able to
- **state the purpose of diesel particulate filters**
- **describe the working principle of diesel particulate filters**
- **state the importance of regeneration of diesel particulate filters**
- **describe the working principle of active regeneration of DPF**
- **describe the working principle of passive regeneration of DPF.**

**Purpose of Diesel particulate filters**

Diesel particulate filters (DPF) also called as 'particulate traps' have been developed to filter out PM from the diesel exhaust gases to meet very stringent emission limits.

During combustion of the fuel and air mix, a variety of pollutant particles generically classified as diesel particulate matter is produced due to incomplete combustion.

**Working principle of diesel particulate filters**

Alumina coated wire mesh, ceramic fiber, porous ceramic monoliths etc., have been studied as filtration media. Presently, ceramic monolith of honeycomb type structure is used to trap the particulate matter as the gas flows through its porous walls. These filters are also termed as 'ceramic wall flow filters'.

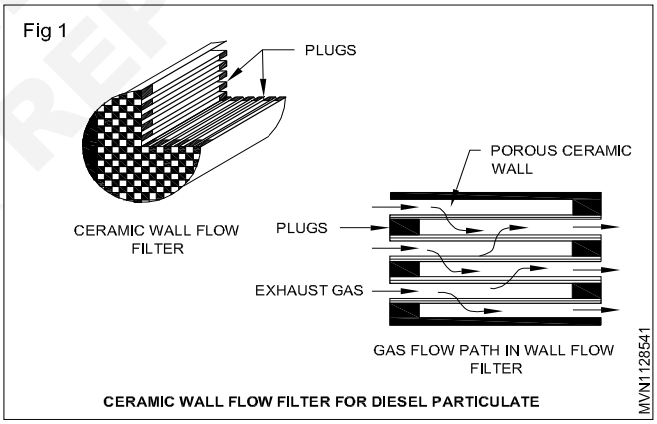
A ceramic honeycomb type particular filter is shown in Fig 1. In this cellular structure, alternate cells are plugged at one end and open at the opposite end. The exhaust gas enters the cells that are open at the upstream end and flows through the porous walls to the adjacent cells. The adjacent cells are open at the downstream end from where the filtered gas exits to the atmosphere. Flow path of gas through walls of the filter is also shown on Fig 1.

**Regeneration of DPF**

It is relatively easy to filter and collect the particulate matter in the trap but the soot is to be burned in-suitable i.e., 'regenerate' the trap so that pressure drop across the filter is kept always at an acceptable level.

Burning of soot particles begins at about 540º C. Such high exhaust gas temperatures do not occur during engine operation for sufficiently long periods of time. The diesel exhaust gas temperatures in the exhaust pipe typically reach to about 300ºC only.

Fig 1




CERAMIC WALL FLOW FILTER FOR DIESEL PARTICULATE

Two types of regeneration systems have been investigated and a few developed for employment on production vehicles

1 Active regeneration

2 Passive regeneration

**Active DPF Regeneration:** In the active regeneration systems, sensors are used to monitor pressure drop across the trap. On receiving the signal from the sensor, the exhaust gas temperature is increased above 500º C by any one of the following techniques

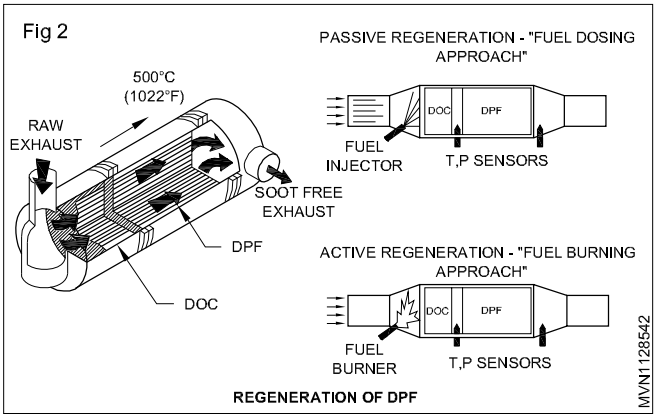
**Engine throttling -** Throttling of air reduces airflow that results in decrease of overall air-fuel ratio, which increases the combustion and exhaust temperatures.

**Use of electric heater upstream of filter -** power to the electric heater is supplied by the engine alternator. A typical truck DPF regeneration system may require a 3 kw heater.

**Use of burner upstream of filter -** A diesel fuel burner is placed in the exhaust in front of the filter to regenerate the diesel particulate filter.

**Passive regeneration:** The passive regeneration systems (Fig. 2) employ catalysts to reduce soot oxidation temperatures to the levels that lie within the normal exhaust gas temperature range . The catalyst is either added to diesel added to diesel fuel in the form of additives or is impregnated on the surface of the filter substrate. Another approach for passive regeneration uses a special oxidation catalyst in the front of the ceramic wall flow particulate filter to promote soot oxidation. This system is known as the continuously regeneration trap (CRT).

Fig 2




REGENERATION OF DPF

## Combustion chamber design

**Objectives:** At the end of this lesson you shall be able to

- **state the importance of combustion chamber design**
- **state the purpose of air swirl combustion chamber design in CI engine.**

The level of emissions can be controlled by suitable modification in the Combustion chamber design that increase gas flow rate, and promote vaporization, distribute the fuel more evenly in the combustion chamber.

The basic requirements of a good combustion chamber are to provide:

High power output

High thermal efficiency and low specific fuel consumption

Smooth engine operation

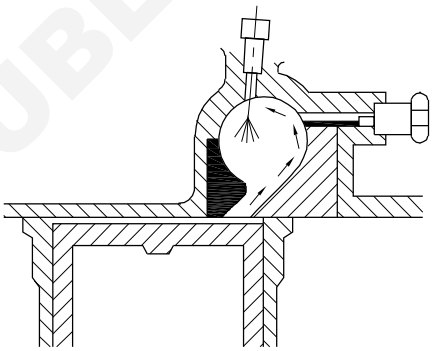
Reduced exhaust pollutants.

Gas flow rate, and volumetric efficiency, can be improved by using 2 intake valves in each cylinder. The effective port opening is increased, and the gas flow rate increases.

Changing valve timing also alters the combustion process. Reducing valve overlap reduces the scavenging effect. It also reduces hydrocarbon emission.

Most important function of CI engine combustion chamber is to provide proper mixing of fuel and air in short possible time. For this purpose an organized air movement called air swirl is to be produced to produce high relative velocity between the fuel droplets and air. (Fig 1).

Fig 1




## Combustion process in CI engine

**Objectives:** At the end of this lesson you shall be able to

- **state combustion process**
- **define perfect combustion**
- **define typical real-world engine combustion process.**

Most vehicle fuels (gasoline, diesel, natural gas, ethanol, etc.) are mixtures of hydrocarbons, compounds that contain hydrogen and carbon atoms.

In a "perfect" engine, oxygen in the air would convert all of the hydrogen in fuel to water and all of the carbon in the fuel to carbon dioxide (carbon mixed with oxygen). Nitrogen in the air would remain unaffected.

In reality, the combustion process is not "perfect," and automotive engines emit several types of pollutants:

a "Perfect" Combustion Process

**FUEL (hydrocarbons) + AIR (oxygen and nitrogen) = CARBON DIOXIDE (CO2) + Water ($H_2O$) + Nitrogen**

b Typical Real-World Engine Combustion Process

**FUEL (hydrocarbons) + AIR (oxygen and nitrogen) = UNBURNED or PARTIALLY BURNED HYDROCARBONS (VOCs) + NITROGEN OXIDES (NOx) + CARBON MONOXIDE (CO) + CARBON DIOXIDE ($CO_2$) + Water ($H_2O$)**

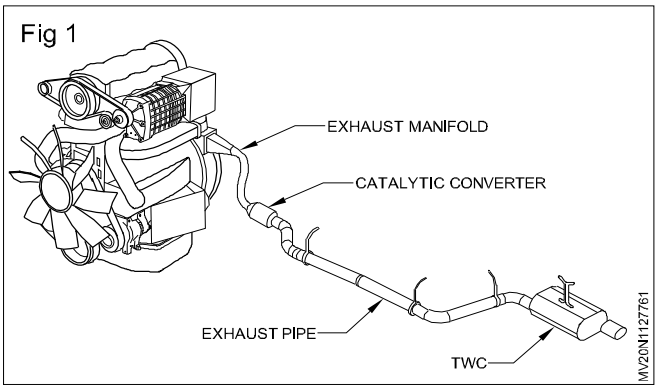
"Perfect" Combustion process is achieved by Ideal compression pressure is reached within the cylinder, condition of spark plug and timing accurate, Temperatures at correct value for engine, fuel, air, amount of fuel correct according to engines requirement, Precise valve timing, That the engine receives the correct amount of air, Electronically managed fuel injection systems use sensors and catalytic converters to control the combustion process and the air-fuel ratio supplied to the engine at all times.

