MECHANIC DIESEL

NSQF LEVEL - 3

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

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Duration : 1 - Year

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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 Mentor Councils 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 Diesel - Trade Theory - NSQF Level - 3 (Revised 2022) in Automotive Sector under Annual Pattern.** The NSQF Level - 3 (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 - 3 (Revised 2022) trainees will also get the opportunities to promote life long learning and skill development. I have no doubt that with NSQF Level - 3 (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,
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New Delhi - 110 001

PREFACE

The National Instructional Media Institute (NIMI) was established in 1986 at Chennai by then Directorate General of Employment and Training (D.G.E & T), Ministry of Labour and Employment, (now under 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 under the Craftsman 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 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 on practical training and will motivate the trainees to focus and perform the skill seamlessly.

IMPs also deals 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 materials.

Chennai - 600 032 **EXECUTIVE DIRECTOR**

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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.

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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 Course of the **Mechanic Diesel** Trade supplemented and supported by instructions/ information's to assist in performing the exercises. These exercises are designed to ensure that all the skills in compliance with NSQF LEVEL - 3 (Revised 2022) syllabus are covered. This manual is divided into Fourteen modules.

Module 1	Safety Workshop Practices
Module 2	Measuring and Marking Practice
Module 3	Fastening and Fitting
Module 4	Electrical and Electronics
Module 5	Hydraulics and Pneumatics
Module 6	Specifications and Service Equipments
Module 7	Diesel Engine Overview
Module 8	Diesel Engine Components
Module 9	Cooling and Lubrication System
Module 10	Intake and Exhaust System of Engine
Module 11	Diesel Fuel System
Module 12	Emission Control System
Module 13	Charging and Starting System
Module 14	Troubleshooting

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 Diesel** Trade. The contents are sequenced according to the practical exercise contained in NSQF LEVEL - 3 (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 the trade theory connected to each exercise atleast 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, straight edge, feeler gauge, thread pitch gauge, vacuum gauge, tire pressure gauge.) Following safety precautions.	1.1.01 to 1.2.17
2	Plan & perform basic fastening & fitting operation by using correct hand tools, Machine tools&equipments.	1.2.18 to 1.3.23
3	Trace and Test all Electrical & Electronic components & circuits and assemble circuit to ensure functionality of system.	1.3.24 to 1.4.31
4	Trace & Test Hydraulic and Pneumatic components.	1.4.32 to 1.4.34
5	Check & Interpret Vehicle Specification data and VIN. Select & operate various Service Station Equipments.	1.5.35 to 1.5.38
6	Dismantle & assemble of Diesel Engine from vehicle (LMV/HMV) along with other accessories.	1.6.39 to 1.7.42
7	Overhaul & service Diesel Engine, its parts and check functionality.	1.7.43 to 1.8.69
8	Trace, Test & Repair Cooling and Lubrication System of engine.	1.8.70 to 1.9.77
9	Trace & Test Intake and Exhaust system of engine.	1.9.78 to 1.10.81
10	Service Diesel Fuel System and check proper functionality.	1.10.82 to 1.11.87
11	Plan & overhaul the stationary engine and Governor and check functionality.	1.11.88 to 1.11.90
12	Monitor emission of vehicle and execute different operation to obtain optimum pollution as per emission norms.	1.11.91 to 1.11.93
13	Carryout overhauling of Alternator and Starter Motor.	1.12.94 to 1.12.95
14	Diagnose & rectify the defects in LMV/HMV to ensure functionality of vehicle.	1.13.97 to 1.14.98

SYLLABUS SYLLABUS FOR MECHANIC DIESEL

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) With Indicative Hours	Professional Knowledge (Trade Theory)
Professional Skill 142 Hrs; Professional Knowledge 34 Hrs	Check & perform Measuring & marking by using various Measuring & Marking tools (Vernier Calipers, Micrometer, Telescope gauges, Dial bore gauges, Dial indicators, straight edge, feeler gauge, thread pitch gauge, vacuum gauge, tire pressure gauge.) Following safety precautions.	1 Demonstration of Machinery used in the trade. (05hrs) 2 Identify safety Gear/PPE (Personal Protective Equipments) and their uses (10 hrs) 3 Importance of maintenance of safety equipment used in Workshop. (05hrs) 4 Demonstration on safe handling and Periodic testing of lifting equipment, and Safety disposal of used engine oil. (10 hrs.) 5 Demonstration on health hazards, occupational safety & first Aid. (05 hrs) 6 Demonstration fire service station to provide demo on Fire safety. (05hrs) 7 Perform use of fire extinguishers. (05 hrs) 8 Perform marking using all marking aids, like steel rule with spring callipers, dividers, scriber, punches, chisel etc. on MS Flat/Sheet Metal. (17 hrs) Measure a wheel base of a vehicle with measuring tape. (08 hrs) 9 Perform to remove wheel lug nuts with use of an air impact wrench (08 hrs) 10 Operate General workshop tools & power tools. (15 hrs)	- Importance & scope of Mechanic Diesel Trade Training. - General discipline in the Institute - Elementary First Aid, Occupational Safety & Health - Knowledge of Personal Safety & Safety precautions in handling Diesel machine. - Concept about HouseKeeping & 5S method. - Safety disposal of Used engine oil, - Electrical safety tips. - Safe handling of Fuel Spillage, - Safe disposal of toxic dust, safe handling and Periodic testing of lifting equipment. (10 hrs) **Hand & Power Tools** - 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. Screwdrivers-blade - Screw driver, Phillips screwdriver, Ratchet screw driver. 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, Circlip pliers, external circlips pliers. - Air impact wrench, air ratchet, wrenches-Torque wrenches, pipe wrenches, Pipe flaring & cutting tool, pullers-Gear and bearing. (15 hrs)

		11 Perform measuring practice on Cam height, Camshaft Journal dia, crankshaft journal dia, Valve stem dia, piston diameter, and piston pin dia with outside Micrometres. (05 hrs) 12 Perform measuring practice on cylinder bore for taper and out-of-round with Dial bore gauges. (10 hrs) 13 Perform measuring practice to measure wear on crankshaft end play, crankshaft run out, and valve guide with dial indicator and magnetic stand (05 hrs) 14 Perform measuring practice to check the flatness of the cylinder head is warped or twisted with straightedge is used with a feeler gauge. (10 hrs) 15 Perform measuring practice to check the end gap of a piston ring, piston-to- cylinder wall clearance with feeler gauge. (09 hrs) 16 Perform practice to check engine manifold vacuum with vacuum gauge. (05hrs) 17 Perform practice to check the air pressure inside the vehicle tyre is maintained at the recommended setting. (05hrs)	**Systems of measurement** - Description, Least Count calculation, care & use of -Micrometers-Outside, and depth micrometer, - Micrometer adjustments, - Description, Least Count calculation, care & use of Vernier Calliper. - Telescope gauges, Dial bore gauges, Dial indicators, straight edge, feeler gauge, thread pitch gauge, vacuum gauge, tire pressure gauge. (09 hrs)
Professional Skill 90 Hrs; Professional Knowledge; 17 Hrs	Plan & perform basic fastening & fitting operation by using correct hand tools, Machine tools&equipments.	18 Perform removal of stud/bolt using stud extractor (05hrs) 19 Perform practice on cutting tools like Hacksaw, file, chisel, Sharpening of Chisels, center punch, safety precautions while grinding. (10hrs) 20 Perform practice on Hacksawing and filing to given dimensions. (25 hrs)	- Different types of metal joint (Permanent, Temporary), methods of, Soldering, etc. **Fasteners** - Study of different types of screws, nuts, studs & bolts, locking devices, Such as locknuts, cotter, split pins, keys, circlips, lockrings, lock washers and locating where they are used. Washers & chemical compounds can be used to help secure these fasteners. Function of Gaskets, Selection of materials for gaskets and packing, oil seals. Types of Gaskets - paper, multilayered metallic, liquid, rubber, copper and printed. - Thread Seal ants-Various types like, locking, sealing, temperature resistance, antilocking, lubricating etc. **Cutting tools** - Study of different type of cutting tools like Hacksaw, File-Definition, parts of a file, specification, Grade, shape,

			different type of cut and uses., OFF-hand grinding with sander, bench and pedestal grinders, safety precautions while grinding. (7 Hrs)
		21 Perform practice on Marking and Drilling clear and Blind Holes, Sharpening of Twist Drills Safety precautions to be observed while using a drilling machine. (10hrs) 22 Perform practice on Tapping a Clear and Blind Hole, Selection of tape drill Size, use of Lubrication, Use of stud extractor. (15 hrs) 23 Perform 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. (25 hrs)	**Drilling machine** - Description and study of Bench type Drilling machine, Portable electrical Drilling machine, drill holding devices, Work Holding devices, Drillbits. **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.(10 hrs)
Professional Skill 92 Hrs; Professional Knowledge; 14 Hrs	Trace and Test all Electrical & Electronic components & circuits and assemble circuit to ensure functionality of system.	24 Perform practice in joining wires using soldering Iron. (20 hrs) 25 Prepare simple electrical circuits, measuring of current, voltage and resistance using digital multimeter. (20 hrs) 26 Perform practice continuity test for fuses, relay and diodes (09 hrs)	**Basic electricity** - Electricity principles, - Ground connections, - Ohm's law, - Voltage, Current, Resistance, Power, Energy. - Voltmeter, ammeter, Ohmmeter, Multimeter, - Conductors & insulators, Wires, Shielding, Length vs. resistance, Resistor ratings (04Hrs)
		27 Check circuit using of service manual wiring diagram for troubleshooting (08 hrs)	- Fuses& circuit breakers, - Ballast resistor, - Stripping wire insulation, - Cable colour codes and sizes, Resistors in Series circuits, - Parallel circuits and Series- parallel circuits (04Hrs)
		28 Execute cleaning and topping up of a lead acid battery. (10 hrs) 29 Perform testing battery with hydrometer. (12 hrs) 30 Perform connecting battery to a charger for battery charging and checking & testing a battery after charging. (08 hrs)	- Description of Chemical effects, Batteries & cells, Lead acid batteries & Stay Maintenance Free (SMF) batteries, - Magnetic effects, Heating effects, Thermo-electric energy, Thermistors, Thermo couples, - Electrochemical energy, Photo-voltaic energy, Piezo- electric energy, Electromagnetic induction,

		31 Perform test of relay and solenoids and its circuit. (05 Hrs)	- Relays, Solenoids, Primary & Secondary windings, Transformers, stator and rotor coils. (6 Hrs)
Professional Skill 35 Hrs; Professional Knowledge; 9 Hrs	Trace & Test Hydraulic and Pneumatic components.	32 Identify of Hydraulic and pneumatic components used in vehicle. (10 hrs) 33 Tracing of hydraulic circuit on hydraulic jack, hydraulic, and Brake circuit. (15hrs) 34 Identify components in Air brake systems (10hrs)	**Introduction to Hydraulics & Pneumatics** - Description, symbols and application in automobile of Gear pump-Internal & External, single acting, double acting & Double ended cylinder; Directional control, Pressure relief valve, Non return valve, Flow control valve used in automobile. (9 hrs)
Professional Skill 25Hrs; Professional Knowledge; 5 Hrs	Check & Interpret Vehicle Specification data and VIN. Select & operate various Service Station Equipments.	35 Identify of different types of Vehicle. (05 hrs) 36 Demonstrate of vehicle specification data. (05hrs) 37 Identify of vehicle information Number (VIN). (05 hrs). 38 Demonstrate of Garage, Service station equipments - Vehicle hoists Two post and four post hoist, Engine hoists, Jacks, Stands. (10hrs)	- 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 - Uses of Vehicle hoists - Two post and four post hoist, Engine hoists, Jacks, Stands. (05 Hrs)
Professional Skill 50 Hrs; Professional Knowledge; 8 Hrs	Dismantle & assemble of Diesel Engine from vehicle (LMV/ HMV) along with other accessories.	39 Identify the different parts of IC Engine (10hrs) 40 Identify the different parts in a diesel engine of LMV/ HMV (10 hrs) 41 Perform practice on starting and stopping of diesel engines. Observe and report the reading of Tachometer, Odometer, temp and Fuel gauge under ideal and on load condition. (10hrs) 42 Practice on dismantling Diesel engine of LMV/HMV as per procedure. (20hrs)	**Introduction to Engine** - 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, - Main Parts of IC 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 light, Parking-brake-engagement warning light and an Engine-malfunction light. - Different type of starting and stopping method of Diesel Engine - Procedure for dismantling of diesel engine from a vehicle. (8 hrs)

Professional Skill; 160 Hrs; Professional Knowledge; 25 Hrs	Overhaul & service Diesel Engine, its parts and check functionality.	43 Perform Overhauling of cylinder head assembly, Use of service manual for 44 clearance and other parameters. (10hrs) 45 Perform practice on removing rocker arm assembly manifolds. (05hrs) 46 Perform practice on removing the valves and its parts from the cylinder head, cleaning. (05hrs) 47 Inspection of cylinder head and manifold surfaces for warping, cracks and flatness. Checking valve seats & valve guide-Replacing the valve if necessary. (05hrs) 48 Check leaks of valve seats for leakage - Dismantle rocker shaft assembly-clean & check rocker shaft - and levers, for wear and cracks and reassemble.(05hrs) 49 Check valve springs, tappets, pushrods, tappet screws and valves tem cap. Reassembling valve parts insequence, refit cylinder head and manifold & rocker arm assembly, adjustable valve clearances, starting engine after adjustments. (10 hrs)	**Diesel Engine Components** - Description and Constructional feature of Cylinder head, Importance of Cylinder head design, - Type of Diesel combustion chambers, - Effect on size of Intake & exhaust passages, Head gaskets. - Importance of Turbulence. Valves & Valve Actuating Mechanism - - Description and Function of Engine Valves, different types, materials, - Type of valve operating mechanism, Importance of Valve seats, Valve seats inserts in cylinder heads, - Importance of Valve rotation, 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 (SOHC and DOHC), importance of Cam lobes, Timing belts & chains, Timing belts & tensioners. (07hrs)
		50 Perform Overhauling piston and connecting rod assembly. Use of service manual for clearance and other parameters. (05 hrs) 51 Perform Practice on removing oil sump and oil pump - clean the sump. (04 hrs) 52 Perform removing the big end bearing, connecting rod with the piston. (04 hrs) 53 Perform 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. (05 hrs) 54 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. (03 hrs) 55 Check connecting rod for bend and twist. Assemble the piston and connecting rod assembly. (04 hrs)	- Description&functionsof 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. - 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. (05 Hrs)

		56 Perform Overhauling of crankshaft, Use of servicemanual for clearance andotherparameters (05hrs) 57 Perform removing damper pulley, timing gear/timing chain, flywheel, main bearing caps, bearing shells and crankshaft from engine (05hrs). 58 Inspect oil retainer and thrust surfaces for wear. (05 hrs) 59 Measure crankshaft journal for wear, taper and ovality. (05hrs) 60 Demonstrate crankshaft for filletradii, bend & twist. (05hrs)	- 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. (04Hrs)
		61 Inspect fly wheel and mounting flanges, spigot and bearing. (05hrs) 62 Check vibration damper for defect. (02hrs) 63 Perform removing camshaft from engine block, Check for bend & twist of camshaft. Inspection of cam lobe, camshaft journals and bearings and measure cam lobe lift. (05 hrs) 64 Fixing bearing inserts in cylinder block & cap check nip and spread clearance & oil holes & locating lugs fix crankshaft on block-torque bolts-check end play remove shaft-check seating, repeat similarly for connecting rod and Check seating and refit. (08 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. (04 Hrs)
		65 Perform cleaning and checking of cylinder blocks. (10 hrs) 66 Surface for any crack, flatness measure cylinder borefor taper & ovality,clean oil gallery passage and oil pipeline. (15hrs) 67 Perform reassembling all parts of engine in correct sequence and torque all bolts and nuts as per workshop manual of the engine. (12hrs) 68 Perform testing cylinder compression, Check idle speed. (08hrs) 69 Perform removing & replacing a cam belt, and adjusting an engine drivebelt, replacing an engine drive belt. (05hrs)	- Description of Cylinder block, - Cylinder block construction, - Different type of Cylinder sleeves (liner). (05 Hrs)
Professional Skill 50 Hrs; Professional Knowledge; 10 Hrs	Trace, Test & Repair Cooling and Lubrication Systemof engine.	70 Perform practice on checking & top up coolant, draining & refilling coolant, checking / replacing a coolant hose. (05 hrs) 71 Perform test cooling system pressure. (04 hrs) 72 Execute on removing & replacing radiator/ thermostat check the radiator pressure cap. (06 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,

		73 Test of thermostat. (03 hrs) 74 Perform cleaning &reverse flushing. (08hrs) 75 Perform overhauling water pump and refitting. (07 hrs) 76 Perform checking engine oil, draining engine oil, replacing oil filter, & refilling engine oil (07 hrs) 77 Execute 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)	**Basic cooling system components** - Radiator, Coolant hoses, - Water pump, - Cooling system thermostat, Cooling fans, - Temperature indicators, - Radiator pressure cap, Recovery system, Thermo-switch. **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. (10 hrs)
Professional Skill 26Hrs; Professional Knowledge 06 Hrs	Trace & Test Intake and Exhaust system of engine.	78 Execute dismantling air compressor and exhauster and cleaning all parts - measuring wear inthe cylinder, reassembling all parts and fitting the min the engine. (7hrs) 79 Execute dismantling & assembling of turbocharger, check for axial clearance as per service manual. (05hrs) 80 Examine exhaust system for rubber mounting for damage, deterioration and out of position; for leakage, loose connection, dentand damage; (08hrs) 81 Perform practice on exhaust manifold removal and installation, practice on Catalytic converter removal and installation. (06 hrs)	**Intake & exhaust systems** - Description of Diesel induction & Exhaust systems. Description & function of air compressor, exhauster, Super charger, Intercoolers, turbo charger, variable turbo charger mechanism. **Intake system components** - Description and function of Air cleaners, Different type air cleaner, Description of Intake manifolds and material, **Exhaust system components** - Description and function of Exhaust manifold, Exhaust pipe, Extractors, Mufflers-Reactive, absorptive, Combination of Catalytic converters, Flexible connections, Ceramic coatings, Back-pressure, - Electronic mufflers. (06Hrs)
Professional Skill 70 Hrs; Professional Knowledge 12 Hrs	Service Diesel Fuel System and check proper functionality.	82 Perform work on removing & cleaning fuel tanks, checking leaks in the fuel lines. (10hrs) 83 Execute over hauling of Feed Pumps (Mechanical & Electrical). (10hrs)	**Fuel Feed System in IC Engine (Petrol & Diesel)** - Gravity feed system, Forced feed system, main parts, Fuel Pumps- Mechanical & Electrical - Feed Pumps. - Knowledge about function, working &types of Carburetor.

		84 Perform bleeding of air from the fuel lines, servicing primary & secondary filters. (10hrs) 85 Execute removing a fuel injection pump from an engine-refit the pump tothe engine re- set timing -fill lubricating-oilstart and adjust slow speed of the engine. (15hrs) 86 Execute overhauling of injectors and testing of injector. (15hrs) 87 General maintenance of Fuel Injection Pumps (FIP). (10hrs)	**Diesel Fuel Systems** - Description and function of Diesel fuel injection, fuel characteristics, concept of Quiet diesel technology &Clean dieseltechnology. **Diesel fuel system components** - Description and function of Diesel tanks & lines, Diesel fuel filters, water separator, Lift pump, Plunger pump, Priming pump, - Inline injection pump, Distributor-type injection pump, Diesel injectors, Glow plugs, Cummins & Detroit Diesel injection. **Electronic Diesel control** - Electronic Diesel control systems, Common Rail Diesel Injection (CRDI) system, hydraulically actuated electronically controlled unit injector (HEUI) diesel injection system. Sensors, actuators and ECU (Electronic Control Unit) used in Diesel Engines. (12hrs)
Professional Skill 25 Hrs; Professional Knowledge 05 Hrs	Plan & overhaul the stationary engine and Governor and check functionality.	88 Execute Start engine adjust idling speed and damping device in pneumatic governor and venture control un it checking.(06hrs) 89 Verify performance of engine with off load adjusting timings. Start engine - adjusting idle speed of the engine fitted with mechanical governor checking- high speed operation of the engine. (07 hrs) 90 Check performance form issing cylinder by isolating defective injectors and test-dismantle and replace defective parts and reassemble and refit back to the engine. (12 hrs)	**Marine & Stationary Engine:** **Types,** - double actingengines, - opposed piston engines, starting systems, cooling systems, lubricating systems, supplying fuel oil, hydraulic coupling, - Reduction gear drive, electromagnetic coupling, - Electrical drive, generators and motors, super charging. (05 Hrs)
Professional Skill 25 Hrs; Professional Knowledge 05 Hrs	Monitor emission of vehicle and execute different operation to obtain optimum pollution as per emission norms.	91 Monitor emissions procedures by use of Engine gas analyser or Diesel smoke meter. (10hrs) 92 Checking & cleaning a Positive crankcase ventilation (PCV) valve. Obtaining & interpreting scan tool data. Inspection of EVAP can inter purges system by use of scan Tool. (10hrs) 93 EGR/SCR Valve Remove and installation for inspection.(05hrs)	**Emission Control Vehicleemissions** - Standards- Euro and Bharat II, III, IV, V Sources of emission, Combustion, Combustion chamberdesign. **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 (05Hrs)
Professional Skill 25 Hrs; Professional Knowledge 05 Hrs	Carryout overhauling of Alternator and Starter Motor.	94 Perform removing alternator from vehicle dismantling, cleaning checking for defects, assembling and testing for motoring action of alternator & fitting to vehicles. (15 hrs) 95 Practice on removing starter motor Vehicle and overhauling the starter motor, testing of starter motor (10 hrs).	- Basic Knowledge about DC Generator & AC Generator. - Constructional details of Alternator - Description of charging circuit operation of alternators, regulator unit, ignition warning lamp- troubles and remedy in charging system. - Description of starter motor circuit, - Constructional details of starter motor solenoid switches, common troubles and remedy in starter circuit. (05 Hrs)
Professional Skill 25 Hrs; Professional Knowledge 05 Hrs	Diagnose & rectify the defects in LMV/ HMV to ensure functionality of vehicle.	96 Execute 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. (25 hrs)	- Troubleshooting : - Causes and remedy 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. (05 hrs)

Organization of ITIs and scope of the Mechanic Diesel trade

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

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 propagatory 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 are 8^{th}, 10^{th} and 12^{th} pass with respect to the trades and admission process will be held in every year in July.

In every year, All India Trade Test (AITT) will be conducted in July and January, with CBT/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. In 2017, for few trades they have introduced and implemented National Skill Qualification Frame work (NSQF) with Level 3,4 & 5.

Scope of the Mechanic Diesel trade

Objectives: At the end of this lesson you shall be able to
- **importance and scope of the Mechanic Diesel trade training**
- **general discipline in the institute.**

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

- Identify the various types of tools equipment, raw materials, spares used in mechanic diesel 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,

Career progress pathways: Can join the apprenticeship training in different types of industries and often National Apprenticeship Certificate (NAC).

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

Job Opportunities

- Mechanic diesel can join in central and state government establishments, like railway, airport, marine, military, joins as a service technician in dealer of agricultural machinery mining, trucks, bus, car, stationary engines, compressors, diesel generators, construction equipments, etc.
- 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 argument 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 unnecessarily interfere in other's activities.

Do very attentive and listen to the lecture carefully during the theory classes and practical demonstration given by the training staff.

Give respect to your trainer and all other training staff, office staff and co-trainees.

Be interested in all the training activities.

Do not make noise or be playful 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.

Knowledge of personal safety and safety precautions in handling diesel machines

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

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

Fig 1

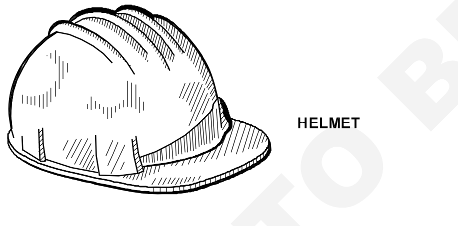


Fig 2

Fig 3

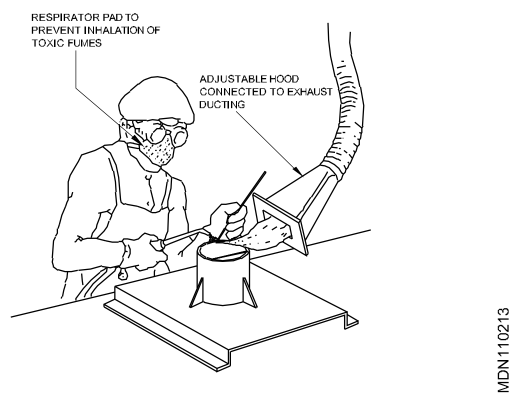


Fig 4

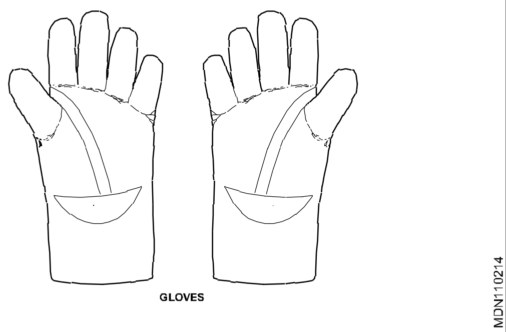


Fig 5

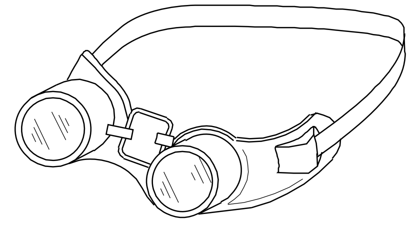


Fig 6

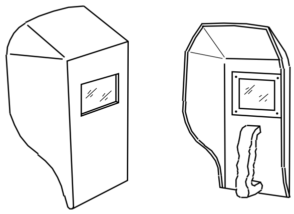


Fig 7

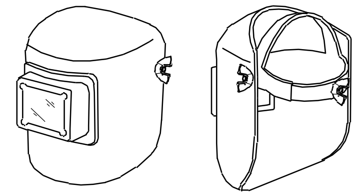


Fig 8

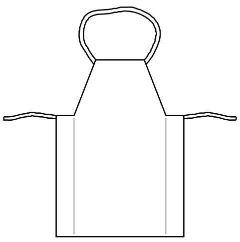
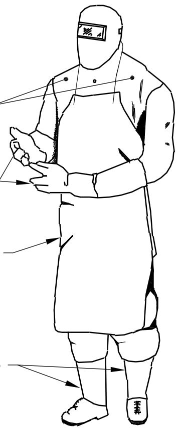


Fig 9



Safety precaution in handling diesel machine

- Diesel mechanic must know the safety rules first and then practice to handling diesel machine as well as we known, when accident starts means safety rules are not followed during the handling of diesel machine. So safety precautions are always based on good sense.
- The following precautions are to be observed to keep a diesel mechanic/personal accident free.

General safety

- Do not spill the fuel and lubricant on work place, the spills may cause for the risk of slipping.
- Keep all flammable material away from the diesel machine.
- Always keep clean hand and tools while work on machine
- Keep the diesel machines operating area free from any form of fire.

Safety operation of diesel machine

- Don't operate the machine with loose engine mounting
- Don't operate the machine without lubricant
- Don't spill diesel during fill in to the fuel tank
- Keep the empty diesel /lubricant can away from the machine.
- Ensure stationary engine exhaust gas outlet should be far away from work place otherwise it will be harmful to human health.
- Use preheat before start the diesel engine.
- Use safe guard around rotating part of the engine.
- Maintain the coolant and lubricant level in the engine.
- Always keep engine in an upright position for easy handling and safety.
- use specified grade lubricant and coolant in an engine

Safety of rubber hose and pipes

- Inspect the rubber hose periodically and replace the damaged parts
- Inspect the fuel leaks in fuel system and rectify the leakages
- Inspect the exhaust gas leaks and rectify the leakages
- Check the engine performance if any air lock in fuel system, bleed the fuel system.

Safety of engine operation

- Check the coolant circulation and pressure cap function
- Check the oil pressure
- Check the tappet noise and rectify the noise/adjust the defective tappet
- Check the abnormal noise in the engine
- Check leakages of lubricant and coolant in the engine and rectify the leakages.
- Ensure free air circulation in engine operating place

Concept of housekeeping and 5-S method

Scan the QR Code to view the video for this exercise

Objectives: At the end of this lesson you shall be able to
- **elements of housekeeping and cleanliness at work place**
- **state the concept of 5-S techniques.**

Concept of housekeeping: House keeping is the systematic process of making home/work place neat and clean. Housekeeper is responsible for systematic administration of activities that provide segregation, storage, transfer, processing treatment and disposal of solid waste (which is collected during cleaning)

Scope of housekeeping maintenance

The scope of work highly depend on where the house keeping activity is performed. In general, maintains clean liness and orderliness, furnishes the room, office, workplace, housekeeping supervisor assisted by an assistant housekeeper.

- Eye appeal
- Safety
- Maintenance

Elements of housekeeping and cleanliness at workplace: The major elements which are normally included in the housekeeping and cleanliness practices at the workplace are described below.

- **Dust and dirt removal:** Working in dusty and dirty area is unhygienic as well as unhealthy for the employees, regular sweeping the workplace for the removal of dust and dirt is an essential housekeeping and cleanliness practice. Further, compressed air is not to be used for removing dust or dirt off employees or equipment. Compressed air can cause dirt and dust particles to be embedded under the skin or in the eye.
- **Employees facilities:** Adequate employees facilities such as drinking water, wash rooms, toilet blocks, and rest rooms are to be provided for the employees at the workplace so that employees can use them when there is a need. Cleanliness at the place of these facilities is an important aspect of the facilities.
- **Flooring:** Floors are to be cleaned regularly and immediately if liquids or other materials are spilled. Poor floor conditions are a leading cause of accidents in the workplace. It is also important to replace worn, ripped or damaged flooring that poses a trip hazard.
- **Lighting:** Adequate lighting reduces the potential for accidents. It is to be ensured that inoperative light fixtures are repaired and dirty light fixtures are cleaned regularly so that the light intensity levels are maintained at the workplace.
- **Aisles and stairways:** Aisles and stairways are to be kept clear and not to be used for storage. It is also important to maintain adequate lighting in stairways. Further stairways need to have railings preferably round railings for adequate grip.
- **Spill control:** The best method to control spills is to prevent them from happening. Regular cleaning and maintenance on machines and equipment is an essential practice. When cleaning a spill, it is required to use the proper cleaning agents or absorbent materials. It is also to be ensured that the waste products are disposed of properly.
- **Waste disposal:** The regular collection of the waste materials contribute to good housekeeping and cleanliness practices. Placing containers for wastes near the place where the waste is produced encourages orderly waste disposal and makes collection easier. All recyclable wastes after their collection are to be transferred to their designated places so that the waste materials can be dispatched to the point of use or sold.
- **Tools and equipment:** Tools and equipment are required to be inspected prior to their use. Damaged or worn tools are to be taken out of service immediately. Tools are to be cleaned and returned to their storage place after use.
- **Maintenance:** One of the most important elements of good housekeeping and cleanliness practices is the maintenance of the equipment and the buildings housing them. This means keeping buildings, equipment and machinery in safe and efficient working condition. When a workplace looks neglected means there are broken windows, defective plumbing, broken floor surfaces and dirty walls etc. These conditions can cause accidents and affect work practices.
- **Storage:** Proper storage of materials is essential in a good housekeeping and cleanliness practice. All storage areas need to be clearly marked. Also it is important that all containers be labeled properly. If materials are being stored correctly, then the incidents of strain injuries, chemical exposures and fires get reduced drastically.
- **Clutter control:** Cluttered workplaces typically happen because of poor housekeeping practices. This type of workplace can lead to a number of issues which include ergonomic as well as injuries. It is important to develop practices where items like tools, chemicals, cords, and containers are returned to their appropriate storage location when not in use.

- **Individual workspace:** Individual workspace need to be kept neat, cleared of everything not needed for work. It is necessary to make a checklist which is to be used by the employees to evaluate their workspace.

It can be said that a clean work area demonstrate the pride employees have with the job and the culture of safety at the workplace.

5 Steps (5-S) - Concept (Fig 1)

5-S is a people-oriented and practice-oriented approach. 5-S expects every one to participate in it. It becomes a basic for continuous improvement in the organisation.

The terms (5-S) 5 steps are;

Step 1: SEIRI (Sorting out)

Step 2: SEITON (Systematic arrangement)

Step 3: SEISO (Shine/cleanliness)

Step 4: SEIKETSU (Stanardization)

Step 5: SHITSUKE (Self discipline)

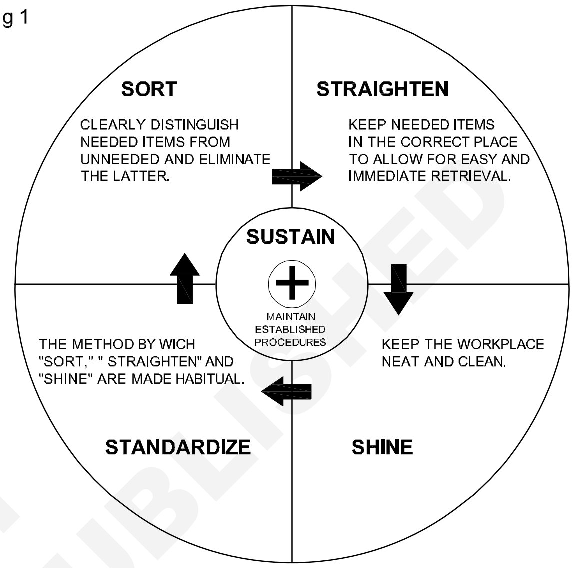
Fig 1 shows the 5-S concept wheel.

The list describes how to organize a work space for efficiency and effectiveness by identifying and storing the items used, maintaining the area and items and sustaining the new order.

Benefits of 5-S

- Work place becomes clear and better organised.
- Working in working place becomes easier.
- Reduction in cost.
- People tend to be more disciplined.
- Delay is avoided.
- Less absenteeism.
- Better use of floor space.
- Less accidents.
- High productivity with quality etc.

Fig 1



5S CONCEPT WHEEL

Safe handling and periodic testing of lifting equipments

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

Scan the QR Code to view the video for this exercise

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 check 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 overhauled once or twice a year.
- Check 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.

Safety disposal of used engine oil

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

Waste oil: The waste oil, 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.

This procedure applies to the disposal of any used oil that is collected during normal work functions at work place. Used oil may include:

1 **Gasoline:** Volatile, flammable, it can be ignited by sparks and flames even at cold temperatures. Vapors can migrate to distant ignition sources and in poorly ventilated spaces, can accumulate to explosive levels. Typical gasoline contains about 150 different chemicals including benzene, toluene and xylene.

Used Oil Disposal

2 **Fuel oils:** Fuel oils such as diesel fuel are petroleum based fluids which are some what volatile and flammable and can be ignited only when heated above 100°F. Vapors can travel and flash from ignition sources and can accumlate to explosive levels in poorly ventilated areas. All fuel oils consist of complex mixtures of aliphatic and aromatic hydrocarbons such as kerosene, benzene, and styrene.

3 **Lubricating oils:** Lubricating oils such as motor oil and hydraulic fluids are not volatile but are combustible. For lubricating oil to catch fire some other intense heat source (i.e., other materials on fire, hot engine manifold, etc.) must be present. Mineral-based lube oils are refined from petroleum or crude oil and contain additives such as lead or metal sulphide and other polymers.

4 **Transformer oil:** Tranformer oil conducts heat away from and insulates equipment used to convert electricity from high amperage to low amperage lines. Transformer oil is a liquid by product of the distillation of petroleum to produce gasoline.

Cooking oils and grease: Cooking oils and grease are not volatile but they are combustible. With a 400°F flash point, another heat source must be present for cooking oils or grease to catch fire. Vegetable oils contain chemical solvents that are strong enough to dissolve engine seals and gaskets.

> **Note: for all other waste chemicals, please refer SOP regarding Used Chemical Disposal.**

Procedures: Products saturated with petroleum products require special handling and disposal by licensed transporters. During the collection of used oil for disposal, some basic principles should be followed:

1 Wear gloves because oil contains chemicals and contaminants that are not good for skin contact.

2 Put used oil in a clean plastic or metal container in good condition and with a tight lid.

3 If the oil is hot, avoid sudden contact with other substances because mixing may cause ignition or the receiving container to fracture due to thermal shock.

4 Do not allow used fuel and used oils to mix with any other substances because unknown and dangerous chemical reactions may occur.

5 Keep used oils away from gas cylinders and gasoline.

6 Do not fill container to the top but allow a couple inches below the rim.

7 Label the container with contents, and department.

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 maybe 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 in fuel tank or fuel container.

6 Use funnel during filling the fuel in fuel tank to avoid fuel 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 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 Automotive 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 cannot re-use 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.

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.**

Scan the QR Code to view the video for this exercise

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 leant 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.
- If you see a person fainting, try to prevent a fall. Lay the person flat on the floor and raise the level of feet above and support.

- If fainting is likely due to low blood sugar, give the person something sweet to eat or drink when they become conscious.

DO NOT

- Do not give an unconscious person any food or drink.
- Do not leave the person alone.
- Do not place a pillow under the head of an unconscious person.
- Do not slap an unconscious person's face or splash water on the face to try to revive him.

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.**

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

1 Water-filled extinguishers

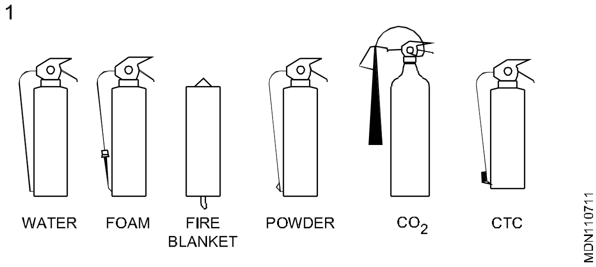
2 Foam extinguishers

3 Dry powder extinguishers

4 Carbon dioxide (CO_2)

5 Halon extinguishers

Fig 1



Scan the QR Code to view the video for this exercise

Marking materials

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.

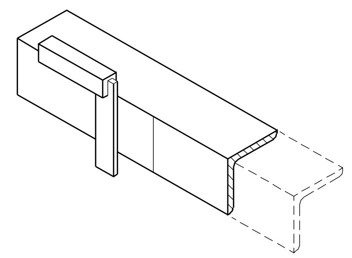
Chalk powder mixed with water

Chalk mixed with methylated spirit

White lead powder mixed with turpentine

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

Fig 1

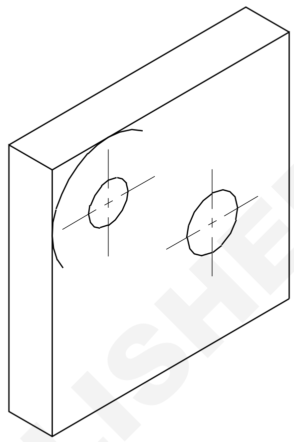


Whitewash is not recommended for workpieces of high accuracy.

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



Copper sulphate

The solution is prepared by mixing copper sulphate in water and a few drops of nitric acid. The copper sulphate is used on filed or machine-finished surfaces. Copper sulphate sticks to the finished surfaces well.

Copper sulphate needs to be handled carefully as it is poisonous. Copper sulphate coating should be dried well before commencing marking as, otherwise, the solution may stick on the instruments used for marking.

The selection of marking medium for a particular job depends on the surface finish and the accuracy of the workpiece.

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

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.