# Catalytic converter

**Objectives:** At the end of this lesson you shall be able to
- **state the purpose of catalytic converter**
- **explain the conversion principle of catalytic converter**
- **describe the EVAP system components.**

Passenger cars and light trucks have been equipped with catalytic converters. A Catalytic converter is located (Fig 1) within the exhaust system and converts to convert harmful emissions as HC, CO, NOx, produced by an internal combustion engine, to less-harmful elements: $H_2O$ (Water), $CO_2$(Carbon Dioxide), and N2 (Nitrogen)

Fig 1



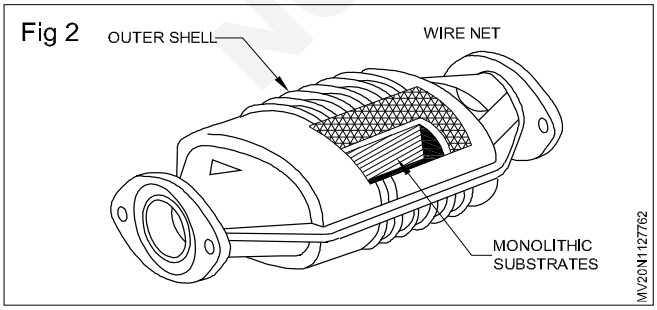

**Block Diagram of three-way catalytic converters (TWC) (Fig 3):** Modern vehicles are fitted with three-way catalytic converters (TWC). The term 'three-way' is in relation to the three regulated emissions the converter is designed to reduce:

- Unburnt Hydrocarbons are oxidized into water/steam.
- Carbon monoxide is oxidized into carbon Dioxide
- Oxides are converted into Nitrogen and Oxygen

The converter uses two different types of catalysts to reduce the pollutants: a reduction catalyst and an oxidation catalyst. A honeycomb structure (Fig 2) as either ceramic or metallic is treated with a wash-coat of precious metals usually platinum, palladium and rhodium through which the exhaust gasses flow. The Surface of the honeycomb material has a rough finish such that it allows the maximum contacts are available to the exhaust gasses.

The exhaust gases first pass over the reduction catalyst in the converter. The platinum and rhodium coating helps to reduce the oxides of nitrogen, together known as 'NOX' emission.

Fig 2



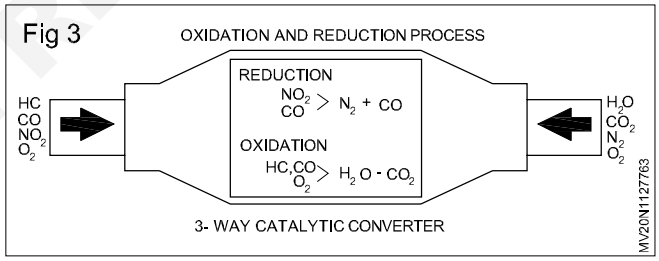

| Material | Conversion for |
|---|---|
| Platinum/palladium | Oxidizing catalysts for HC and CO |
| Rhodium | Reducing catalyst for NOx |
| Cerium | Promotes oxygen storage to improve oxidation efficiency |

The three - way Catalyst, which is responsible for performing the actual feed gas conversion, formed by coating the internal substrate with the following type materials.

The electronic control unit, or ECU, monitors the air-fuel ratio by using an exhaust gas oxygen, or EGO, sensor, also known as a lambda sensor. This sensor tells the engine computer how much oxygen is in the exhaust and uses this information via the ECU to control the fuel injection system.

The ECU can increase or decrease the amount of oxygen in the exhaust by adjusting the air-to-fuel ratio. The system ensures that the engine runs at close to the stoichiometric point in normal driving conditions. It also ensures that there is always sufficient oxygen in the exhaust system to allow the oxidization catalyst to deal with unburned hydrocarbons and carbon monoxide.

Fig 3

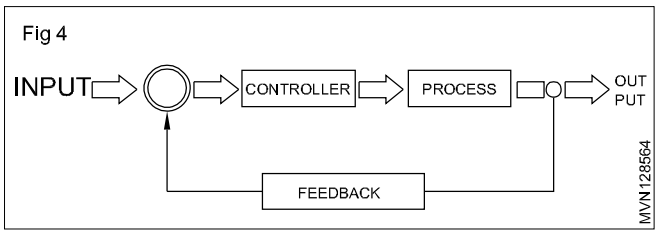



**Closed loop control system**

Control system in which the output has an effect on the input quantity in such a manner that the input quantity will adjust itself based on the output generated is called closed loop control system

In this way closed loop control system is called automatic control system.

Fig 4



# Crankcase emission control

**Objectives:** At the end of this lesson you shall be able to
- **state the purpose of crankcase ventilation**
- **describe the working principle of positive crank case ventilation (PCV) system**
- **explain different stages of PCV valve operation**
- **describe the working principle of crankcase depression regulator valve (CDRV) for diesel engine.**

### Purpose of crankcase ventilation

The first controlled emission was crankcase vapors. While the engine is running during combustion some unburned fuel and other products of combustion leak between the piston rings and the cylinder walls, down into the crankcase. This leakage is called blow-by. Blow by gases are largely HC gases

Unburned fuel, and water from condensation, also find their way into the crankcase, and sump. When the engine reaches its full operating temperature , the water and fuel evaporate. To prevent pressure build - up, the crankcase must be ventilated.

In earlier vehicles, crankcase vapors were vented directly to the atmosphere through a breather tube, or road draught tube. It was shaped to help draw the vapors from the vapors from the crankcase, as the vehicle was being driven.

Modern vehicles are required to direct crankcase breather gases and vapors back into the inlet system to be burned.

A general method of doing this is called positive crankcase ventilation, or PCV.

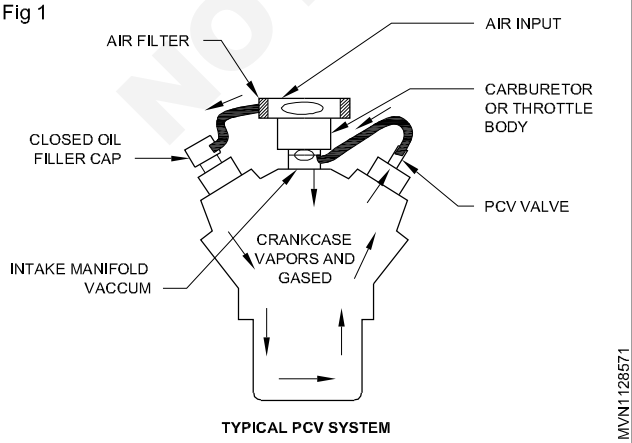
PCV working principle

The PCV vacuum circuit works as follows (Fig 1). Air for the system enters the air cleaner area. The air then goes through the air filter, through a tube, and through the closed oil filler cap.

The intake main fold vacuum the draws the crankcase vapors and gases back to the PCV valve. From the PCV valve, the vapors and gases are drawn into the intake of the engine to be burned by combustion.

If too many vapors and gases get into the intake main fold, it may upset the air-fuel ratio. The PVC valve helps to control the amount of vapors and gases going back into the intake main fold.