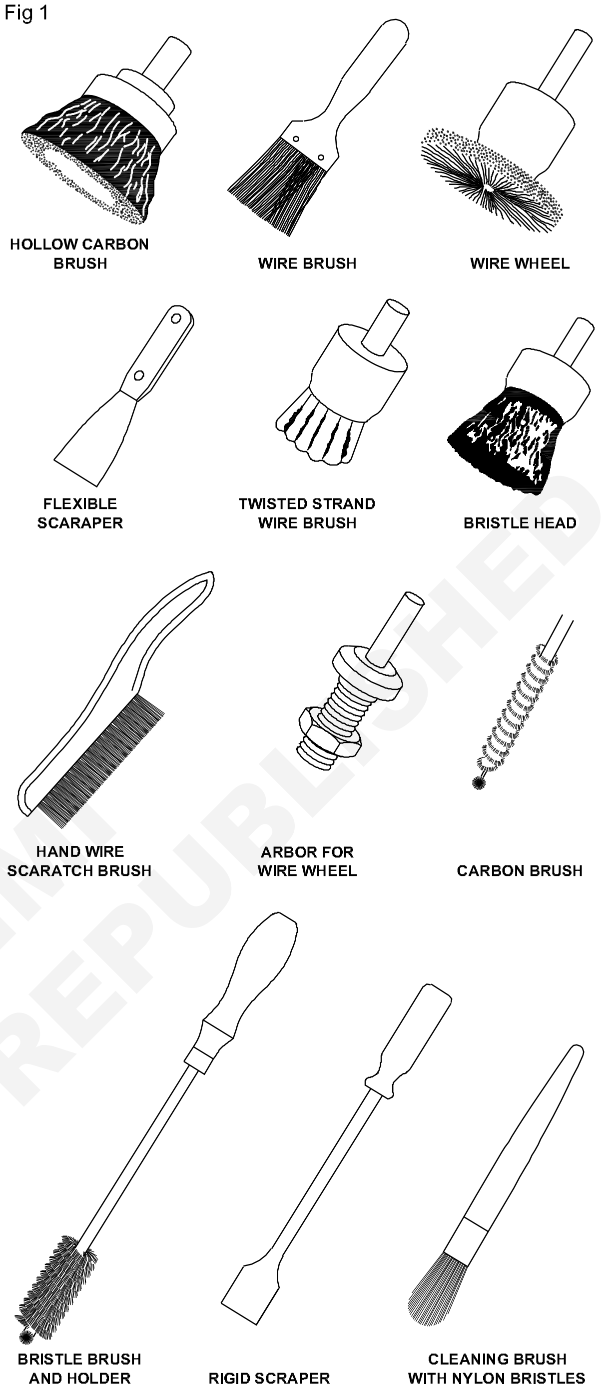
Emery paper is defined as a paper coated with abrasive particles in one side and used to produce smooth, shiny finish to manufactured products.

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.**

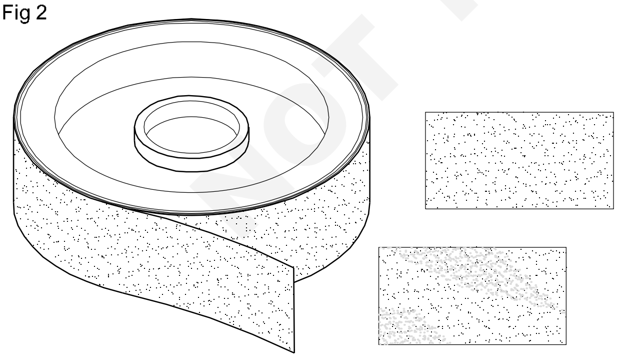
Fig 1



CLEANING TOOLS

MDN120121

Fig 2



EMERY SHEET

MDN120122

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 workpiece 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 shaft 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.

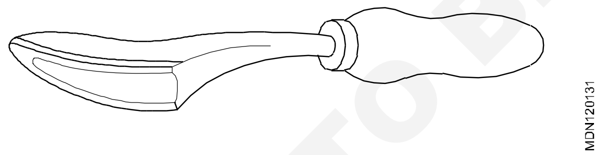
Use: It is used to scrap the high spots of a flat surface

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)

Fig 1

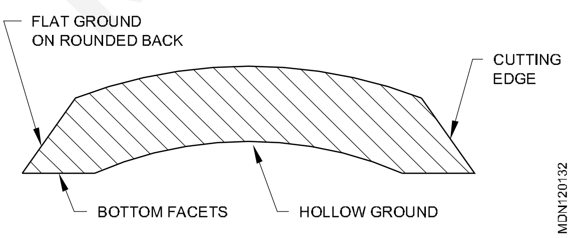


The round bottom face is curved and is hollow in the middle.

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

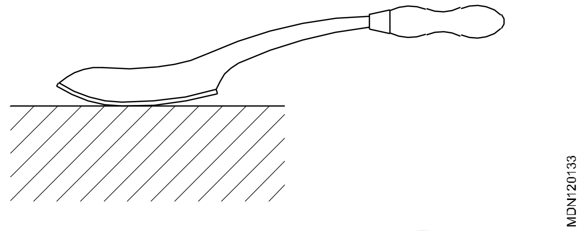
The cutting angle is between 45^0 and 65^0.

Fig 2



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

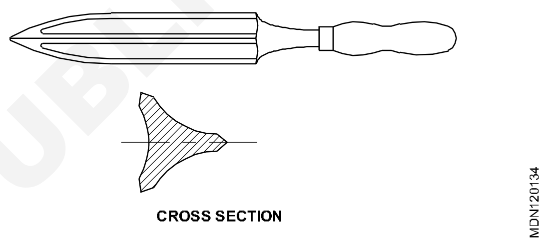
Fig 3



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

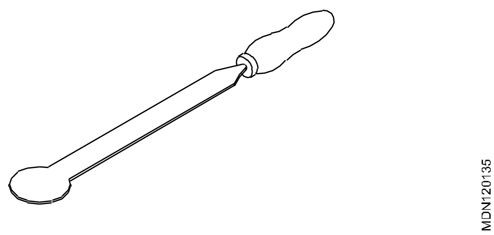
The cross-section of this is triangular. This has more number of cutting edges and the hollow portion between the cutting edges helps in re-sharpening easily.

Fig 4



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.

Fig 5



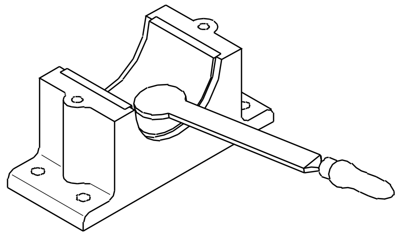
It is useful for scraping large bearings. (Fig 6) This scraper can be used in a longitudinal direction like a flat scraper or with a circumferential movement like a half round scraper. This dual action helps to prevent ridges on the scraped surfaces.

Always use scrapers with firmly fitted handles.

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

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

Fig 6

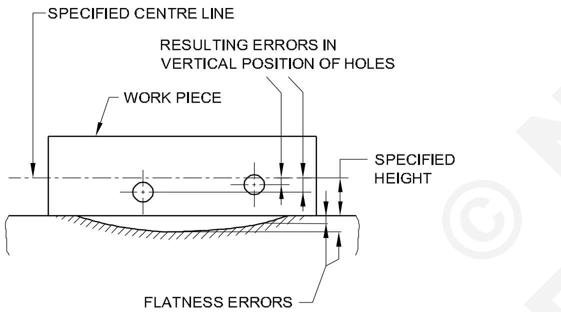


Surface plates

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.

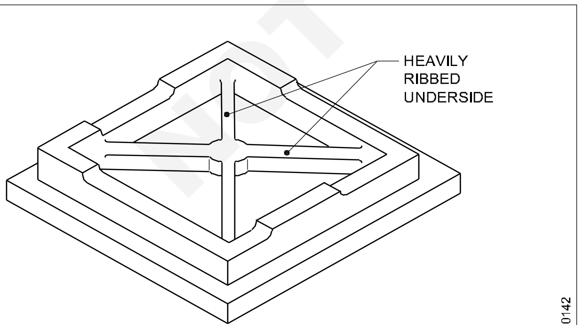
Fig 1



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

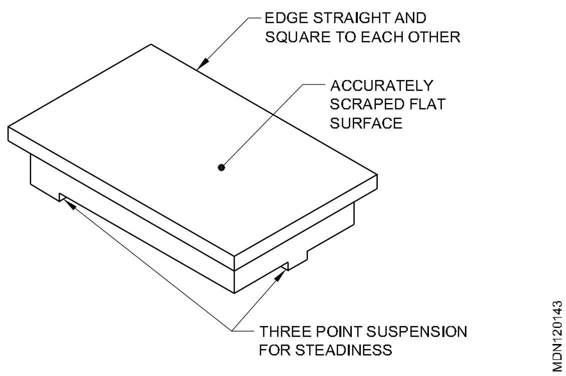
Specifications: Cast iron surface plates are designated by their length, breadth, grade and the Indian Standard number.

Example

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

Marking-off tables (Fig 3): These are heavily ribbed cast iron tables fitted with strong rigid legs. The top surface is accurately machined flat, and the sides square.

Fig 3



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

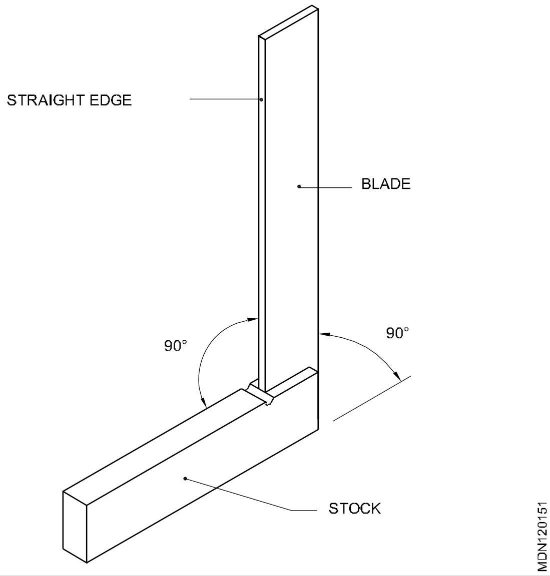
These lines serve as guides for positioning components while setting and marking.

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.

Fig 1



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 2

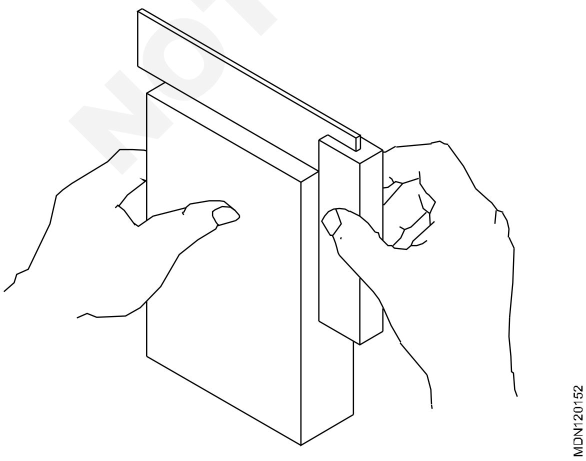


Fig 3

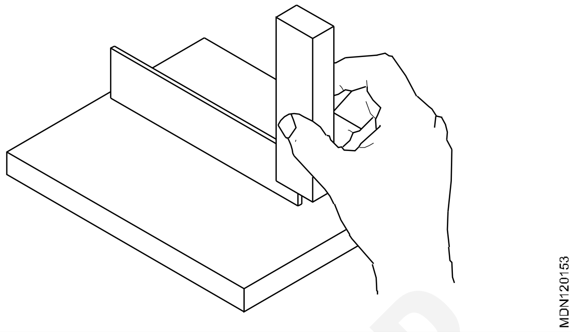


Fig 4

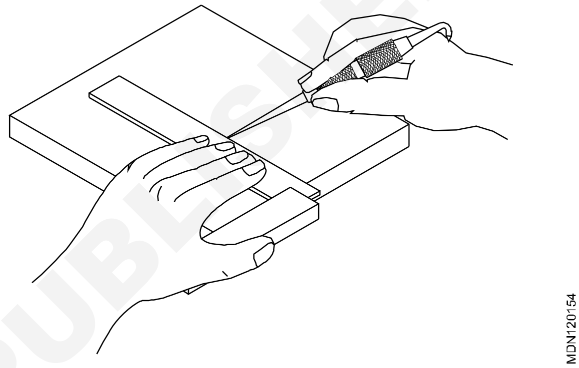


Fig 5

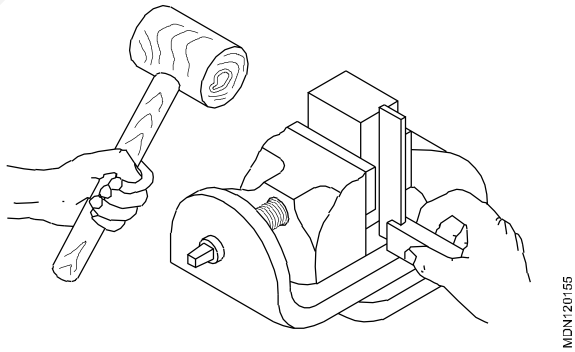


Fig 6 shows the method of using a try square and a steel rule for accurate measurements.

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

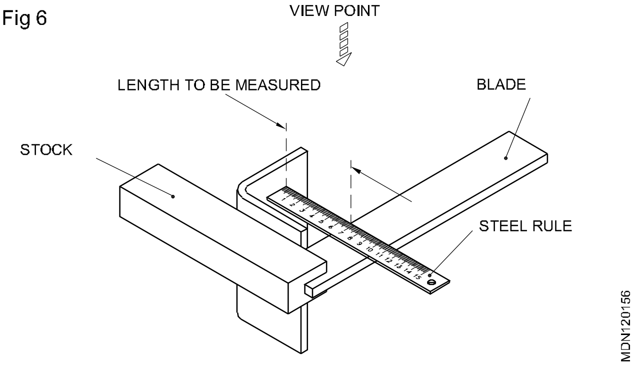
An experienced person can transfer measurements from a steel rule very accurately.

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

Fig 6



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.**

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.

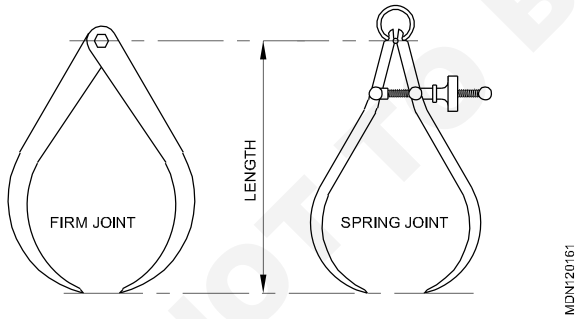
Types of joint: The commonly used calipers are:

- 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)

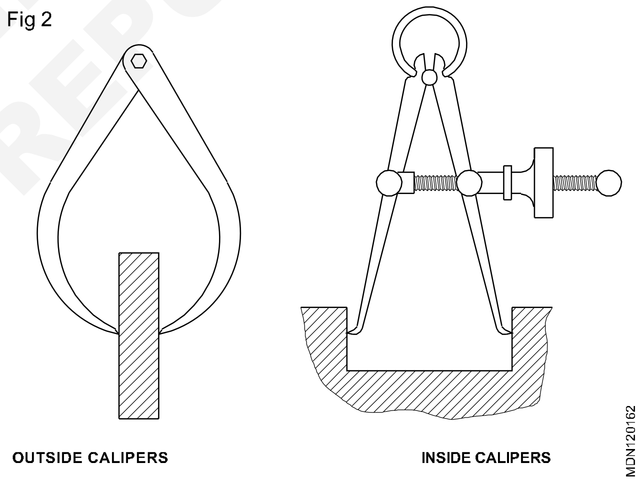
For this type of calipers, the legs are assembled by means of a pivot loaded with a spring. For opening and closing the caliper legs, a screw and nut are provided.

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.

Fig 2



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 used along with steel rule, 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

Objectives : At the end of this lesson you shall be able to
- **state the constructional features of jenny calipers**
- **name the types of jenny calipers**
- **state the uses of jenny calipers.**

Jenny calipers are used for marking and layout work.

These calipers are also known as hermaphrodite calipers, odd leg calipers, and leg and point calipers.

Jenny calipers have one leg with an adjustable divider point, while the other is a bent leg. The legs are joined together to make a firm joint.

Uses

Jenny calipers are used for marking lines, parallel to inside and outside edges and for locating the centre of round bars.

These calipers are available with the usual bent leg or with a heel. The calipers, with ordinary bent legs, are used for drawing lines parallel along an inside edge, and the heel type is used to drawing parallel lines along outer edges (Fig 1 & 2).

The jenny calipers should be slightly inclined while scribing lines.

Fig 1

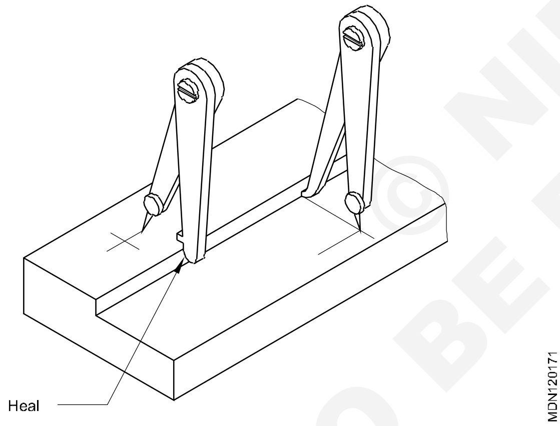
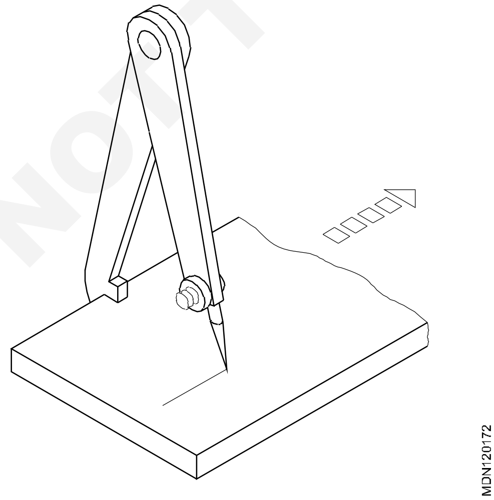


Fig 2



Jenny calipers can also be used for scribing lines along curved edges (Fig 3 & 4). While setting dimensions and scribing lines, both legs should be of equal length.

Fig 3

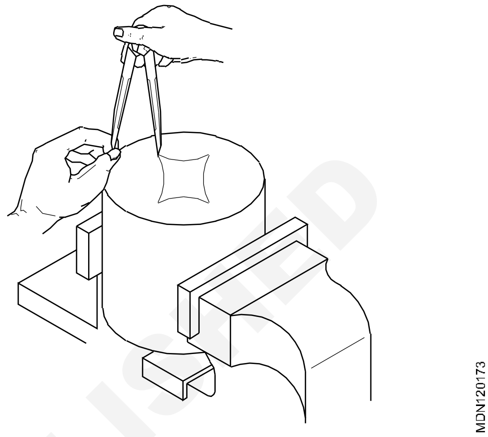
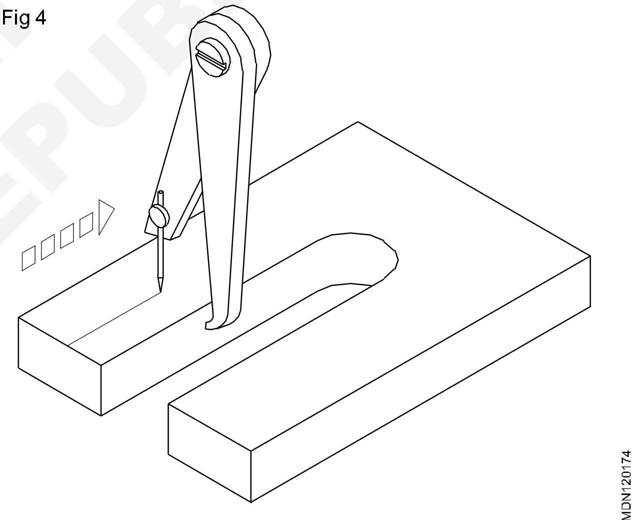
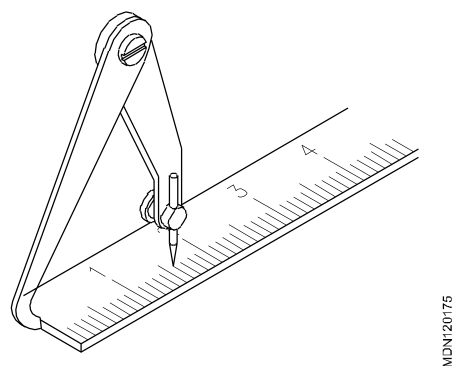


Fig 4



While setting dimensions for accurate setting the jenny caliper point should `click' into the graduation (Fig 5).