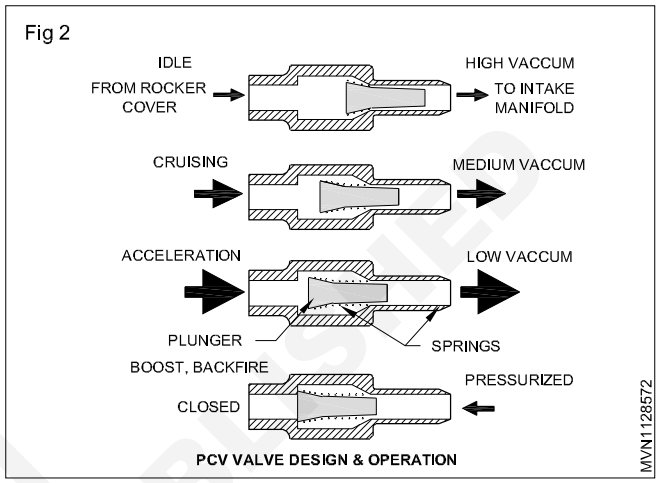
Fig 1




TYPICAL PCV SYSTEM

As shown in the diagram (Fig 2), the PCV valve consists of a tapered plunger and two springs, and limits the air flow based on intake main fold vacuum.

Fig 2




PCV VALVE DESIGN & OPERATION

During idle and deceleration when blow-by gases are minimal, the low pressure (or “high” vacuum) in the intake manifold pulls the plunger against the springs and restricts the airflow through the valve.

During acceleration and heavy-load operations when blow-by gases are at their maximum, low vacuum in the intake main fold allows the springs to keep the plunger “ back” for maximum airflow through the PCV valve.

In the case when the intake main fold becomes pressurized, such as during boost on turbocharged engines or during backfire, the plunger’s seat is forced against the valve case preventing air from entering the crankcase.

Crankcase depression regulator valve (CDRV) for diesel engine

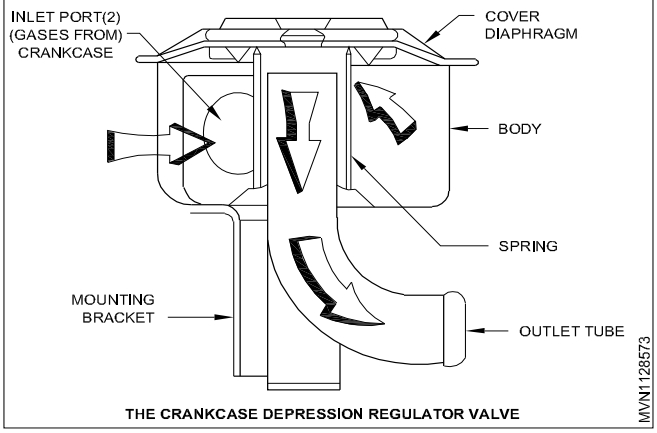
A crankcase depression regulator valve (CDRV) is used to regulate the flow of crankcase gases back into the engine. This valve is designed to limit vacuum in the crankcase . The gases are drawn from the valve cover through the CDRV and into the intake main fold.

Fresh air enters (Fig 3) the engine through the combination filter, check valve, and oil fill cap. This air mixes with blow-by gases and enters the opposite valve cover. These gases pass through a filter on the valve cover and are drawn into the connected tubing.

Intake main fold vacuum acts against a spring loaded diaphragm to control the flow of crankcase gases. Higher vacuum levels pull the diaphragm close to the top of the outlet tube. This reduces the amount of gases being drawn from the crankcase and decreases vacuum in the crankcase. As intake vacuum decreases, the spring pushes

the diaphragm away from the top of the outlet tube allowing more gases into the main fold. The diesel crankcase ventilation system should be cleaned and inspected every 15,000 miles (24,000 km) or at 12 month intervals.

Fig 3




THE CRANKCASE DEPRESSION REGULATOR VALVE

## Exhaust Gas Recirculation (EGR) valve

**Objectives:** At the end of this lesson you shall be able to

- **state the purpose of exhaust gas recirculation (EGR) system**
- **describe the working principle of EGR valve**
- **describe the working principle of linear electronic EGR valve**
- **describe the working principle EGR system in diesel engines.**

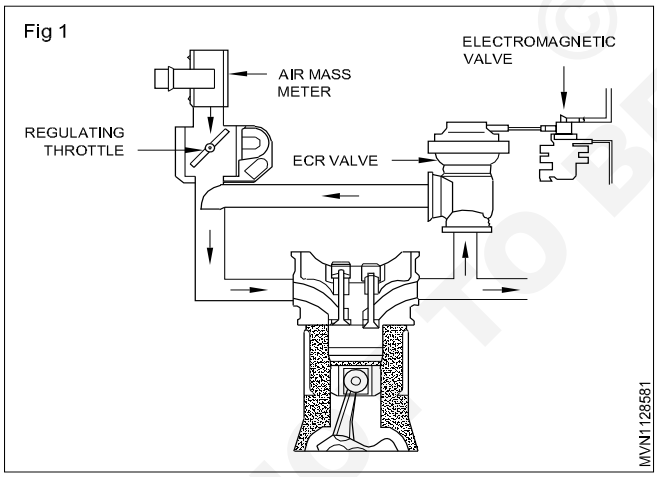
### Purpose of exhaust gas recirculation (EGR) system

Purpose of exhaust gas recirculation (EGR) system's purpose is to reduce NOx emissions that contribute to air pollution.

### Working principle of EGR valve

Exhaust gas recirculation reduces the formation of NOX and engine knock control. By re-circulating a allowing a small amount of exhaust gas into the intake air-fuel mixture on intake manifold as shown in Fig 1.

Fig 1



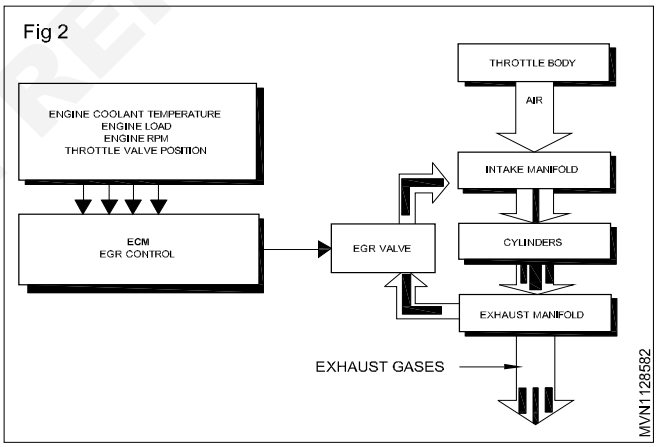

EGR,valve, connected between the exhaust port, or manifold, and the intake system.

If engine conditions are likely to produce oxides of nitrogen, the EGR valve opens, letting some gases is (only about 6 to 10% of the total) pass from the exhaust, into the intake system. During combustion, these exhaust gases absorb heat from the burning air and fuel. This lowers peak combustion temperatures ( below 1500 degrees c) to reduce the reaction between the reaction between nitrogen and oxygen that forms NOx.

Older EGR systems use a vacuum regulated EGR valve while newer vehicles tend to have an electronic EGR valve to control exhaust gas recirculation.

When the engine is idling, the EGR valve is closed and there is no EGR flow into the manifold. The EGR valve remains closed until the engine is warm and is operating under load. As the load increase and combustion temperatures start to rise, the EGR valve opens and starts to leak exhaust back into intake manifold (Fig 2) This has a quenching effect that lowers combustion temperatures and reduces the formation of NOx.

Fig 2




The EGR valve opens and closed the passage between the exhaust manifold and intake manifold. Vacuum is remove EGR valves.

Inside the vacuum actuated EGR (Fig 3) valve is a valve, diaphargm and spring. When vacuum is applied to diaphragm lifts the valve off its seat allowing exhaust gases into the intake air stream. When vacuum is removed the spring forces the diaphragm and valve downward closing the exhaust passage.