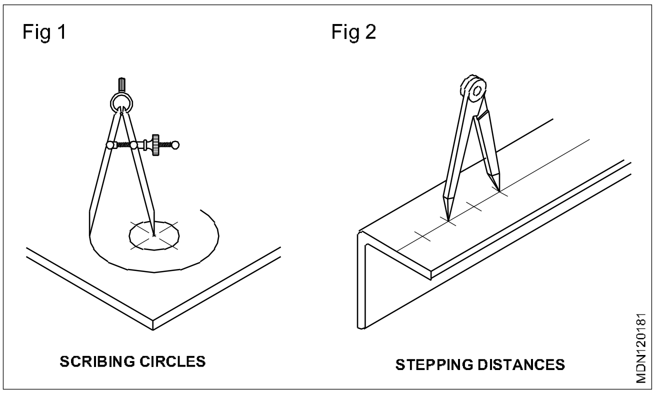
Fig 5



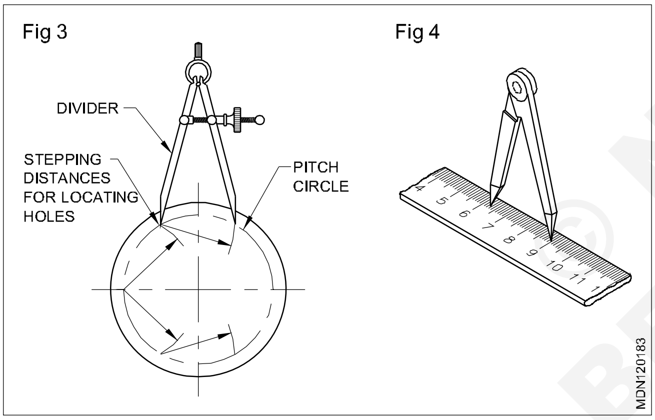
Dividers

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.**

Dividers are used for scribing circles, arcs and transferring and stepping of distances. (Fig 1 to 3)

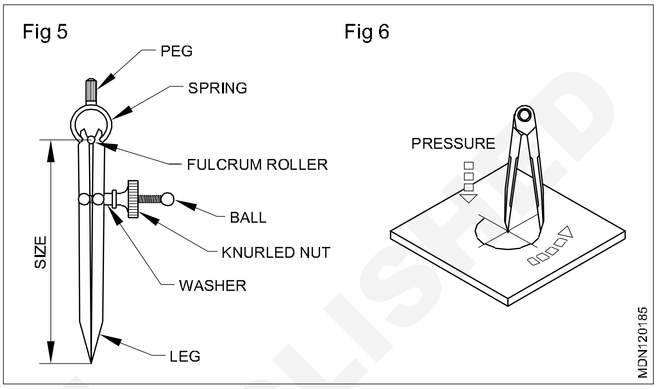


Dividers are available with firm joints and spring joints. The measurements are set on the dividers with a steel rule. (Fig 4)



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 5)

For the correct location and seating of the divider legs, prick punch marks of 30° are used. (Fig 6)



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

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

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.

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.**

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)

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.

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 1

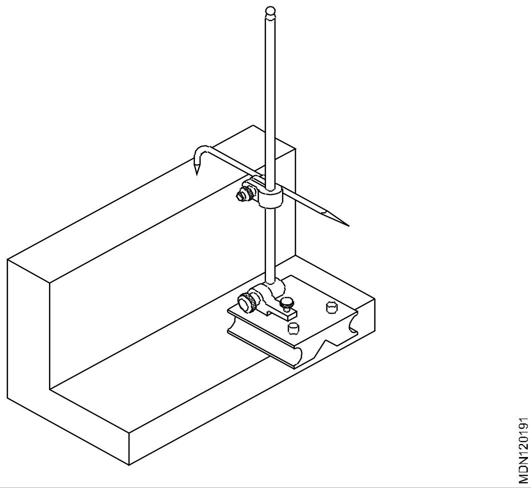


Fig 2

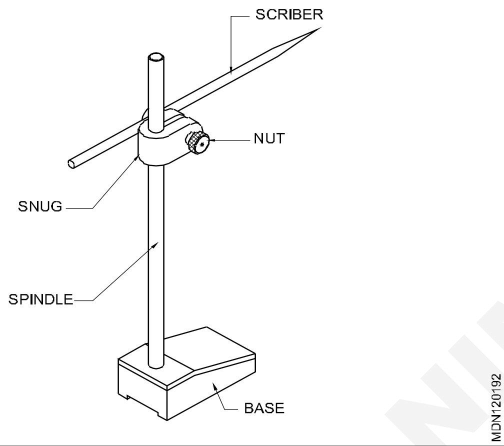


Fig 3

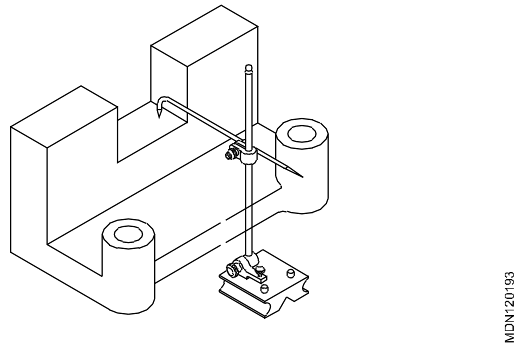
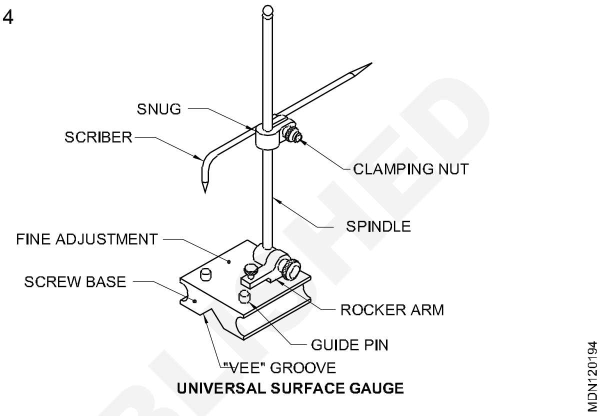


Fig 4



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.**

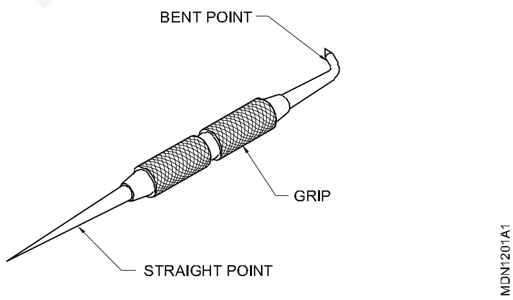
In layout work, it is necessary to scribe lines to indicate the dimensions of workpieces to be filed or machined .

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).

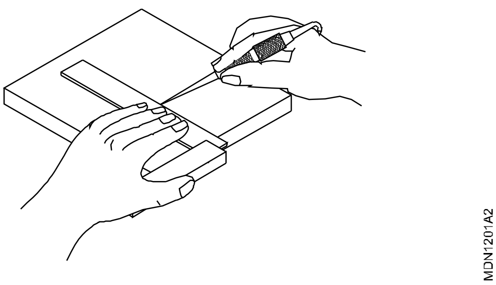
Fig 1



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



Wheelbase, wheel track and measuring tape

Objectives: At the end of this lesson you shall be able to
- **define wheelbase and 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

1 Dress makers

2 Civil Engineers

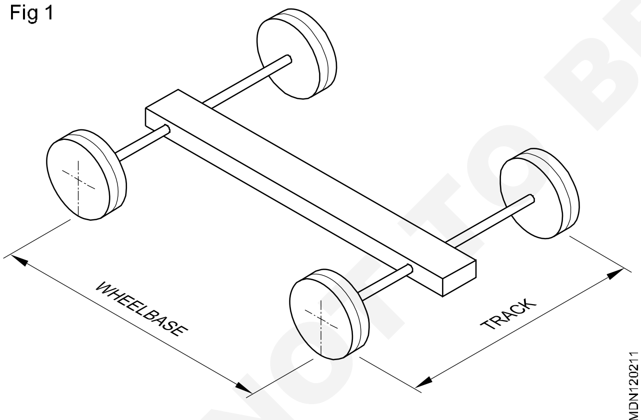
3 Mechanical Engineers

4 Surveyors

5 Carpenters

6 Medical field

Fig 1

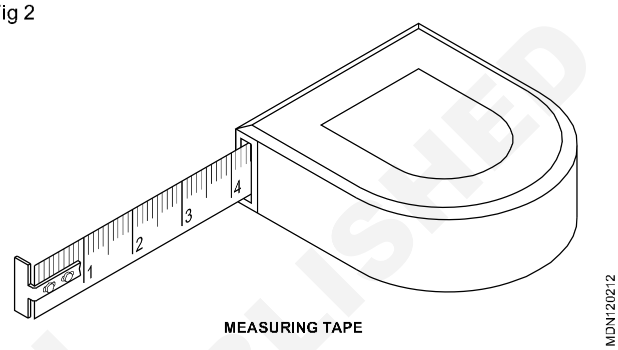


Accuracy

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 2



MEASURING TAPE

Fig 3

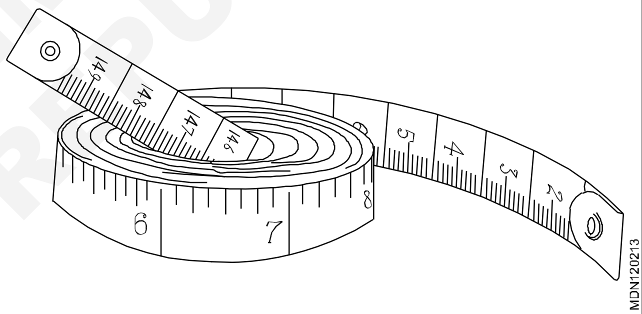
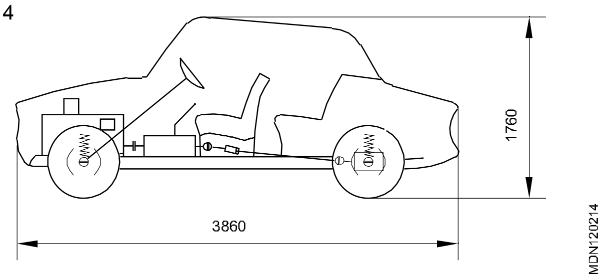


Fig 4



Length measurement

Scan the QR Code to view the video for this exercise

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 (SI) is the metre. The table given below lists some multiples of a metre.

Metre (m)	=	1000 mm
Centimetre (cm)	=	10 mm
Millimetre (mm)	=	1000 micro metre
Micrometre (m)	=	0.001 mm

Measurement in engineering practice

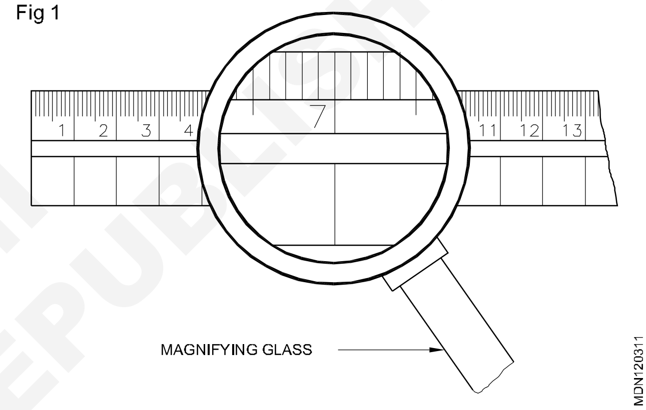
Usually, in engineering practice, the preferred unit of length measurement is the millimetre (Fig 1).

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 wih 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 rule.**

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

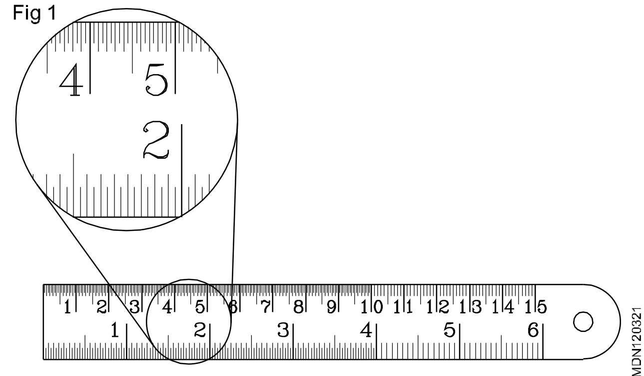
Sizes of steel rules (Fig 1)

Steel rules are available in different lengths, 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.

Fig 1



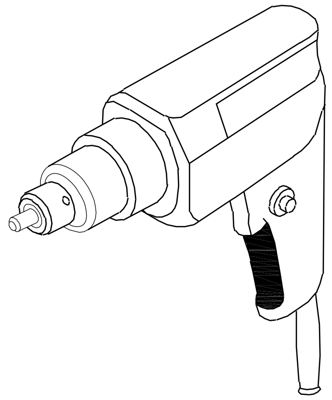
Air impact wrench, air ratchet

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)

Air ratchet (Fig 3): 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 an 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.

Fig 2

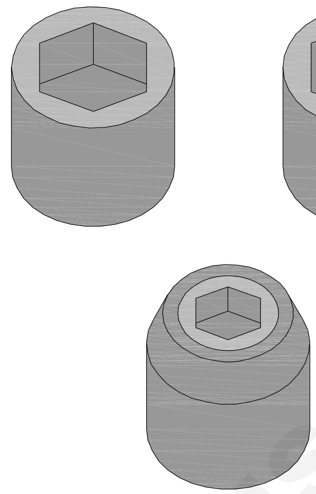
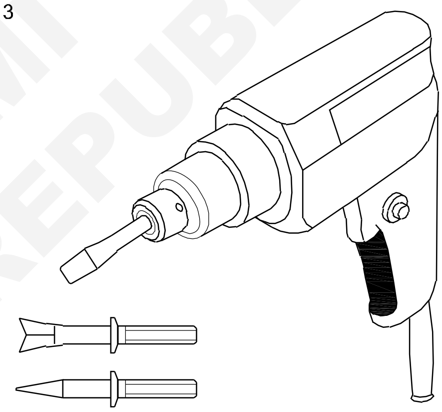


Fig 3



Air chisel: Air chisel is used for cutting the bolts to nuts of vehicle body sheet.

The compressed air provides more force and much efficient than a hand chisel and hammer.

Air chisel can be used with different types of chisel kit, depending upon the job.

Punches

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)

Fig 1

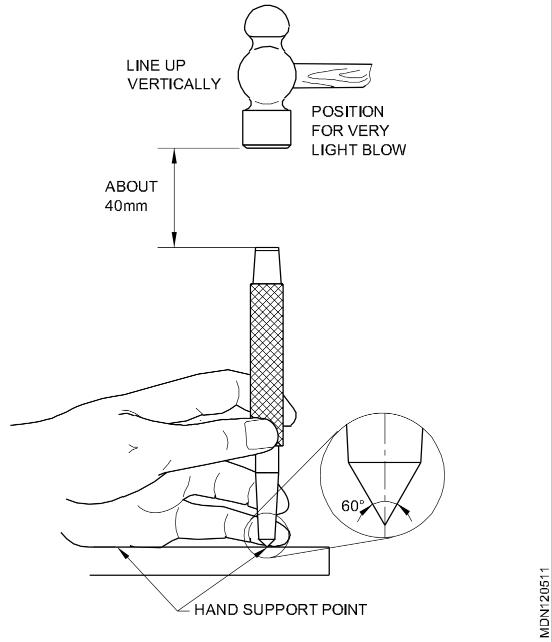


Fig 2

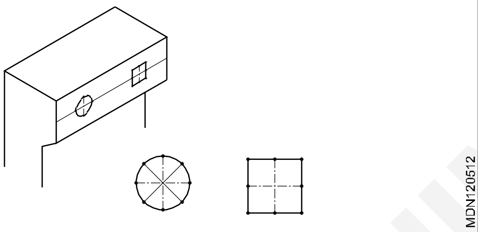
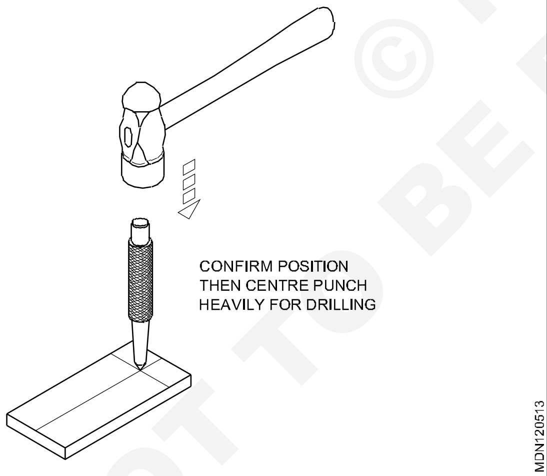


Fig 3



- to locate the pivot points of compasses for scribing circles. (Fig 4)

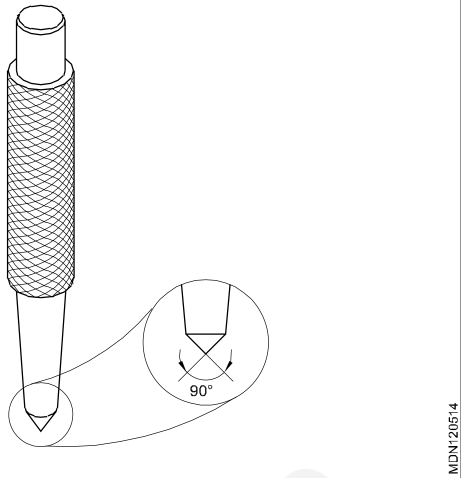
A 100 mm prick punch with a 7 mm diameter body could have a 2.5 mm diameter point ground to an angle of 60° or 30°

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 10mm diameter body and a 6mm diameter point ground to an angle of 90°

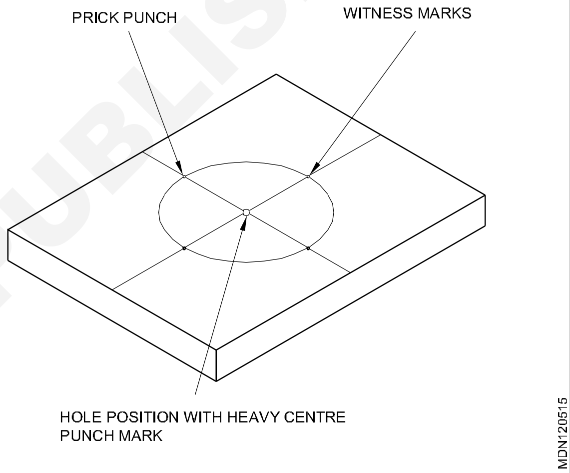
Fig 4



Centre punches are used;

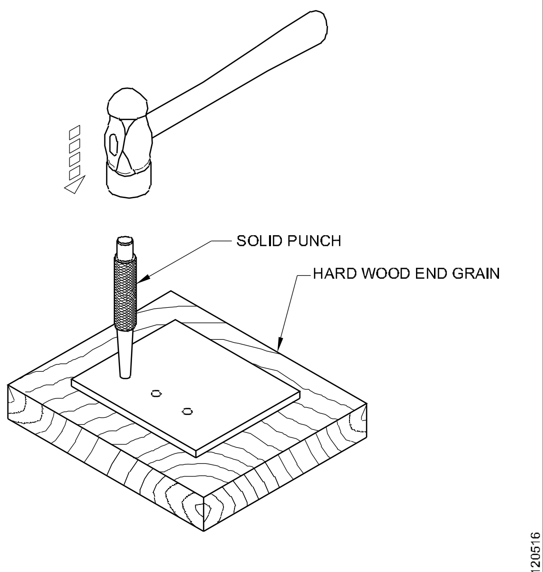
- to make deeper witness marks on scribed lines and to locate a centre position and make it easier for the drill to start correctly. (Fig 5)

Fig 5



Solid punch (Fig 6)

Fig 6



PUNCHING HOLES FOR RIVETS WITH A SOLID PUNCH

In riveting sheet metal, holes must be equally spaced and lined up. The holes in the metal are usually punched with solid punches.

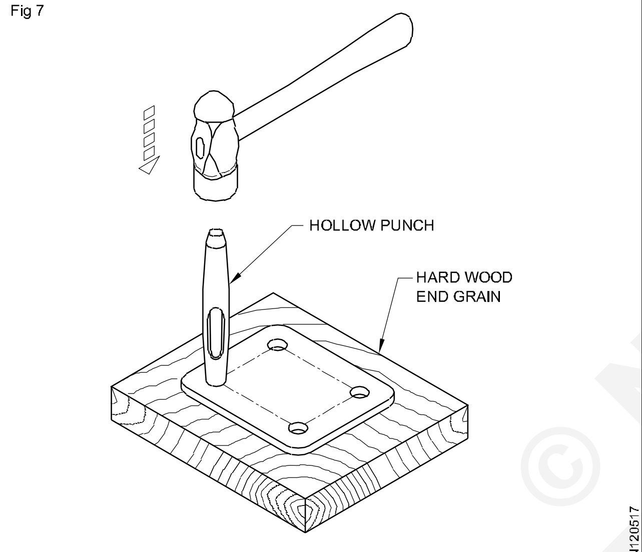
Letter and number punches

These punches are known as letter stamps or number stamps, letter punches are used to emboss the impression of a letter or 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.

Fig 7



USING A HOLLOW PUNCH

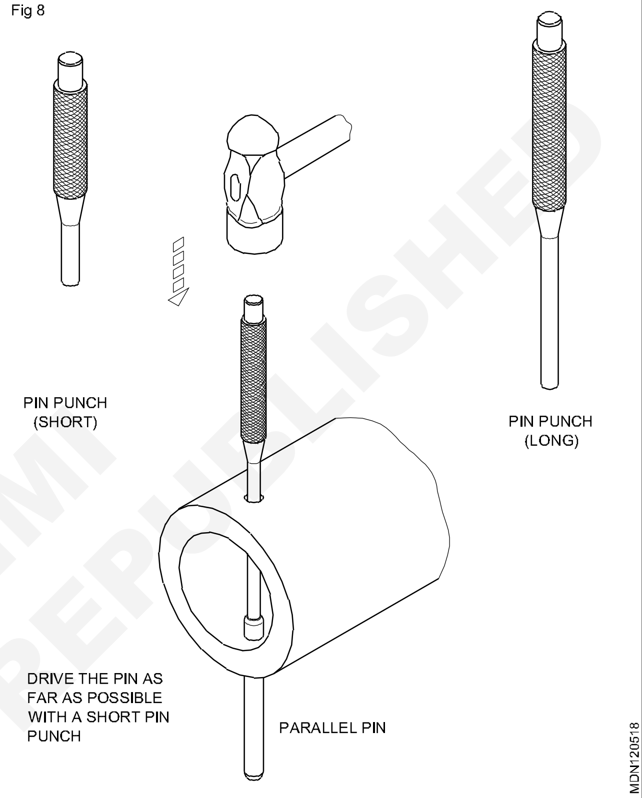
While using solid or hollow punches, the materials is rigidly supported with a block of wood (with the end of grain up) or lead. This will also avoid any damage to the tip of the punch while punching.

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 chisel.**

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.

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

1 Head

2 Body

3 Point or cutting edge

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.

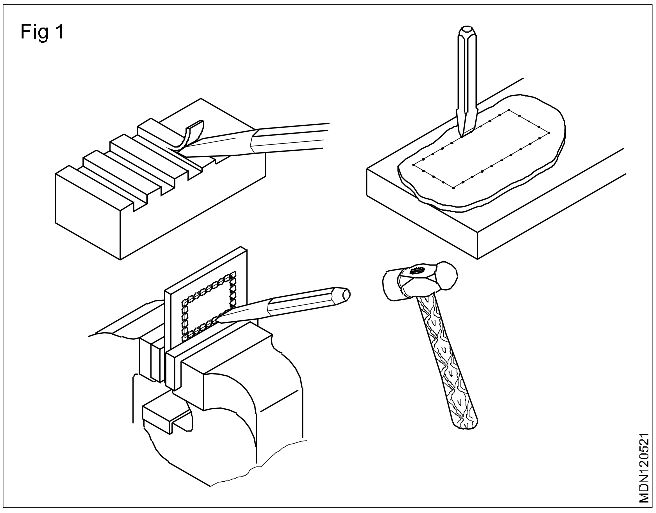
Common types of chisel: There are four common types of chisel;

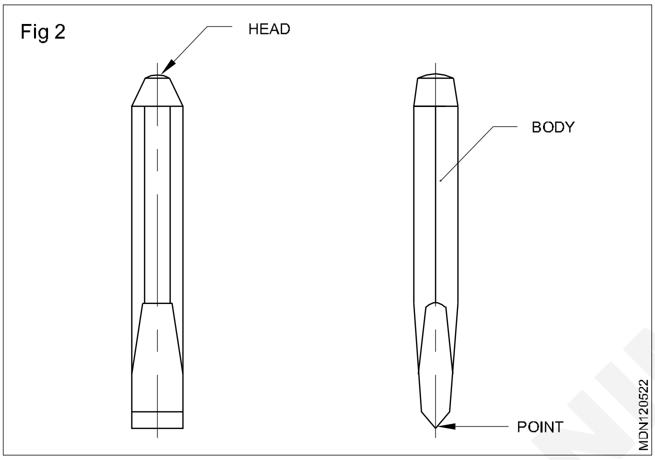
- Flat chisel (1)
- Cross-cut chisel (2)
- Half round nose chisel
- Diamond point chisel

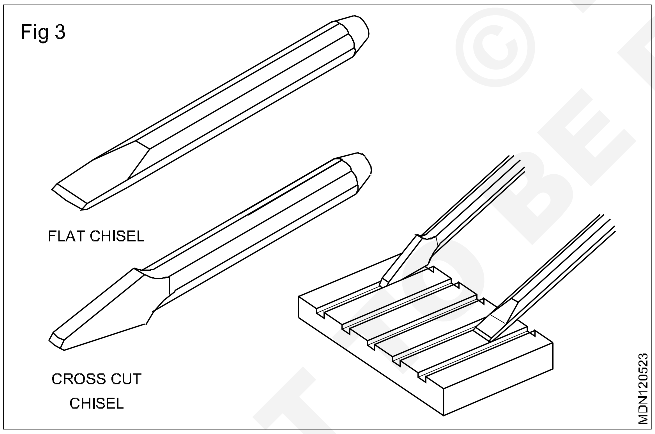
Flat chisel (Fig 3)

These are used to remove metal from large flat surfaces and chip excess metal of weld joints and castings.

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







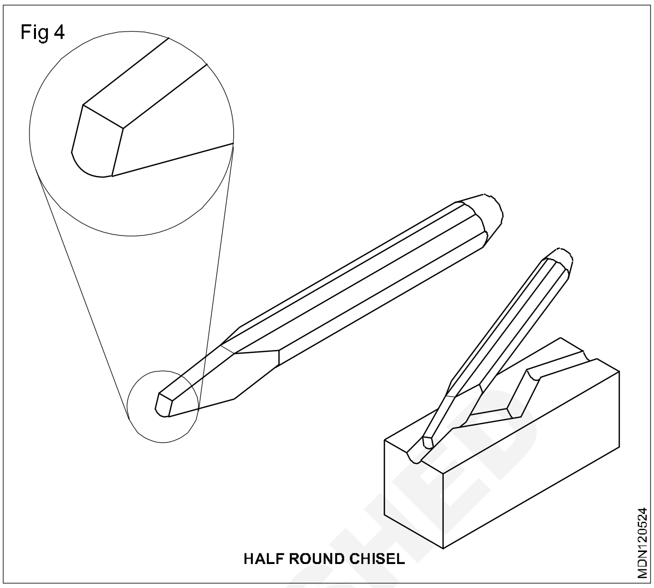
Half round nose chisel (Fig 4): These are used for cutting curved grooves (oil grooves)

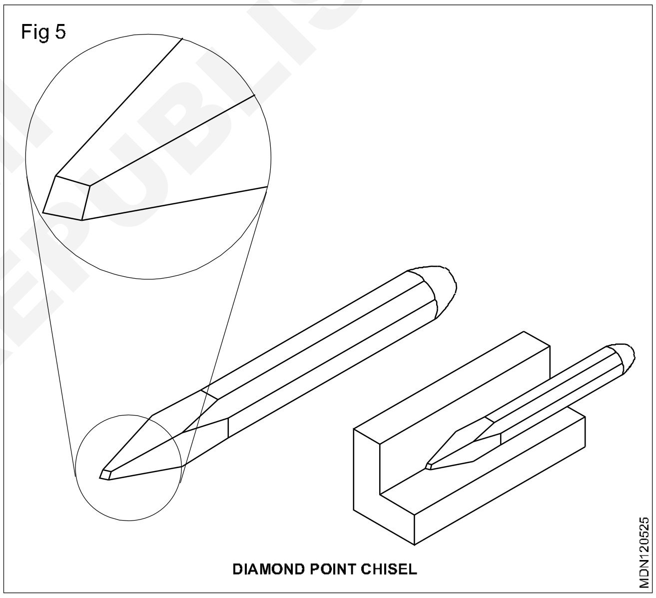
Diamond point chisels (Fig 5): These are used for squaring materials at the corners.

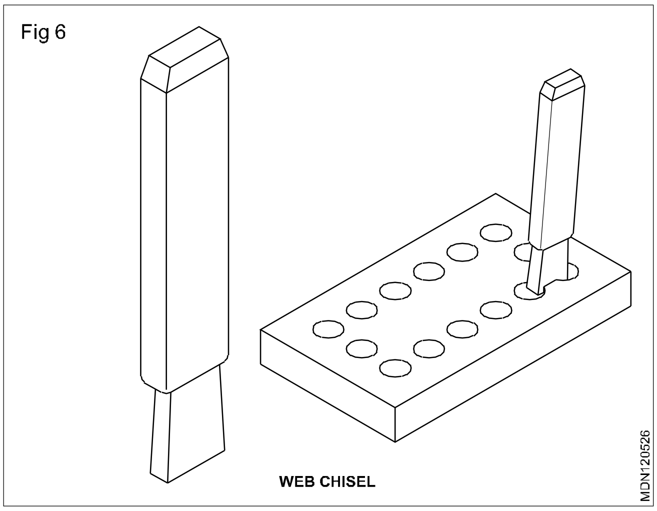
Web chisel/punching chisel (Fig 6): These are used for separating metals after chain drilling. Chisel are specified according to their;

- 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.







Angles of chisels

Objectives : At the end of this lesson you shall be able to
- **select the point angles of chisels for different materials.**
- **state the different cutting angles of a chisel**
- **state the effect of rake and clearance angles.**

Point angles and materials (Fig 1)

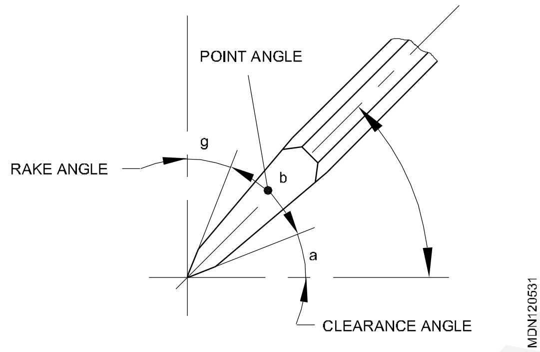
Correct point/cutting angles of the chisel depends on the materials to be chipped. Sharp angles are given for soft materials, and wide angles for hard materials.

The correct point angle and angle of inclination generate the correct rake and clearance angles.

Rake angle (Fig 1)

Rake angle `γ' is the angle between the top face of the cutting point, and normal to the work surface at the cutting edge.

Fig 1

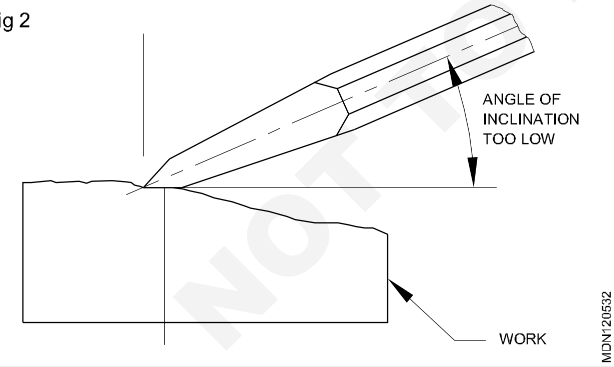


Clearance angle (Fig 1)

Clearance angle `α' is the angle between the bottom face of the point and tangent to the work-surface originating at the cutting edge.

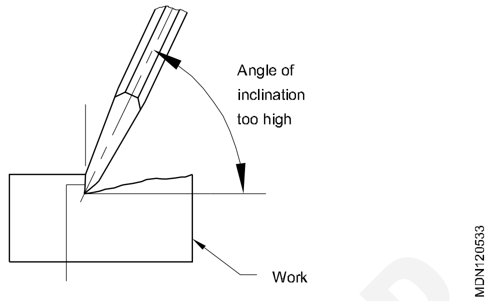
If the clearance angle is too low or zero (Fig 2), the rake angle increases. The cutting edge cannot penetrate into the work. The chisel will slip.

Fig 2



If the clearance angle is too great (Fig 3), the rake angle reduces. The cutting edge digs in, and the cut progressively increases.

Fig 3



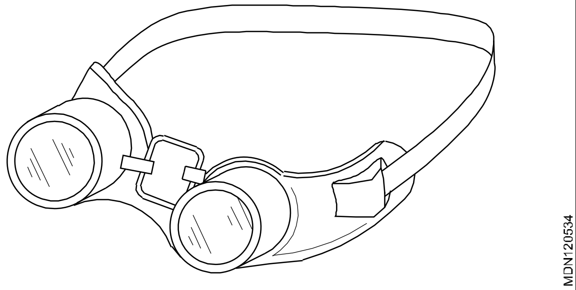
Material to be cut	Point angle	Angle Inclination
High carbon steel	65°	39.5°
cast iron	60°	37°
Mild steel	55°	34.5°
Brass	50°	32°
Copper	45°	29.5°
Aluminium	30°	22°

Chipping goggles (Fig 4): It is used to protect the eyes while chipping the slag or grinding the job.

It is made of Bakelite frame fitted with clear glasses and an elastic band to hold it securely on the operator's head.

It is designed for comfortable fit, proper ventilation and full protection from all sides.

Fig 4



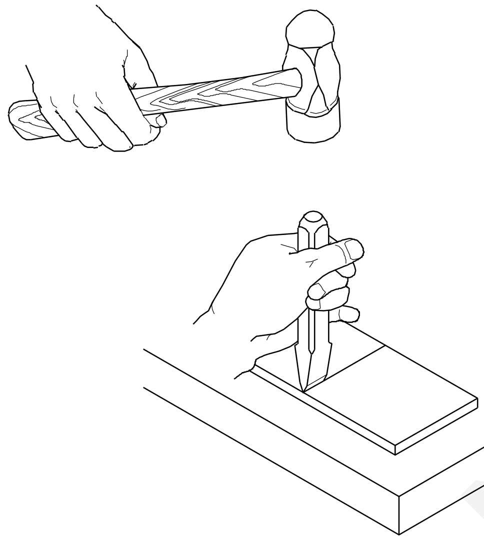
Hammers

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
- Straightening
- Forging
- Bending
- Chipping
- Riveting

Fig 1



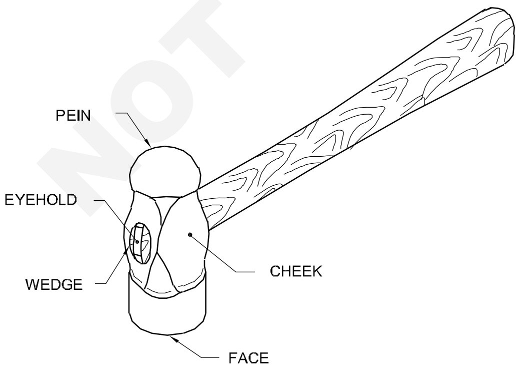
Major parts of a hammer (Fig 2)

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

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

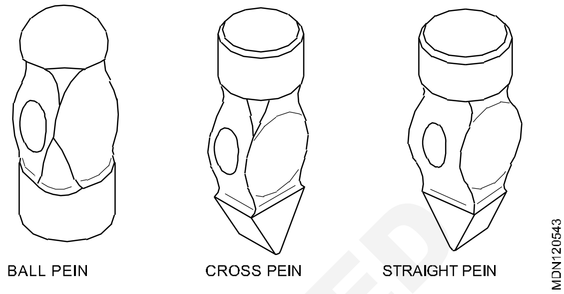
Fig 2



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 a different shapes like the (Fig 3)

Fig 3



- ball pein
- cross pein
- straight pein

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

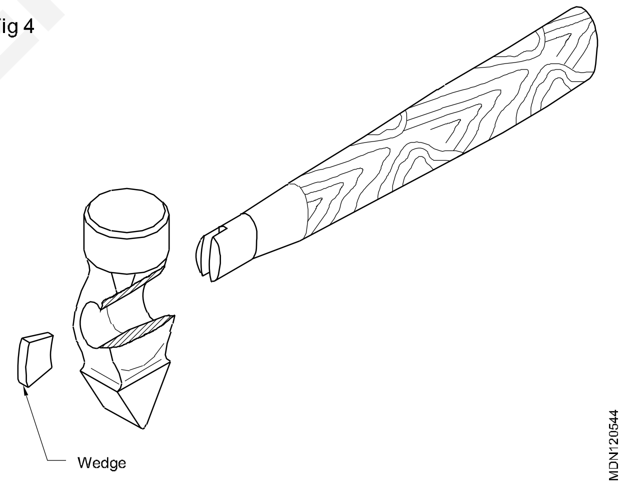
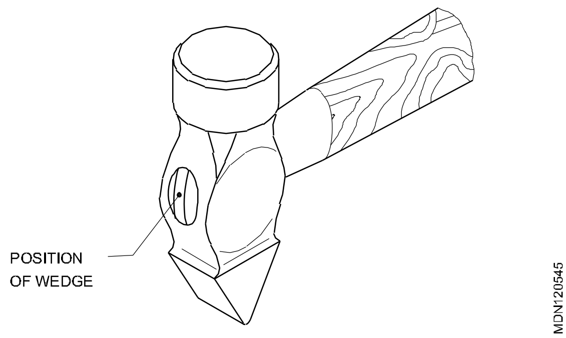


Fig 5



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

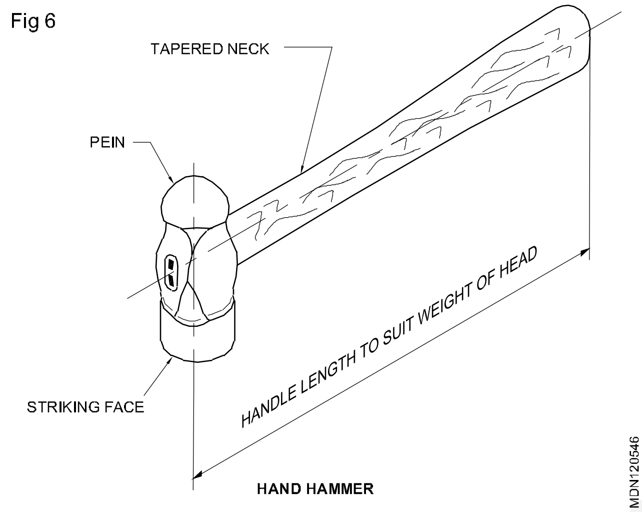
select a hammer with the correct weight suitable for the job

check the head and handle for any cracks

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

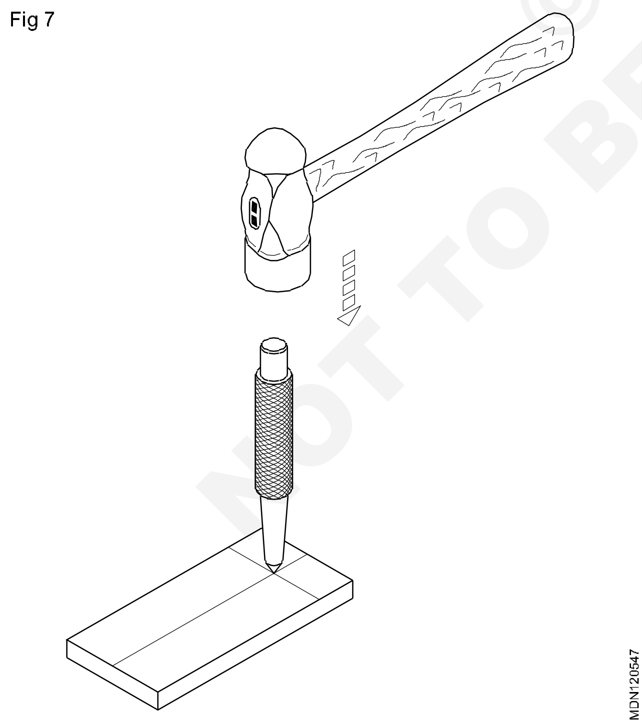
The figure (Fig 6) shows the different parts of a hammer. The handle is fitted in the eye-hole of the hammer.