### Current technology of EGR valve

### Linear electronic EGR valves

Electronic EGR valve is the "linear" EGR valve. (Fig 4) This type uses a small computer - controlled stepper motor to open and close the EGR valve instead of vacuum.

Fig 3

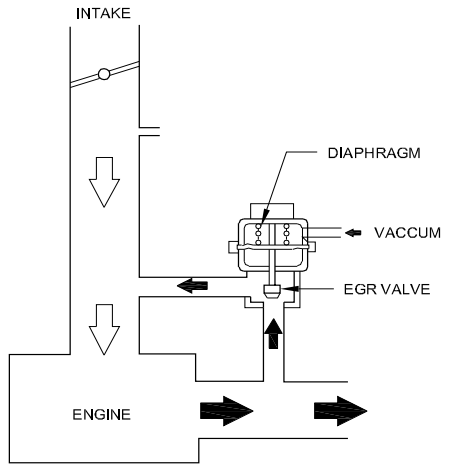
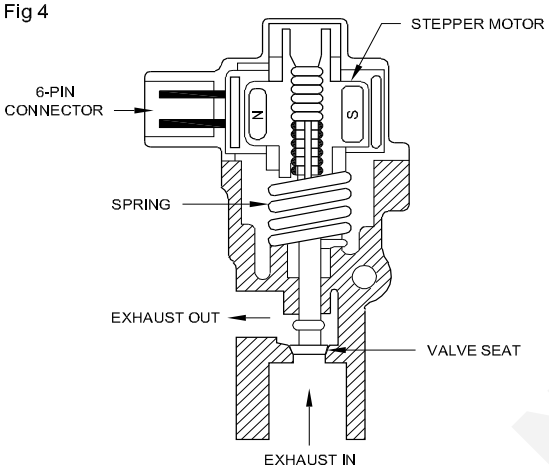



Fig 4



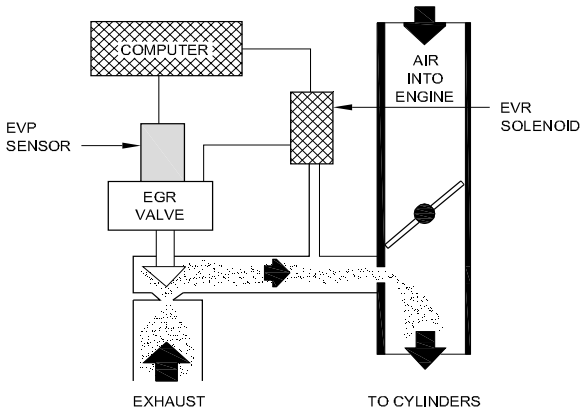

LINEAR EGR VALVE

The advantage of this approach is that the EGR valve operates totally independent of engine vacuum. It is electrically operated and can be opened in various increments depending on what the engine control module determines the engine needs at any given moment in time.

Liner EGR valves may also be equipped with an EGR valve position sensor (EVP) to keep the computer informed about what the EGR valve is doing.

The EVP sensor (Fig 5) also helps with self - diagnostics because the computer looks for an indication of movement from the sensor when the it commands the EGR valve to open or close. The sensor works like a throttle position sensor and charges resistance. The voltage signal typically varies from 0.3 (closed) to 5 volts (open).

Fig 5




LINEAR EGR SYSTEM CIRCUIT

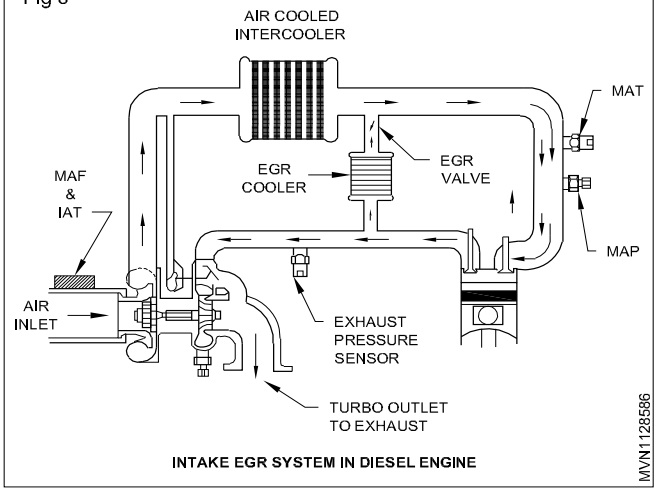
**EGR system in diesel engines**

The EGR systems (Fig 6) are quite the same as those used in gasoline engines, which means a sample of exhaust introduced into combustion chambers to reduce combustion temperatures. One of the main different is that most manufactures cool the incoming EGR gases before introducing them into the cylinders. This reduces the temperature of combustion and therefore reduces the amount of NOx emitted by the exhaust as shown in Fig 3.

Most systems with EGR coolers use engine coolant that passes through a separate circuit to cool the recirculated exhaust gases.

The ECU/PCM operates and monitors the EGR system, EGR flow is controlled by the ECU/PCM through a digital EGR valve. EGR flow will occur only when the engine is at a predetermined level and conditions are.

Fig 6




INTAKE EGR SYSTEM IN DIESEL ENGINE

# Selective Catalytic Reduction (SCR)

**Objectives:** At the end of this lesson you shall be able to

- **state the purpose of selective catalytic reduction (SCR)**
- **state the selective catalytic reduction (SCR) system components**
- **describe the working principle of selective catalytic reduction (SCR).**

**Purpose of selective catalytic reduction (SCR)**

selective catalytic reduction (SCR) is the process by which oxides of nitrogen (Nox) contained in diesel exhaust are reduced to nitrogen ($N_2$) and water ($H_2O$)

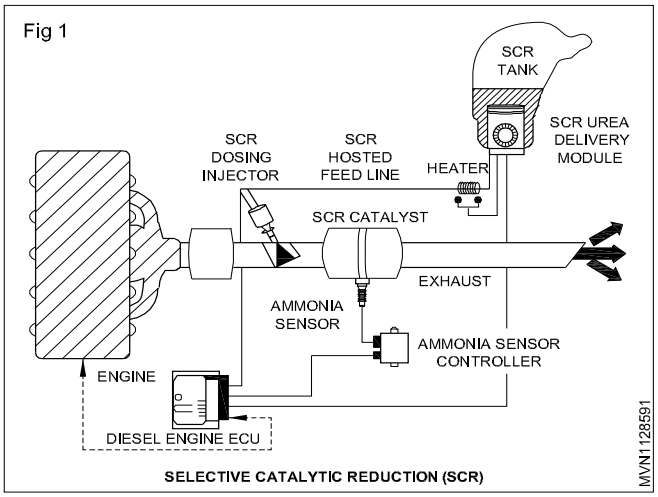
**Selective catalytic reduction**

**Selective:** targets NOx in diesel exhaust

**Catalytic:** reduces a catalyst

**Reduction:** NOx is reduced to nitrogen ($N_2$) (Fig.1)

Fig 1




SELECTIVE CATALYTIC REDUCTION (SCR)

SCR requires diesel exhaust fluid (DEF) - a urea based solution

SCR reduces NOX emissions up to 93%

Selective catalytic reduction (SCR) system components

- Diesel exhaust Fluid (DEF)
- DEF injector
- Mixing tube
- SCR catalyst

**Working principle of SCR system:** SCR works by injecting diesel exhaust fluid (DEF), into the hot exhaust stack. DEF works in conjunction with the hot exhaust gases and catalyst to break NOx into two components of our normal atmosphere air vapor and nitrogen.

**Engine:** The NOx reduction process starts with an efficient CRD engine design CRD engine design that burns clean ultra low sulfur diesel (ULSD) and produces inherently lower exhaust emissions- exhaust that is already much cleaner due to leaner and more complete combustion.

**Diesel exhaust fluid (DEF) tank and pump:** Under the direction of the vehicle's onboard computer, Def is delivered in precisely metered spray patterns into the exhaust stream just ahead of the SCR converter.