Fig 6



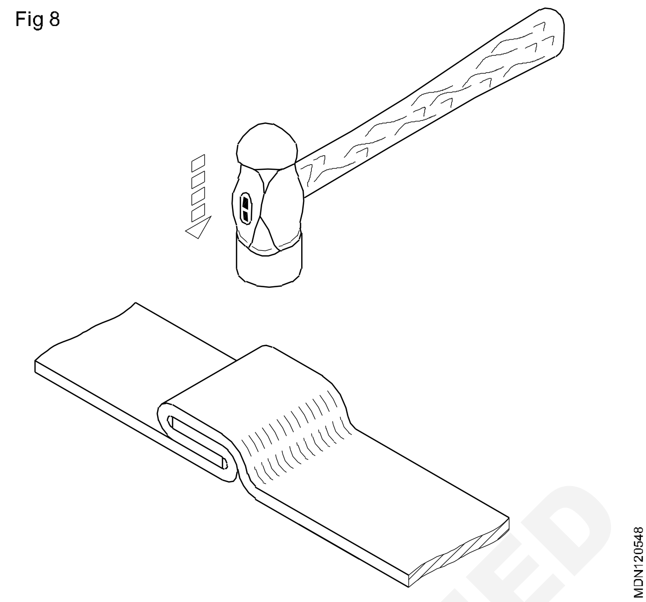
The face of the hammer is used for general work, such as striking chisels and punches and levelling and working over joints. (Fig 7)

Fig 7



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

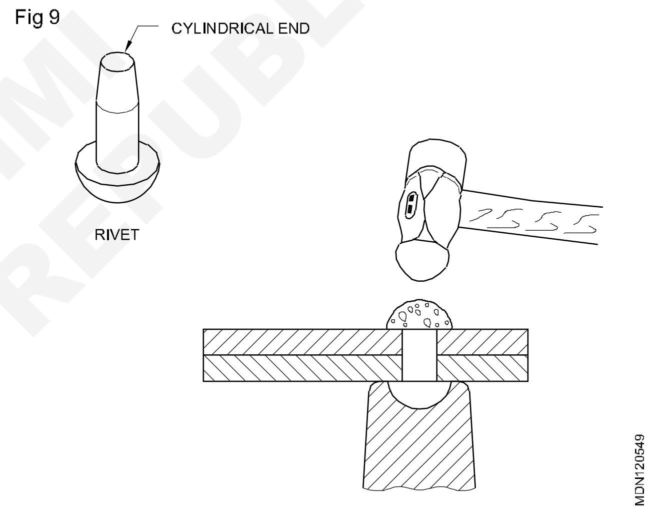
Fig 8



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

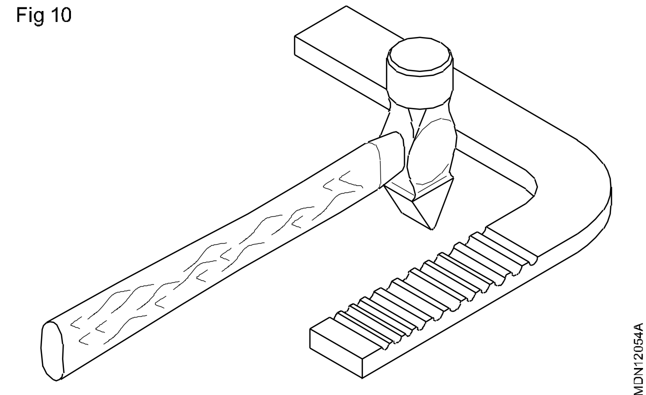


Cross pein hammer (Fig 10)

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.

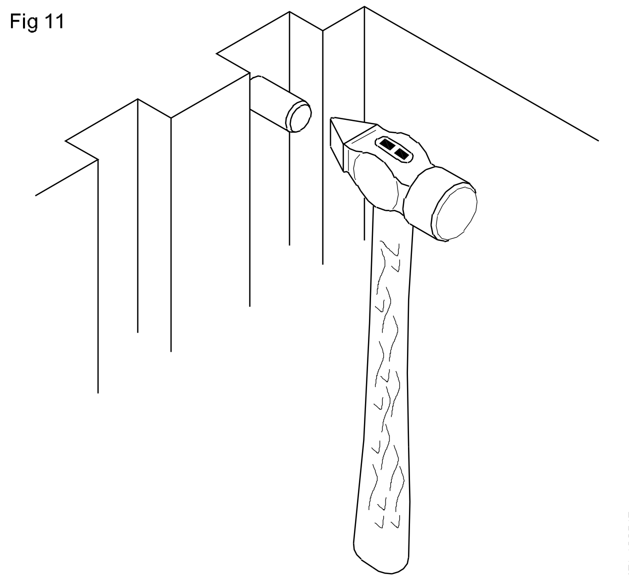
Fig 10



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).

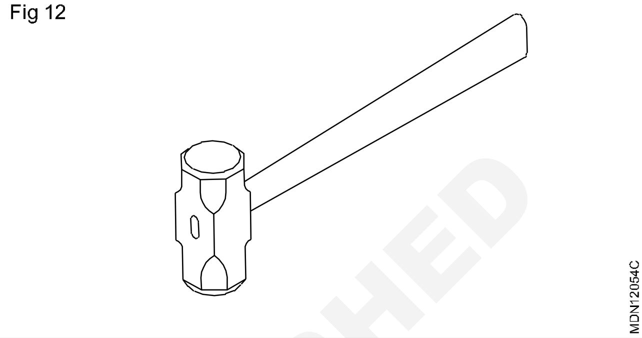
Fig 11



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 sledge hammer (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



Wooden mallet

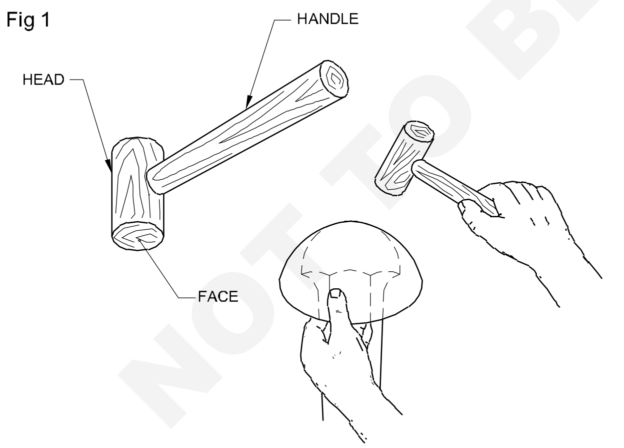
Objectives : At the end of this lesson you shall be able to
- **name the different types of mallets**
- **state the uses of each type of mallets.**

Mallets: Mallets are soft hammers and are made of raw hide, hard rubber copper, brase, 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.

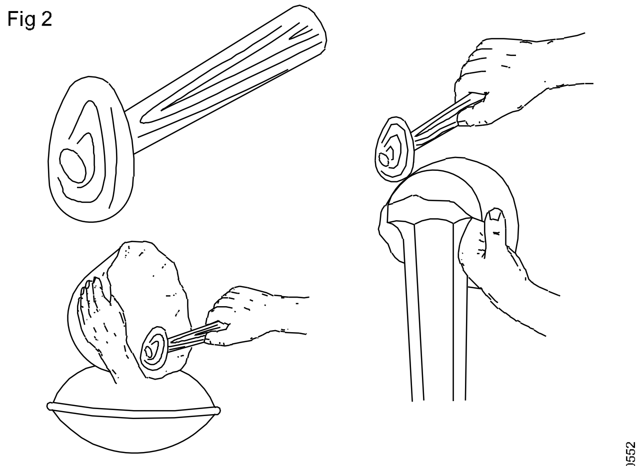
Fig 1



STANDARD WOODEN MALLET

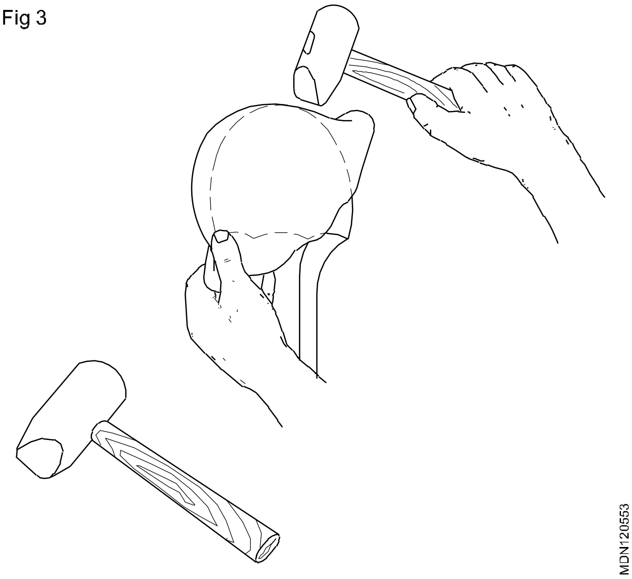
- **Bossing mallets** (Fig 2) are used for hollowing panel beatings etc.
- An **end-faked mallet** (Fig 3) is used for stretching, hammering etc.

Fig 2



SHAPING THE HEMISPHERICAL BOWL BY RAISING BOSSING MALLET

Fig 3



Screwdrivers

Objectives : At the end of this lesson you shall be able to
- **classify the hand-held screwdrivers**
- **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): 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.

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 1

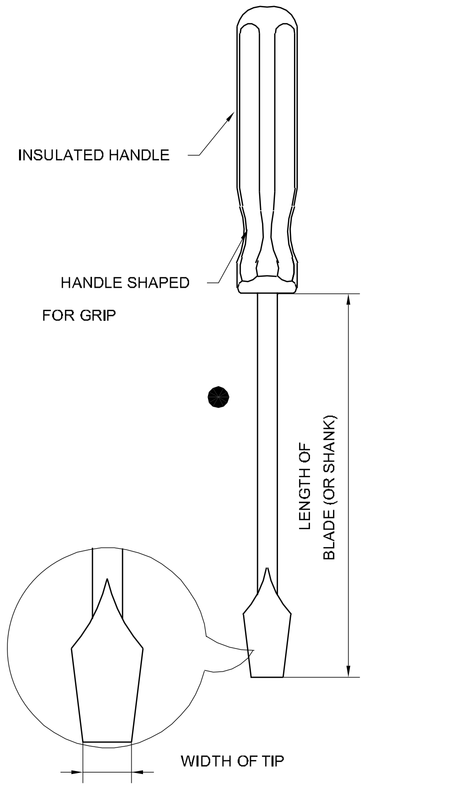


Fig 2

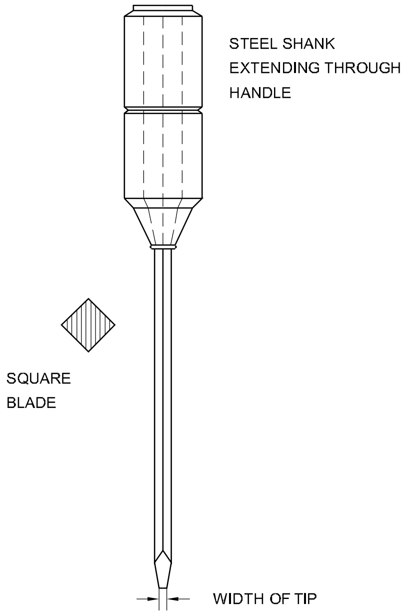
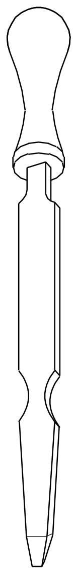
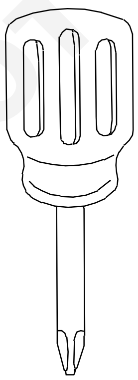


Fig 3



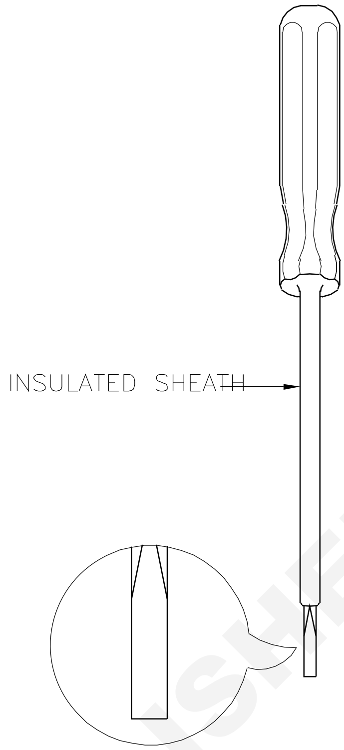
Stumpy screwdrivers (Fig 5): These are small stumpy screwdrivers. They are used when other types of screwdrivers cannot be used due to the space limitations.

Fig 5



STUMPY SCREW DRIVER

Fig 4



LIGHT DUTY SCREW DRIVER

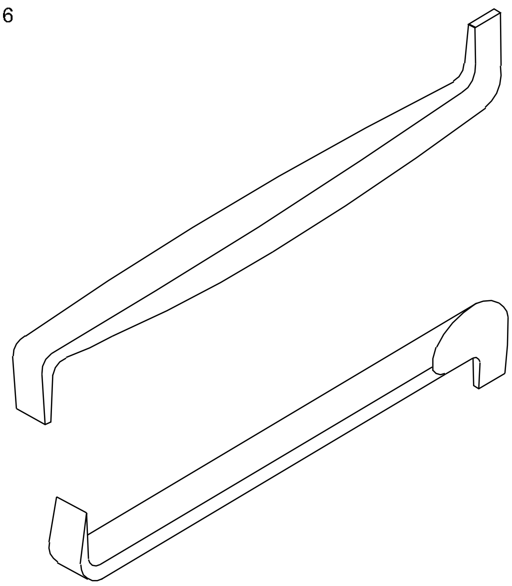
Special screwdrivers and their uses

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



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.

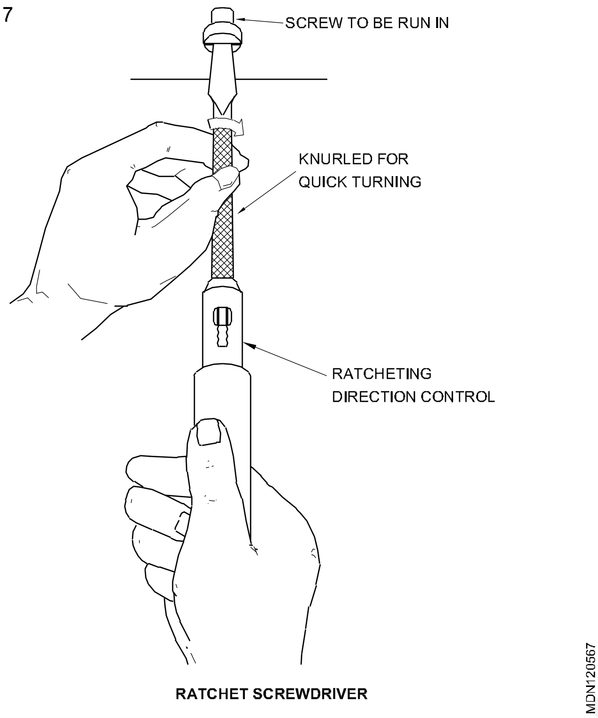
They are used for turning screws in confined spaces.

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.

Fig 7



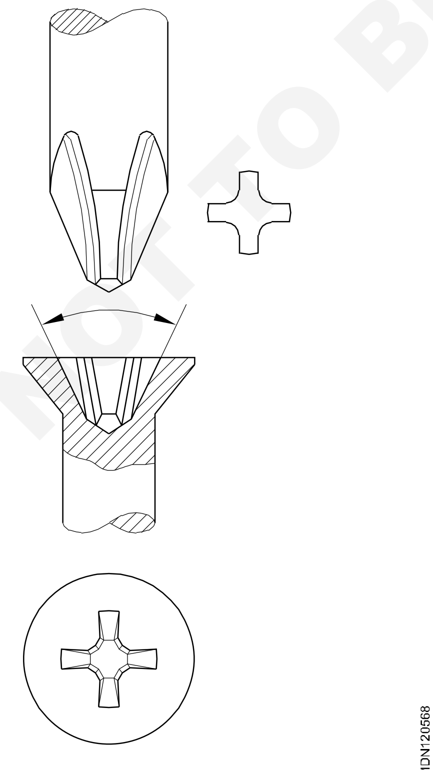
RATCHET SCREWDRIVER

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°

Fig 8

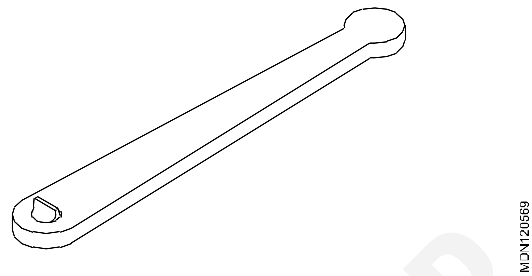


The extreme end is ground to 110°.

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.

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

Fig 9



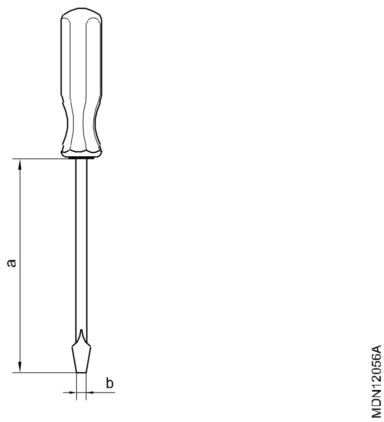
Specification of screwdriver: Screwdrivers are specified (Fig 10) according to the;

- 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

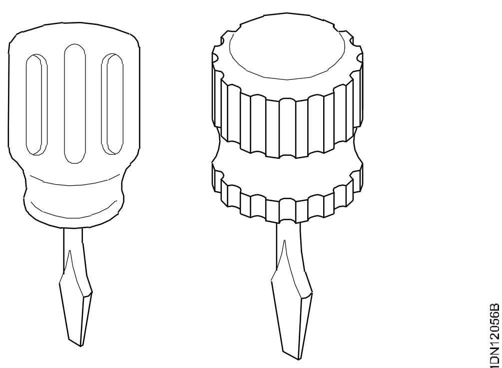


Screwdrivers for special uses

Small sturdy screwdrivers (Fig 11) are available for use where there is limited space.

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

Fig 11



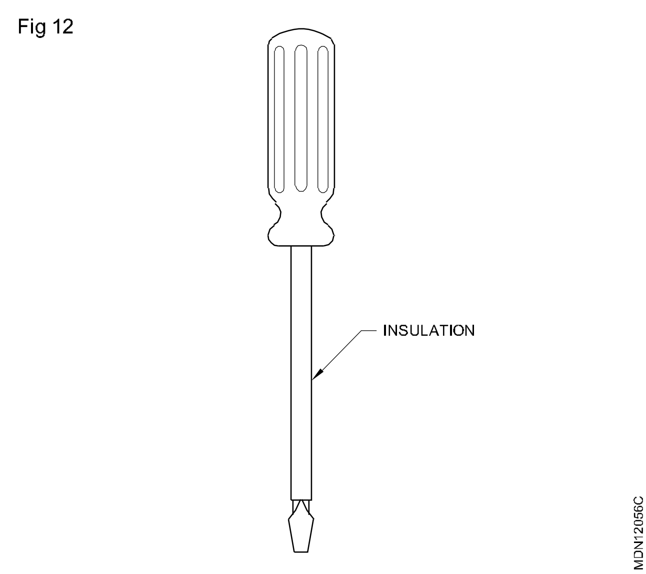


Fig 12

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.

While using a Phillips screwdriver apply more downward pressure.