DEF is a urea based solution, Composition - 67.5% de-ionized water - 32.5% urea

Urea- Under heat, decomposes to ammonia (NH3) and carbon dioxide ($CO_2$)

Ammonia (NH3) reacts with NOx in the presence of a catalyst

DEF is required for the selective catalytic reduction (SCR) system to function

**SCR catalytic converter:** This is where the conversion happens. Exhaust gases and an atomized mist of DEF enter the converter simultaneously. Together with the catalyst inside the converter, the mixture undergoes a chemical that produces nitrogen gas and water vapor.

**Control device**

Exhaust gases are monitored via a sensor as they leave the SCR catalyst. Feedback is supplied to the main computer to alter the DEF flow if NOx levels fluctuate beyond acceptable parameters.

## EGR vs SCR

**Objective:** At the end of this lesson you shall be able to

- **state the difference between exhaust gas recirculation (EGR) Vs selective catalytic reduction (SCR).**

**EGR Vs SCR**

For 2010, the environmental protection agency (EPA) requires that diesel truck emissions contain a 97 percent reduction in their Sulphur content. Engine manufacturers have come up with two advanced pollution control technology options for cars, trucks, and buses which include:

Exhaust gas recirculation (EGR) is an other way to reduce NOx formation. In an EGR system, engine exhaust is recycled back through the engine to dilute the oxygen. Almost all engine manufacturers use a form of EGR, as it takes both EGR and SCR to achieve near-zero NOx emissions.

While stand alone EGR systems help to reduce NOx, there are some disadvantages:

Selective catalytic reduction (SCR) is an exhaust after treatment system that injects a small amount of a chemical called diesel exhaust fluid (DEF) into the exhaust. DEF is mixed with exhaust in the presence of a catalyst turning NOx (oxides of nitrogen - a harmful pollutant that contributes to smog and acid rain) into harmless nitrogen and water vapor.

Majority of the engine manufacturers have added SCR to their exhaust systems such as; volovo, mack, daimler, and hino to name a few. Difference between EGR & SCR

| EGR | SCR |
|---|---|
| Reduces overall engine efficiency | More power |
| Large cooling system | Fuel efficiency |
| Exhaust back pressure | Larger service intervals |
| Additional engine components | Reliability and durability |
| Recirculates 30% exhaust | Uses diesel exhaust fluid |
| Back pressure sensor | SCR chamber never requires service |
| No additional fluid | |
| Increased maintenance cost | |

# Alternator

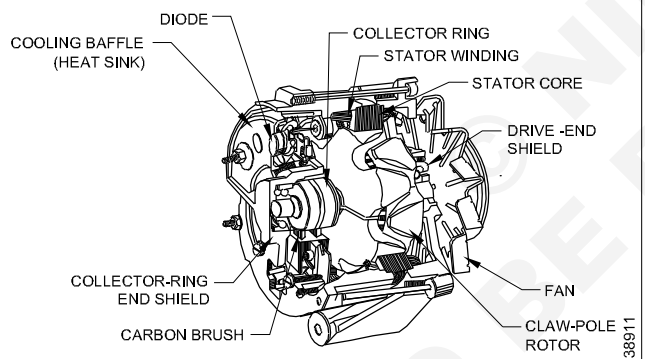
**Objectives:** At the end of this lesson you shall be able to
- **explain the purpose of an alternator**
- **describe the circuit of the alternator**
- **list out the different parts of the alternator**
- **explain the functions of the various parts of an alternator**
- **explain the working of an alternator.**

### Purpose of alternator (Fig 1)

Right from the beginning, vehicles were fitted with dynamos for producing electricity. In present day vehicles the number of electrical accessories used has increased. Thus the demand for higher capacity generators has arisen. This can only be met by increasing the capacity of the generator and also by running it at higher speeds.

The vehicles in large cities have to, often, move at very slow speeds due to heavy traffic. Normally a DC dynamo will not be able to charge the battery at such low speeds. The speed of the dynamo cannot be increased beyond a certain limit. Therefore, an alternator or AC generator is used. An alternator can produce more electricity at low r.p.m.

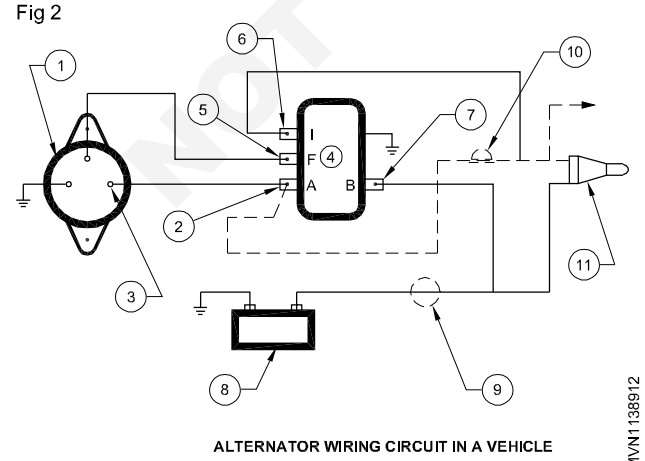
Fig 1




SECTIONAL VIEW OF BOSCH CLAW-POLE ALTERNATOR

### Alternator wiring circuit in a vehicle (Fig 2)

Fig 2



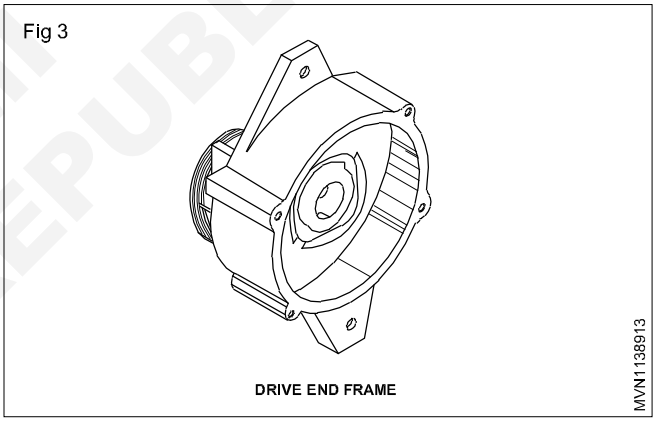

ALTERNATOR WIRING CIRCUIT IN A VEHICLE

The alternator's (1) output terminal (3) is connected to the 'A' terminal (2) of the voltage regulator. The alternators (1) field terminal (5) is connected to the 'F' terminal of the voltage regulator (4). The 'B' terminal of the regulator is connected to the battery (8) via the ammeter (9). The battery's (8) connection is also connected to the 'A' terminal (2) of the regulator (4) via the ignition switch (11) and indicator lamp (10). The terminal I (6) of the voltage regulator (4) is connected to the Ignition terminal (SW).

### Description of parts of an alternator

### Drive end frame (Fig 3)

Fig 3




DRIVE END FRAME

The drive end frame supports a pre-lubricated sealed bearing in which the drive end of rotor shaft rotates.

The rotor and its shaft is mounted and encased between drive end frame and slip ring end frame.

### The rotor assembly (Fig 4)

This consists of a steel shaft which carries the driving pulley and cooling fan, a cylindrical iron core, and two insulated slip rings. A large number of turns of insulated wire are wound over the core to form the field winding.

Each end of the winding is connected to its own slip ring and spring-loaded brush. The winding is enclosed by two iron pole pieces with eight interlocking fingers which become alternate north and south poles when direct current is passed through the winding via the brushes.

### Stator assembly (Fig 5)

It is a stationary part which is held between two end covers. (Fig 1 & 5)

Fig 4

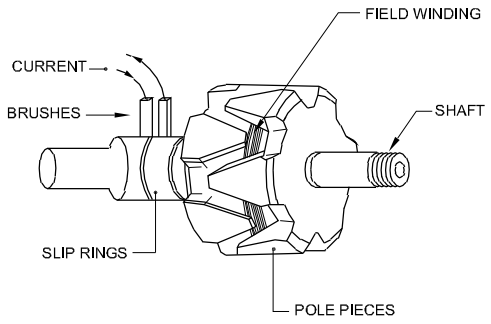
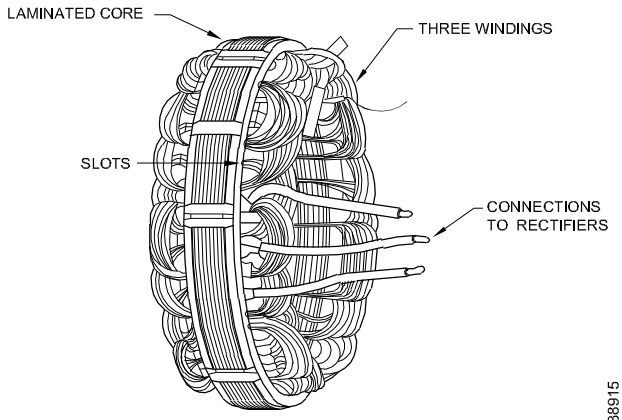



Fig 5




This consists of a laminated, cylindrical, iron core which is slotted to permit the fitting of three sets of insulated windings. In the lighter units these windings are star connected and in the heavier units delta connected. The number of coils depends on the number of poles.

The 'N' pole and 'S' pole of the magnet pass each stator winding and due to interruption of the magnetic flux the current is generated in the stator windings.

**Diodes**

The diodes are made of silicon and these allow current to flow in one direction only. They are so connected as to allow the current to flow from the alternator to the battery but not in the opposite direction.

Three diodes on the negative side are connected to the rear end housing and three diodes on the positive side are mounted on an insulated heat sink.

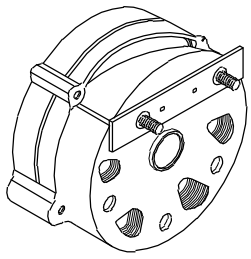
The diodes convert the AC produced by the alternator to DC since the Automotive accessories are designed to utilise DC current.

**Slip ring end frame (Fig 6)**

The slip ring end frame supports the rectifier mounting plates and a pre-lubricated bearing for rotor/shaft rotation.

The rectifiers are pressed into the slip ring end head or heat sink and are connected to the stator leads.

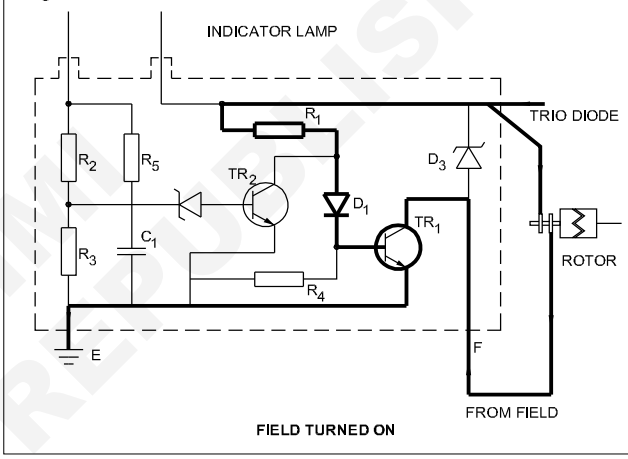
Fig 6




**Electronic regulator (Fig 7 & 8)**

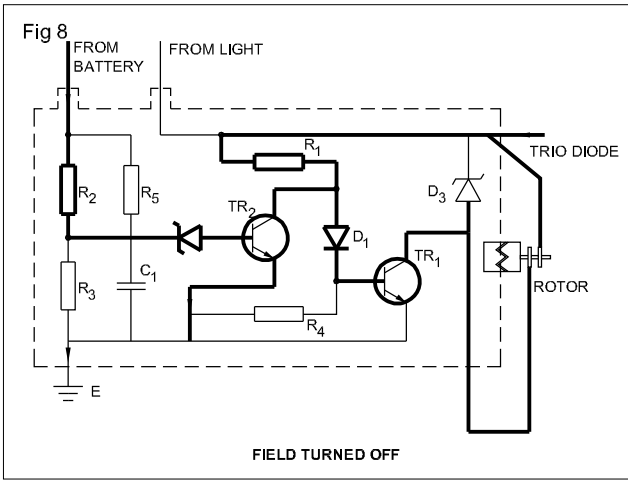
To protect the battery and the accessories against high voltage, the alternator voltage must be controlled. This is done by using a voltage regulator which varies the current flow to the rotating field (rotor). The regulator work is done by electronically.

Fig 7




A transistor regulator consists primarily of resistors, capacitors (condensers), diodes and transistors. It is a complete static unit which controls the alternator voltage. It is durable and efficient. It safely allows a high field-current flow, and it has a longer service life than the vibrating contact regulator. An equally important feature is the ease with which it can be tested, adjusted and serviced.

Fig 8



When the permanently magnetized rotor rotates, an alternating voltage is induced in the stator winding which is rectified by the three negative and three positive diodes and DC current flows into the battery. The rectified current of each phase winding also flows over diodes D1, D2, D3 into the regulator to resistor R1, to the collector of resistor TR3 and to the resistor R3 to ground. The transistor TR3 is not switched on because the low voltage allows zenier diode D6 and diode D5 to block the base circuit. However, transistors TR2 and TR1 are switched on because current can now flow over both emitter bases to ground.

With both transistors switched on, current from the output terminal of the alternator supplies current to the regulator over resistor R5 to the field coil and transistor TR1 (collector elements) to ground. Output current also flows from resistor R5 to resistors R2 and R4 to ground. As charging voltage increases, the voltage impressed across resistor R4 is also impressed across diode D5 and zenier diode D6.

When the breakdown voltage is reached, transistor TR3 switches on because the emitter-base circuit ground is completed. This causes TR2 and TR1 to shut off since current now flows over the lower resistance circuit from resistor R1, transistor TR3 (collector-emitter) to ground, robbing the current flow from transistor TR2. The field current flow stops. As system voltage decreases, diodes D5 and D6 stop conducting current and transistor TR3 shuts off. This cycle repeats many times per second to maintain present alternator voltage. The capacitors C1, C2 and C3 and diode D4 perform the same function.

**Operation of alternator** (Fig 9)

When the engine is started, the belt drives the rotor (3) assembly.

During rotation the 'S' poles and 'N' poles of the rotor magnet pass through each stator coil (4).

Due to this rotation of the rotor assembly the current is generated in the stator coil (4), alternatively positive and negative.

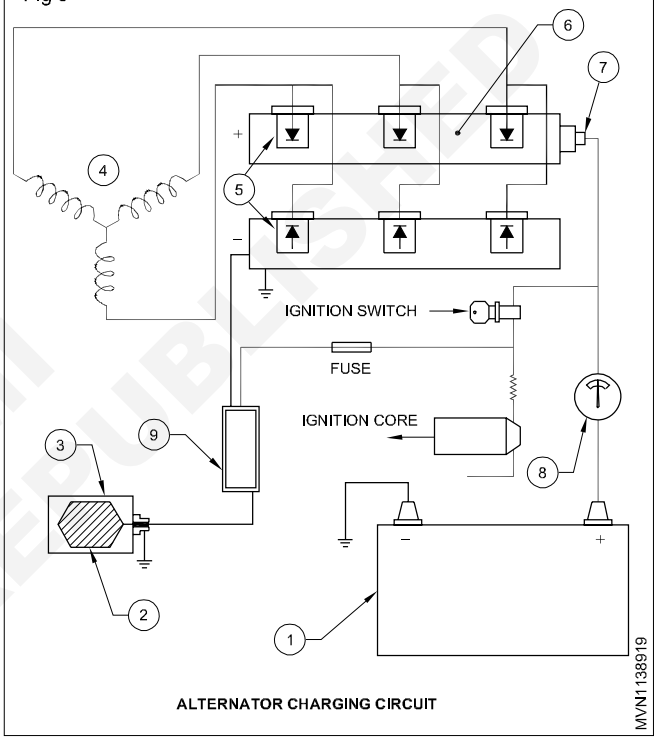
If more rotor magnets pass through each stator coil (4) in a given time, the generation of current will be more, since they form the ends of metal fingers, each finger acting like a magnet. These fingers interlock but do not touch each other.