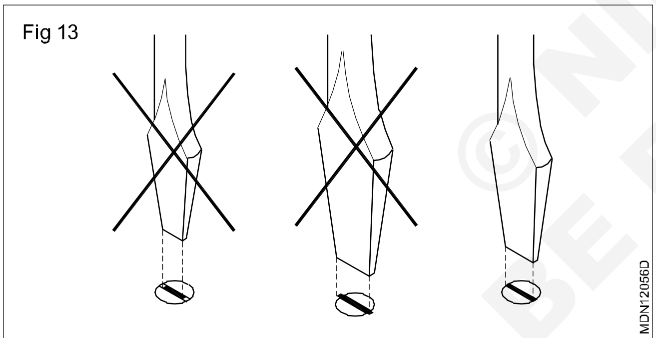


Fig 13

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

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

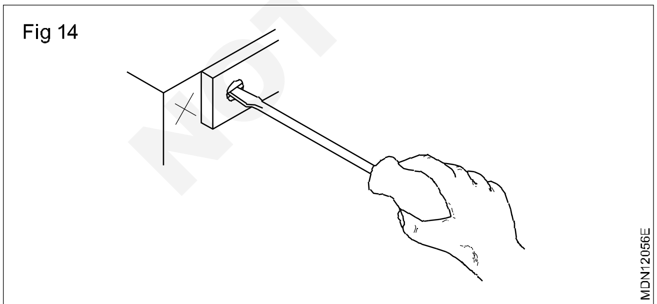


Fig 14

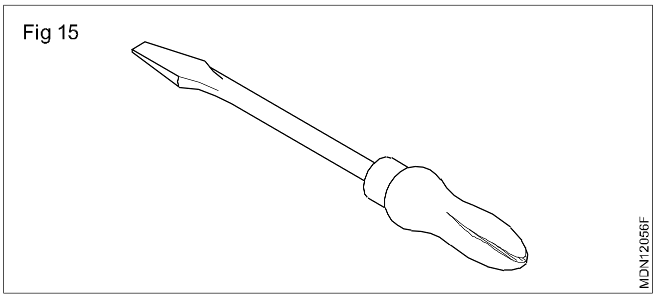


Fig 15

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.

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 & Philips 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.

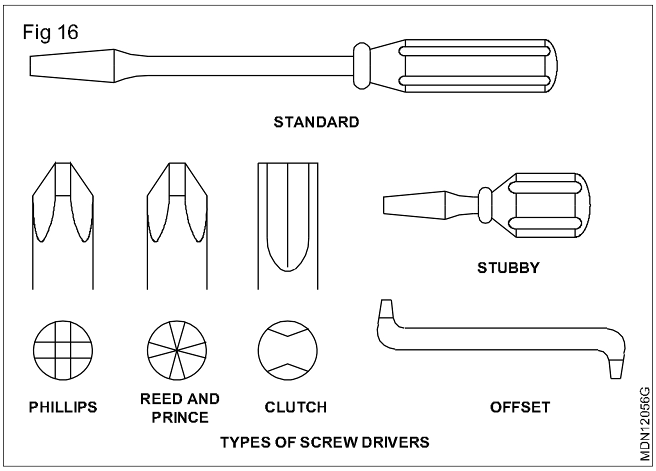


Fig 16

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**.

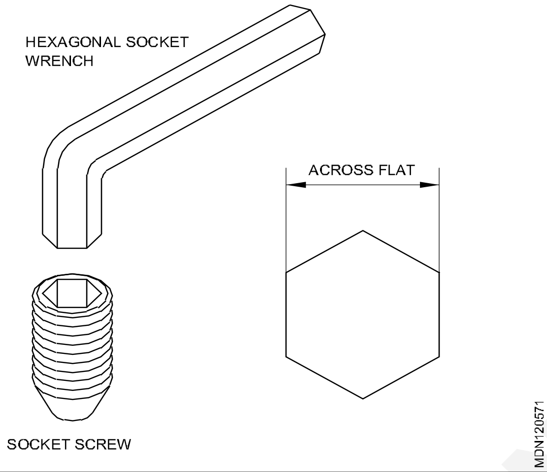
Hexagon socket screw keys/Allen keys are made from hexagonal section bars of chrome vanadium steel.

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)

Fig 1



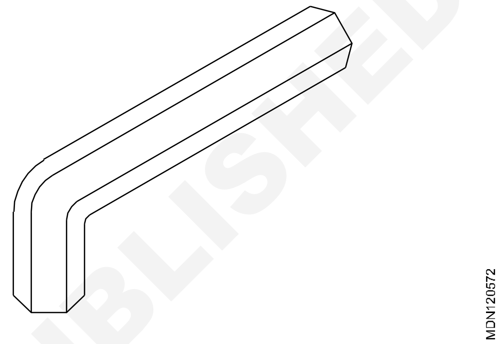
Allen keys, available in different sets in plastic wallets, surprise of a set of 8 (2 to 10mm)

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.

Fig 2



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.**

Vices are used for holding workpieces. They are available in different types. The vice used for bench work is called 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 filing, 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.

Fig 1

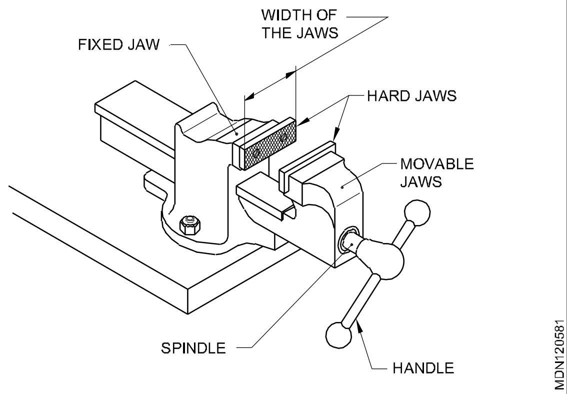
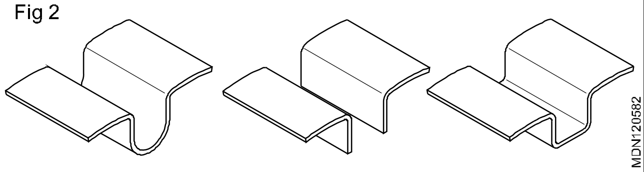


Fig 2



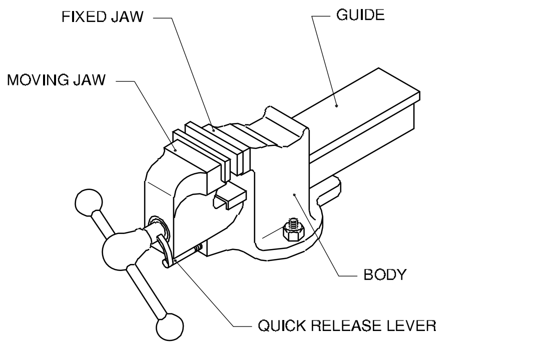
Types of vice

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 vice 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.

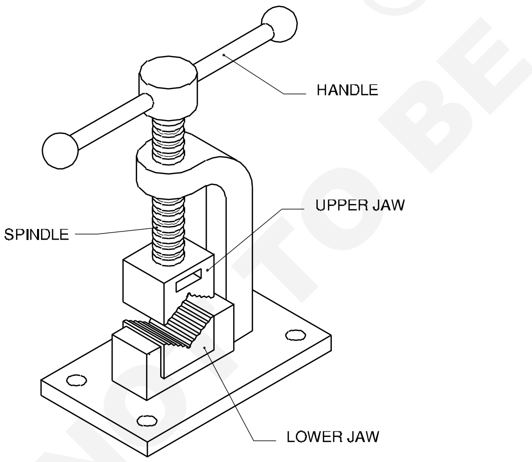
Fig 1



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.

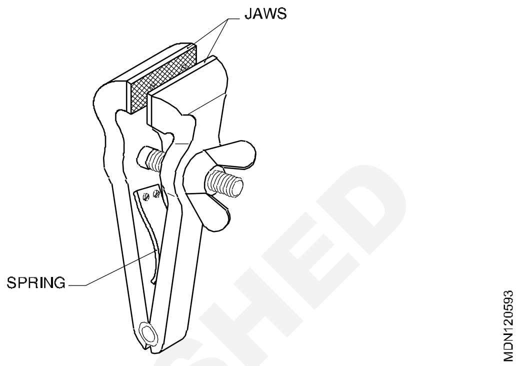
Fig 2



Hand vice (Fig 3): Hand vice is 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.

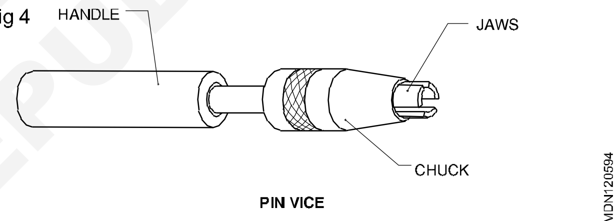
The length varies from 125 to 150 mm and the jaw width from 40 to 44 mm. The jaws can be opened and closed using the wing nut on the screw that is fastened to one leg and passes through the other.

Fig 3



Pin vice (Fig 4): The pin vice is used for holding small diameter jobs. It consists of a handle and a small collet chuck at one end. The chuck carries a set of jaws which are operated by turning the handle.

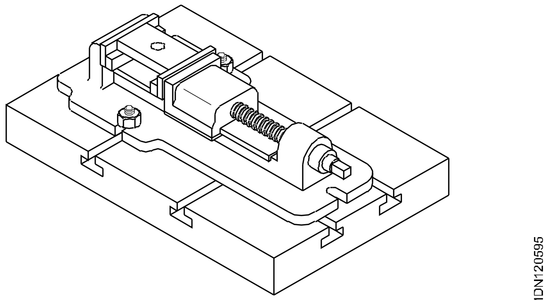
Fig 4



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.

Fig 5



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.

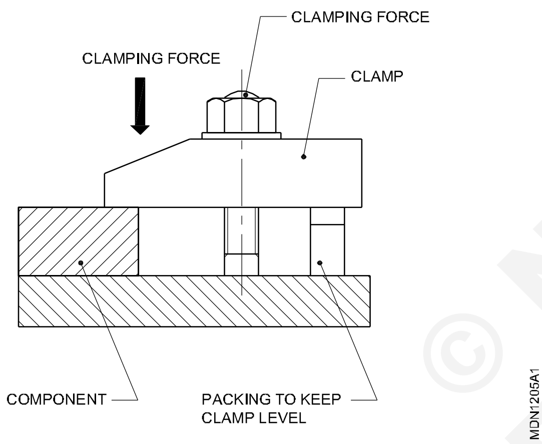
Should provide the required clamping force.

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.

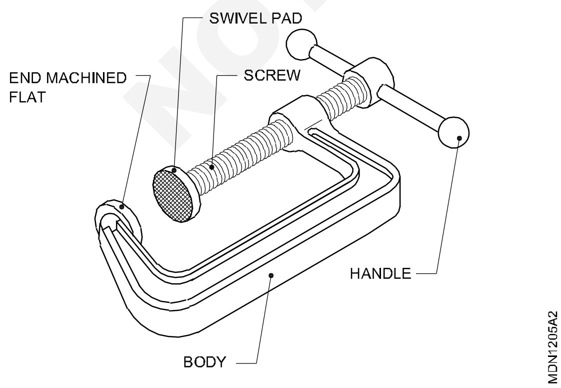
Fig 1



'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)

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)

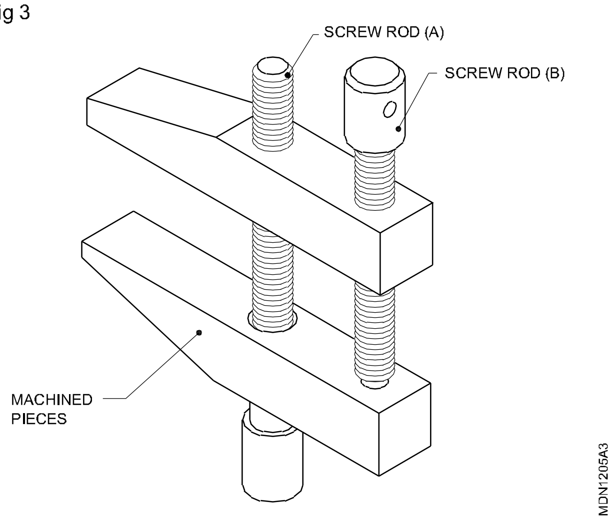
The head of the screw-rod (B) is provided with a hole through which a cylindrical pin may be passed for tightening purposes. The toolmaker's clamps are for holding a previously machined work which is flat and parallel.

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.

Fig 3



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.

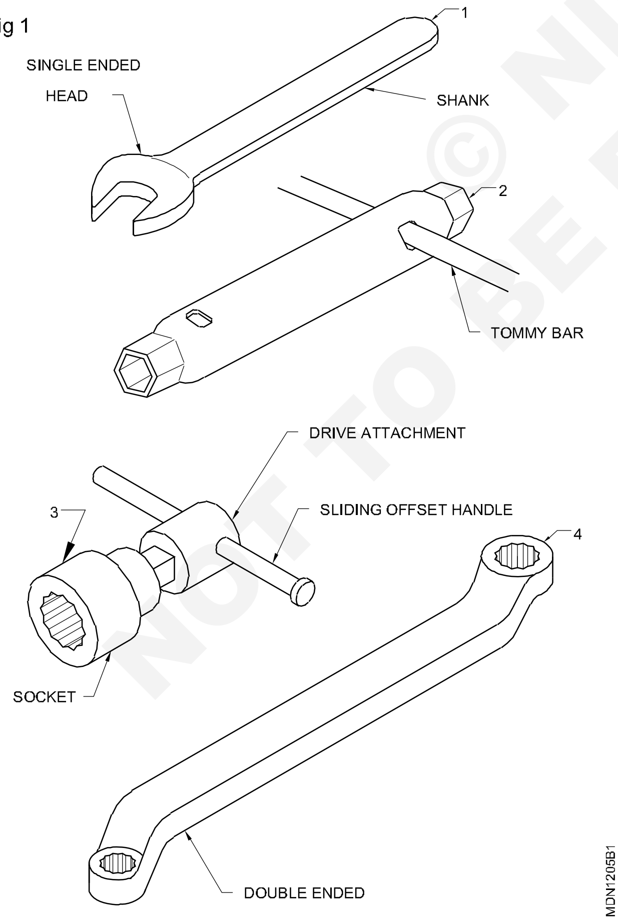
Spanners are considerably in shape to provide ease of operation under different conditions.

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.

Fig 1



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.

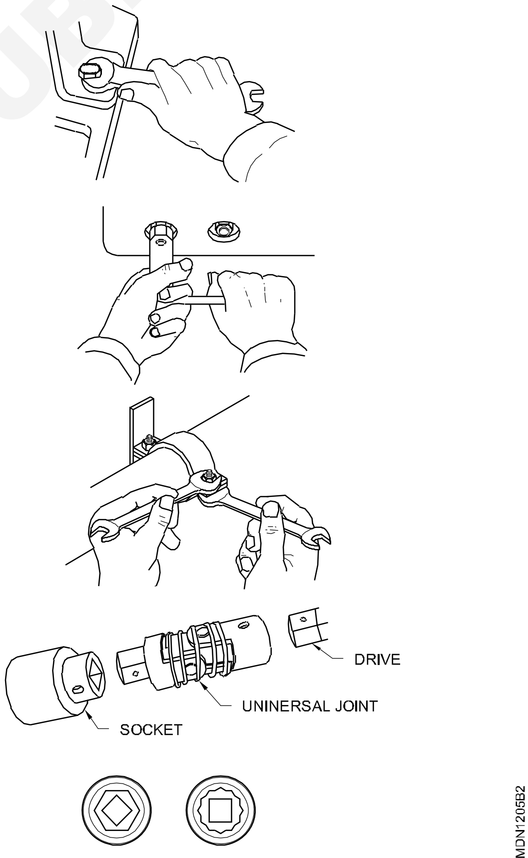
Keep yourself balanced and firm to avoid slipping yourself, if the spanner slips suddenly, Hold on to some support, if there is any chance of falling.

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)

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.

Fig 3

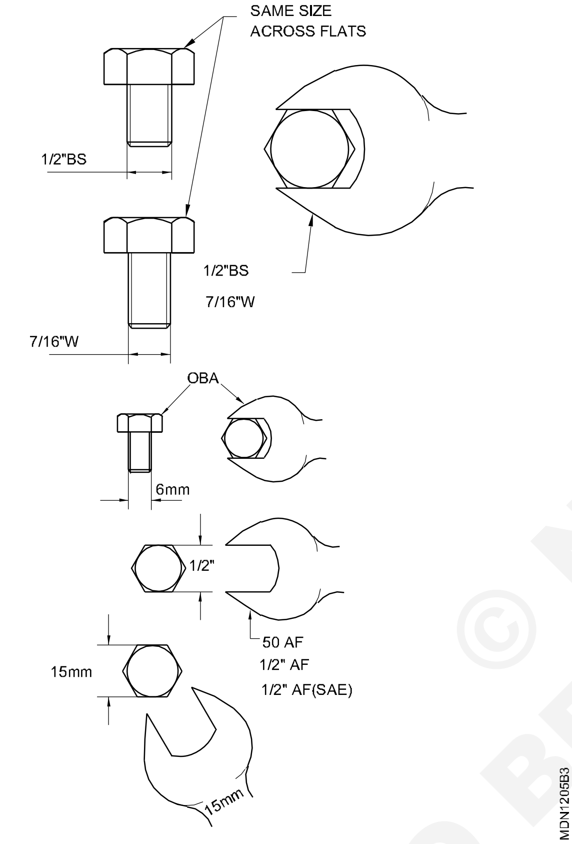
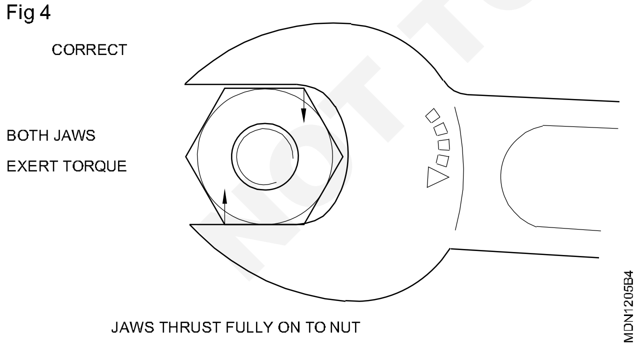


Fig 4



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.

Place the spanner so that its jaws hold fully on the flats of the nut

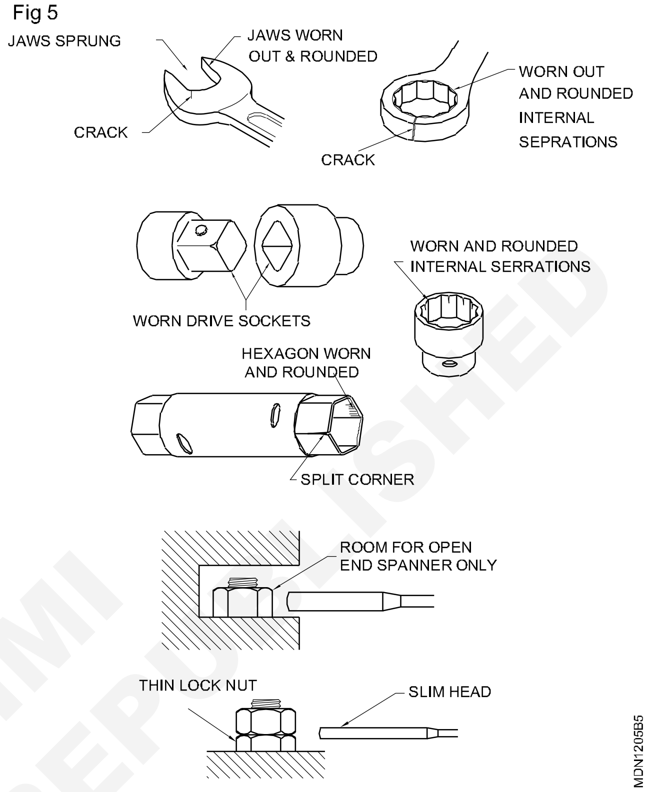
Incorrect use damages the spanners & the nuts too.

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. (Fig 5)

Fig 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 250mm 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 ½^0 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.

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.