The current produced is allowed to pass through silicon diodes (5) mounted on the heat sink (6). The diodes convert the AC to DC.

The heat produced in the diodes is dissipated by the heat sink.

The current passes through the battery terminal (7), the ammeter (8) and to the battery (1) for charging.

Fig 9




ALTERNATOR CHARGING CIRCUIT



## Differences between alternator and dynamo

**Objectives:** At the end of this lesson you shall be able to
- **list out the differences between alternator and dynamo**
- **state the precautions to be followed while using alternators**
- **state the common troubles and their remedies in alternators.**

**Precautions to be followed while handling alternators**

- Ensure all connections are tight and clean.
- Ensure that there is no open circuit in the charging circuit.
- Observe correct polarity when refitting battery in the vehicle. Reversed battery connections may damage the rectifier and the vehicle wiring.
- Do not short or ground any of the terminals of the alternator or regulator.
- Do not allow water to seep into the alternator.
- Do not operate the alternator unless it is connected to a load.
- Disconnect the battery, alternator and regulator before carrying out any arc welding on the vehicle.
- The alternator should not be mounted near the exhaust manifold without suitable heat protection.
- Do not attempt to polarise the alternator.
- The field circuit must never be grounded on this system between the alternator and the regulator.
- Maintain belt tension.

**Differences between Alternator and DC Generator/Dynamo**

| | Alternator | DC Generator/Dynamo |
|---|---|---|
| 1 | The alternator develops DC current | The generator develops AC. |
| 2 | It produces enough current during idling speeds of the engine (18 to 20 amps). | It produces very little current during idling. (No charging of battery is possible) |
| 3 | No cut out is required in the charging circuit as diodes do not allow return current. | Cut out relay is used in the charging circuit. |
| 4 | For the same output the weight of the alternator is less. Ex.12 V - 8 kg | But the weight of the generator is more. Ex.12 V - 12 kg |
| 5 | The alternator limits its own current. No current regulator is used. | The generator does not limit its own current. Hence a current regulator is required. |
| 6 | Diode rectifiers do not pass the current in the reverse direction. | In the generator charging circuit a cut out relay acts as a reverse current relay. |
| 7 | In the alternator the voltage is only to be regulated. regulated to a certain value. | In the generator both voltage and current are to be |
| 8 | Alternator can run up to a very high speeds (say 20,000 r.p.m.). | Generator r.p.m. is limited to 9000. |
| 9 | Less maintenance due to use of slip ring and brushes. | Frequent maintenance due to use of commutator and carbon bushes. |
| 10 | The alternator charges the battery at low engine speeds (Idling r.p.m.). | The generator does not charge the battery at low idle speeds. |
| 11 | It has high output weight ratio. | It has low output-weight ratio. |
| 12 | The alternator is simple and robust in construction, looks compact. | The generator is not very robust. |
| 13 | Due to transformation of mechanical energy to electrical energy, the alternator works with 50% efficiency only. | In the generator transfer losses are very minimum and its efficiency of working is very high. |
| 14 | The alternator uses diode rectifiers to rectify AC into DC for charging the battery. | The generator uses commutator and brushes to do the rectification of AC to DC. |

## Common troubles and remedies in alternator

**Objectives:** At the end of this lesson you shall be able to
- **state the causes and their remedies for no charge when engine is running**
- **state the causes and their remedies for low output voltage**
- **state the causes and their remedies for excessive output (charging at high rate)**
- **state the causes and their remedies for noisy alternator.**

| | Trouble | Causes | Remedy |
|---|---|---|---|
| 1 | No charge when engine is running. | Blown fuse wire in regulator. | Locate cause and rectify and then replace fuse. |
| | | Drive belt slipping. | Adjust belt tension. |
| | | Broken drive belts. | Replace. |
| | | Worn out or sticky brush. | Rectify. Replace. |
| | | Open field circuit. | Rectify. |
| | | Open charging circuit. | Rectify. |
| | | Open circuit in stator winding. | Rectify. |
| | | Open rectifier circuit. | Rectify. |
| | | Defective diodes. | Replace. |
| | | Defective gauge | Replace. |
| 2 | Low charging rate | Low regulator setting | Adjust setting |
| | | Open rectifier | Replace |
| | | Grounded stator winding | Replace the stator |
| | | High resistance in the charging circuit | Rectify |
| 3 | Overcharging | Sticky regulator contacts<br>Loose regulator ground connection | Clean and adjust<br>Tighten |
| | | Voltage regulator set to high | Adjust |
| 4 | Noise operation | Loose mounting | Tighten |
| | | Worn drive belt | Replace |
| | | Worn bearing | Replace |
| | | Open or shorted rectifiers | Replace |
| | | Shorted stator windings | Replace |
| | | Cooling fan touch withbody | Rectify/replace |

# Starting motor circuit and constructional details

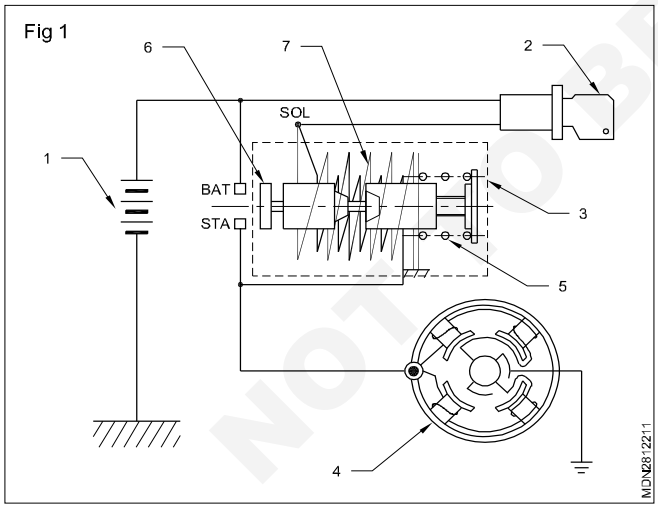
**Objectives:** At the end of this lesson you shall be able to

- **explain starting circuit**
- **explain the need of starter motors**
- **explain the construction of a starter motor**
- **explain the functions of a starter motor**
- **explain the functions of a starter drive unit**
- **explain the need of a solenoid switch**
- **explain the construction of a solenoid switch**
- **explain the functions of the solenoid switch.**

The starting system is used to start the engine. When the starter switch is pressed/ turned, current flows to the starter motor from the battery and the starter motor's shaft rotates. A drive pinion is connected to the starter motor shaft. The drive pinion turns the engine flywheel till the engine starts.

**Description of solenoid and starting circuit:** The -ve terminal of the battery (1) (Fig 1) is connected to earth. The +ve terminal of the battery (1) is connected to the solenoid switch's (3) battery terminal. From there a wire is connected to the starter switch's (2) input terminal. From the input terminal of the starter switch (2), a wire is connected to the solenoid winding's (7) input terminal. The other end of the winding is connected to earth. From the starter terminal of the solenoid switch a connection is given to the starter motor's (4) input terminal. In a starter motor an internal connection is given to connect the field windings as well as the armature through the brushes and the other end is connected to earth.

Fig 1




When the key switch is turned, a small amount of current flows from the battery (1) to the starter solenoid (3). This current energies the solenoid windings and the plunger (6) moves to connect the battery's and starter motor's terminal in the solenoid switch (3).

Current now flows directly to the motor (4). When the switch is released the current flow stops and the return spring (5) pulls the plunger (6) back, disconnecting the starter motor from the battery.

**Starter motor**

The engine crankshaft must be rotated at a speed of a minimum 100 r.p.m. to start the engine. This action is called engine cranking. As it is hard to rotate the engine at that speed by hand or with a lever, a starter motor is used to crank the engine.

**Location of the starter motor**

The starter motor is fixed in the rear side of the engine, when the starter is switched on the starter motor's pinion engages with the flywheel ring gear and rotates the flywheel.

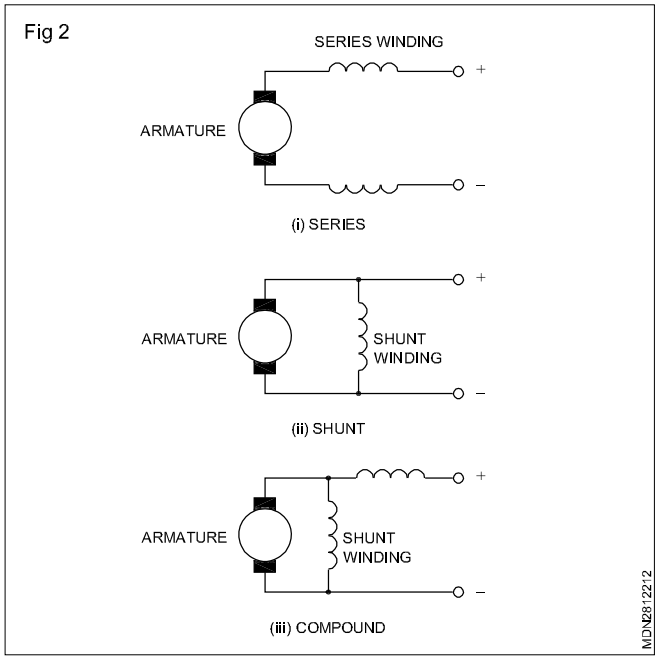
**Principle**

When a current is passed through an armature coil which is placed between two stationary magnets an e.m.f. is induced and the armature coil starts rotating.

**Construction:** Three kinds of DC starter motors are used.

- Series (Fig 2)
- Shunt
- Compound

Fig 2



In Automotives the series wound type is generally used. In this the field and armature coils are connected in series. This enables the motor to produce a high starting torque. The armature windings (1) are fixed in slots and their ends are soldered to the commutator segments (2). The pole shoes (3), two or four in number, are screwed to the yoke (4) and they have field windings (5). These windings help to produce the magnetic field. The insulation pieces are placed between the pole shoes (3) and metal yoke (4). Copper segments are provided with mica insulation in between the commutator brushes (6).

These brushes (6) slide in the brush holders and are kept in contact with the commutator with the help of small springs (8). The brushes (6) are given a curvature at the bottom to have more contact with the commutator (2). The armature is supported either on bushes or coil.

The commutator end is covered by a bracket called commutator end bracket (9). At the drive end, it is covered by the drive end bracket (10). Both the brackets are connected by through bolts (11). At the drive end in the armature shaft, a drive mechanism (12) is fitted.

**Common troubles and remedy in starter circit**

| Troubles | Remedies |
|---|---|
| Heavy starter cable terminal worm unit solenoid coil defective sleeve operating lever bend | Replace<br>Replace the solenoid<br>Replace/Replace |
| Pinion gear teeth wornout | Replace the pinion |
| Armature short circuit | Rewinding/Replace |
| Cummulator wornout | Reground/Replace |
| Carbon brush wornout | Replace |
| Carbon brush spring tension week | Replace |
| Field winding short circuited | Rewinding |
| Pinion gear returning spring broken | Replace |
| Starter motor mounting loose connection | tighten |
| Solenoid plunger jam | Check the fork lever |
| Plunger contact point pitted /burnt | Clean /Replace |

## Trouble shooting (causes and remedies)

**Objectives:** At the end of this lesson you shall be able to
- **causes and remedy for engine does not start**
- **causes and remedy for high fuel consumption**
- **causes and remedy for over heating**
- **causes and remedy for low power generation**
- **causes and remedy for excessive oil consumption**
- **causes and remedy for low oil pressure and high oil pressure**
- **causes and remedy for engine noise.**

**Engine does not start**

| Probable causes | Remedies |
|---|---|
| Low fuel in tank | Fill fuel |
| Choked fuel hose | Replace |
| Clogged fuel filter | Replace |
| Air lock in fuel system | bleed the air lock |
| Clogged exhaust ports | Clean |
| Reputed cylinder head gasket | Replace |
| Worn piston rings | Replace worn piston and rings |
| Broken valve timing belt/chain | Replace |
| Poor valve seating | Repair |
| Valve seat pitted | Replace |
| Main fuse is blown off | Replace |
| Defective starting relay | Repair/Replace |
| Main ignition switch open circuited | Repair or Replace |
| Defective brushes in starter | Replace |
| Open in field or armature circuit of starter | Repair/Replace |
| Loose battery terminal connection | Clean and retighten |
| Run down battery | Recharge |

**High fuel consumption**

| Causes | Remedies |
|---|---|
| Weak compression | Replace positioning/liner/piston |
| Fuel leakage in fuel system | Repair or Replace |
| Idle speed adjusting screw set in correctly | Adjust as prescribed |
| Clogged /dirty air filter | Replace or clean |
| Leakage of combustion gases from cylinder<br>Valve improper seating | Retighten or replace head gasket head<br>Repair |
| Valve clearance improper adjustment | adjust as prescribed |
| Injector defective | Overhand the injector |
| Inter cooler defective | Repair or Replace |
| Wrong injection timing | Set proper timing |
| Defective fuel pump | Overhaul / replace |

**Engine overheating**

| Causes | Remedies |
|---|---|
| Excessive carbon deposit in engine | Decarbonise |
| Loose or broken fan belt | Adjust or replace |
| Not enough coolant | Clean or top up coolant |
| Lack of lubrication | Top up engine oil |
| Erratically working thermostat | Replace |
| Radiator core tubes clogged | Repair or Replace |
| Poor water pump performance | Repair or Replace |
| Wrong injection timing | Set proper timing |
| Leaky radiator core tube | Repair |
| blocked silencer | Clean |
| Closed radiator shutter | Open |
| Closed radiator fins | Straighten |
| Clogged oil filter | Replace |
| Poor performance of oil pump | Repair or replace |

**Low power generation**

| Causes | Remedies |
|---|---|
| Leaky cylinder head gasket | Replace |
| Improper valve seating | Repair |
| Broken valve spring | Replace |
| Worn piston ring/bore | Replace or rebore |
| Piston rings sized in grooves or broken | Replace |
| Exhaust port clogged | Clean |
| Weak compression | Adjust valve clearance |
| Defective fuel feed pump | Repair or Replace |
| Clogged fuel filter | Replace |
| Clogged air cleaner | Replace |
| Wrong injection timing | Set properly |
| Wrong tappet clearance | Adjust correct clearance |
| Defective injector | Repair or Replace |

**High oil consumption**

| Causes | Remedies |
|---|---|
| External oil leakage | Rectify the leakage |
| High oil level | Remove excess oil |
| Valve oil seal damaged | Replace oil seal |
| Piston/rings wornout | Replace piston/rings |
| Engine oil low viscosity | Replace the oil |
| Oil reaching in exhaust manifold | Replace exhaust valve guides and valve |
| Oil reaching to combustion chamber | Replace the piston rings |

**Low oil pressure**

| Causes | Remedies |
|---|---|
| Low oil viscosity | Replace oil |
| Oil strainer blocked | Clean |
| Wornout oil pump gear | Replace gears |
| Strainer pipe mounting loose | Tighten |
| Defective oil pressure gauge | Replace |
| Defective pressure relief valve | Replace |
| Crank/camshaft bearing wornout | Replace bearing |
| Low oil level in the sump | Top up |

**High oil pressure**

| Causes | Remedies |
|---|---|
| High oil viscosity | Replace oil and use correct viscosity |
| Defective oil pressure gauge | Replace |
| Defective pressure relief valve | Replace or adjust correct value |
| Oil passages blocking | Clean the oil passages |

**Engine noise**

| Causes | Remedies |
|---|---|
| Wornout gudgeon pins | Replace |
| Wornout piston and rings | Replace |
| Piston ring broken | Replace |
| Vehicle over load | Avoid over loading |
| Tighten wheel bearing | Adjust |
| Clutch slipping | Adjust or Replace |
| Big end bearing wornout | Replace |