Fig 6

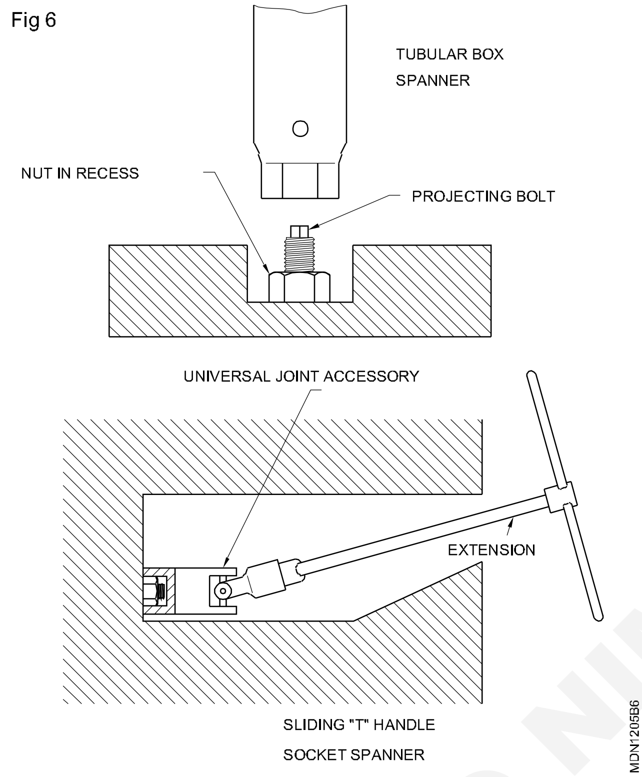


Fig 7

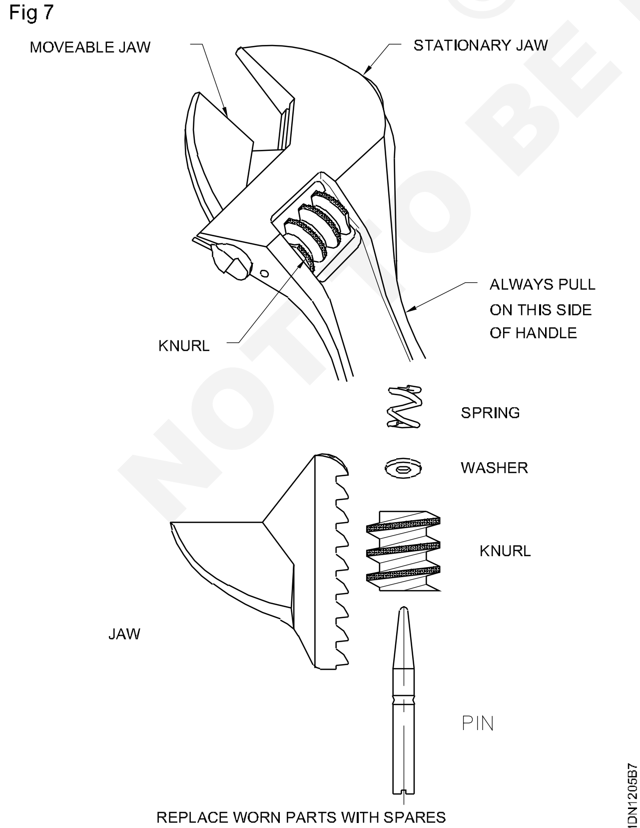
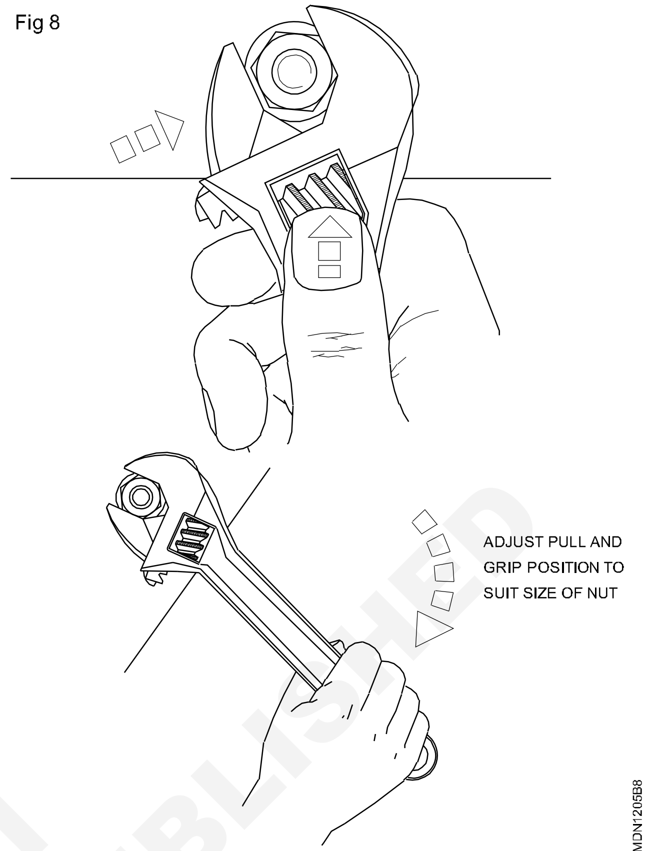


Fig 8



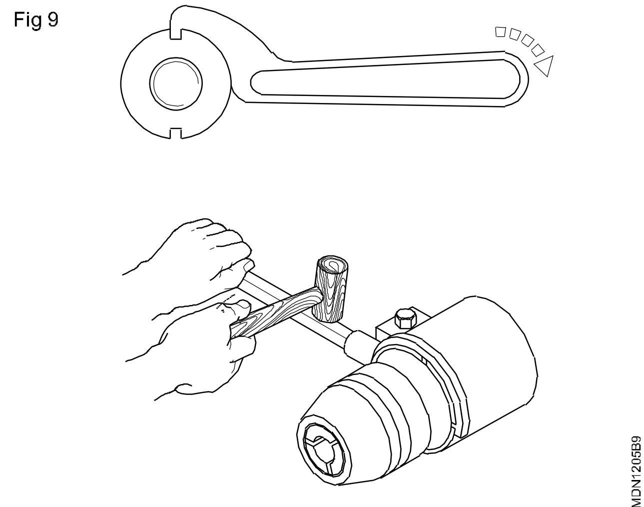
Push the jaws into full contact with the nut.

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 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 19mm to 120mm. The applications of 'C' spanners are shown in the figure.

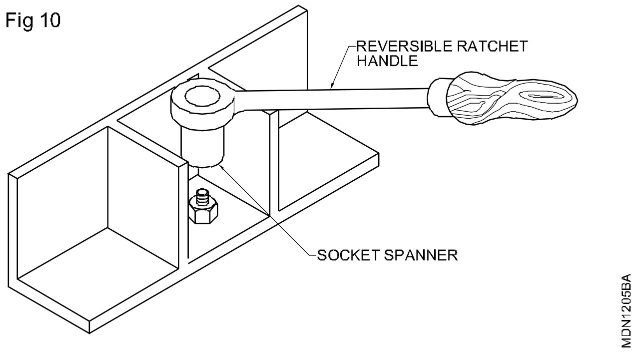
Fig 9



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

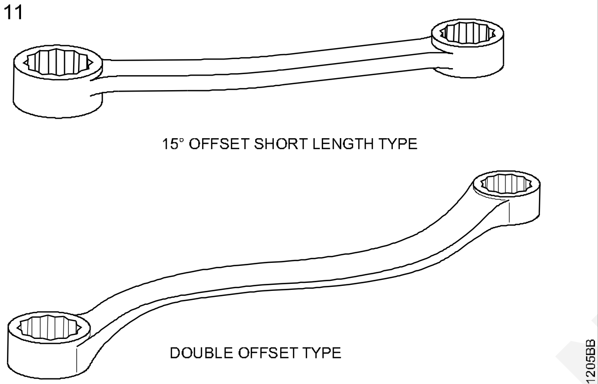
With socket spanners (Fig 10), use the reversible ratchet handle for doing fast work, where turning space is restricted.

Fig 10



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

Fig 11



RING SPANNER

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

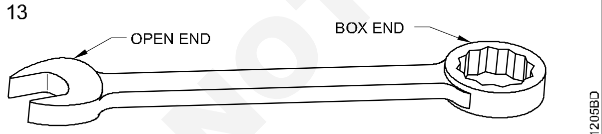
Safety

1 Avoid cutting hardened objects.

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

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



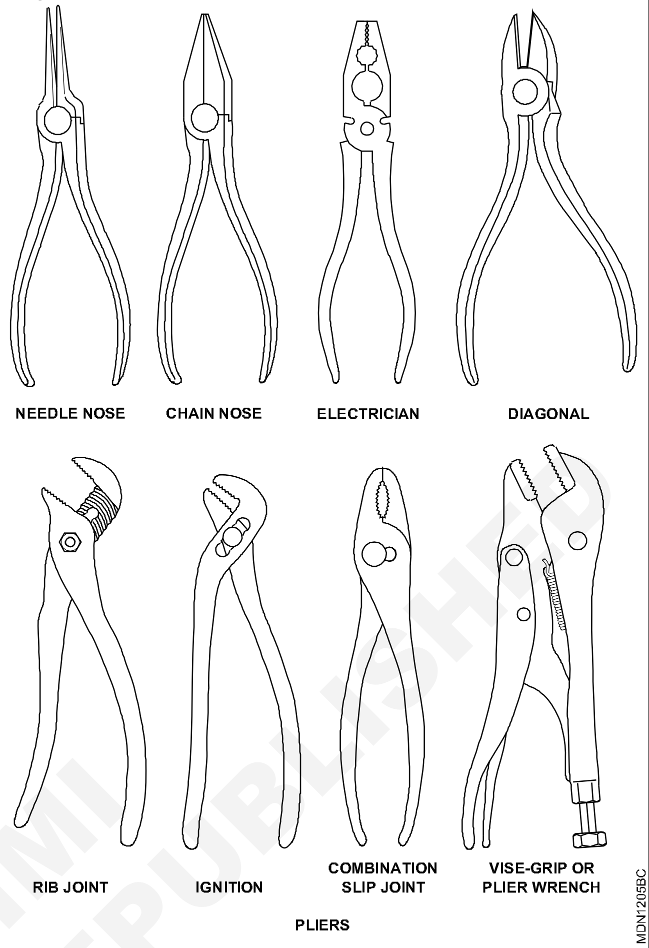
COMBINATION OF RING AND OPEN END SPANNER

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.

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

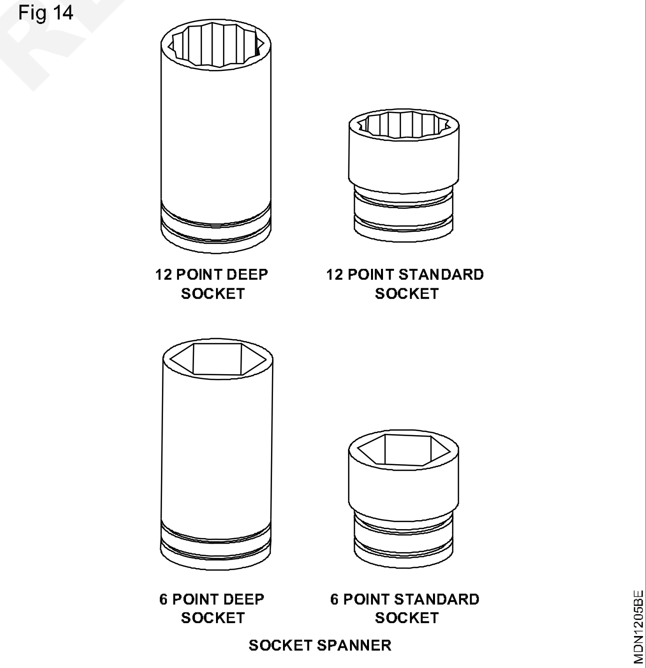
Swivel socket (Fig 15): The swivel socket allows the user to turn fasteners at an angle.

Fig 12



PLIERS

Fig 14



SOCKET SPANNER

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 15

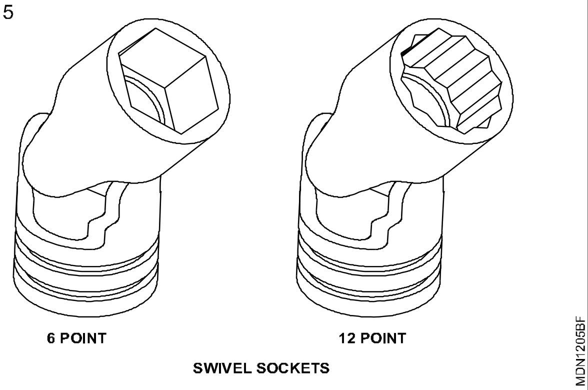


Fig 16

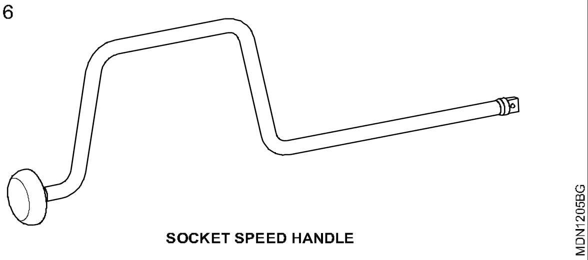
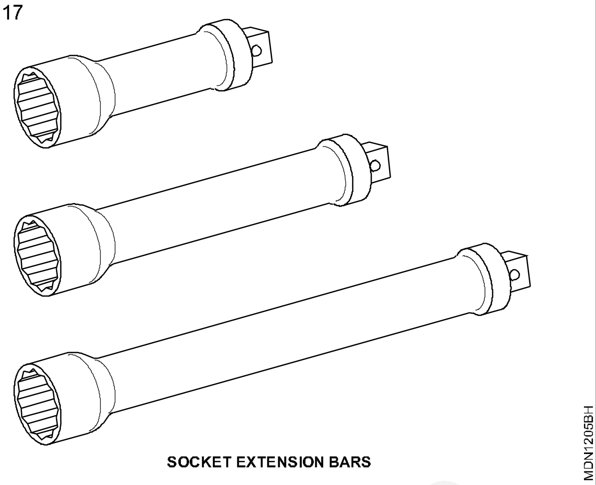


Fig 17



Pliers

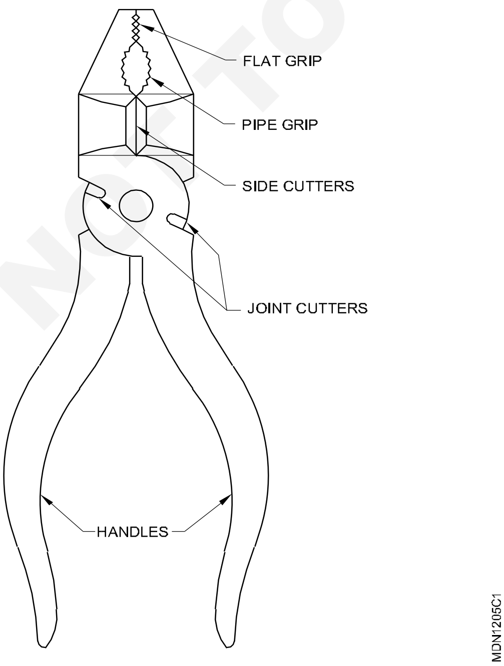
Objectives : At the end of this lesson you shall be able to
- **state the features of pliers**
- **state the uses of pliers.**

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

Fig 1

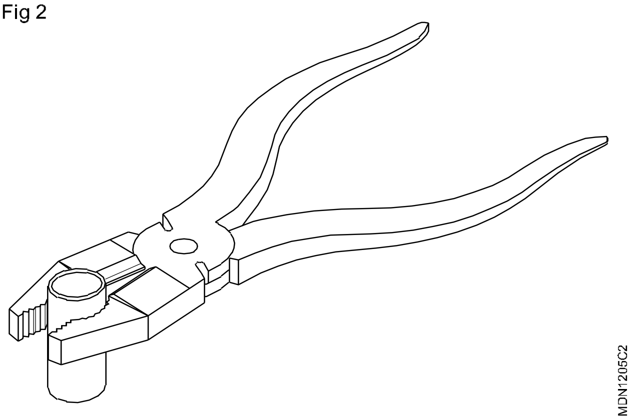


Features

Flat jaw tips are serrated for general gripping.

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

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)

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 3

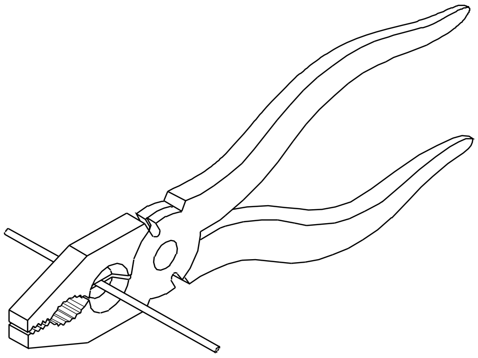


Fig 4

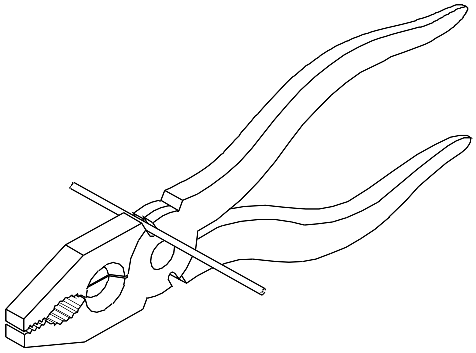
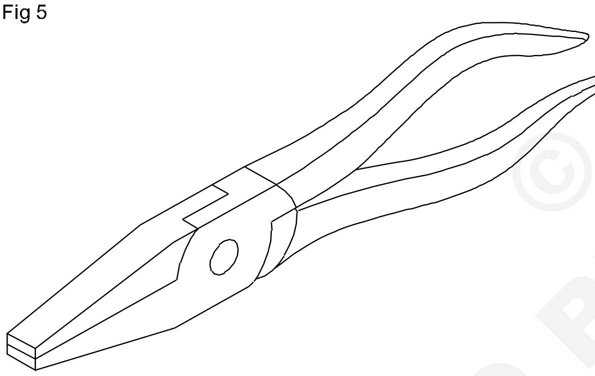
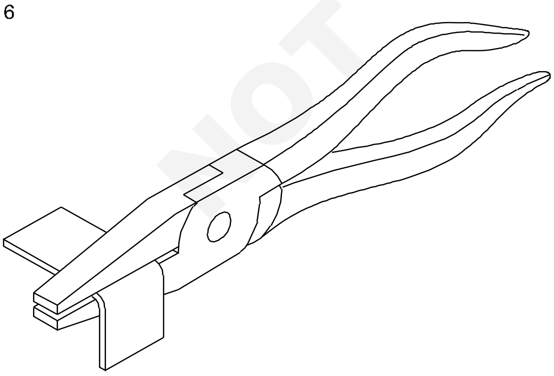


Fig 5



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

Fig 6



Round nose 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

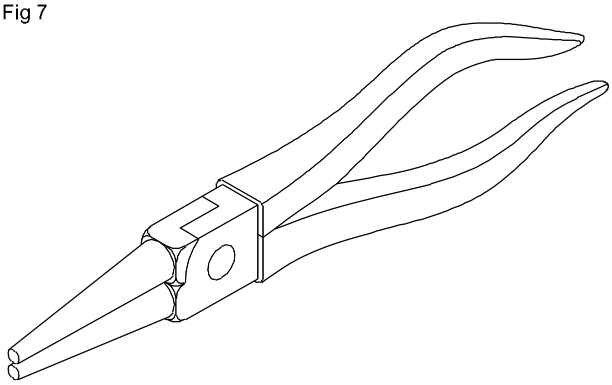
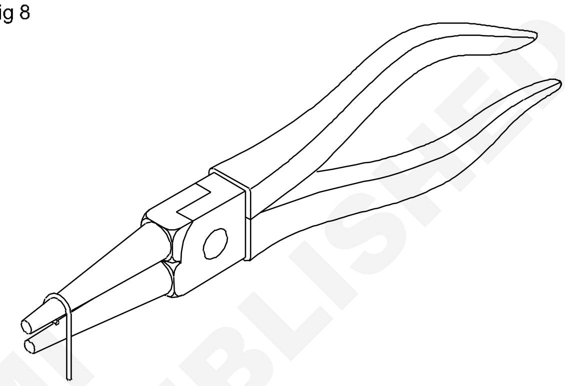


Fig 8

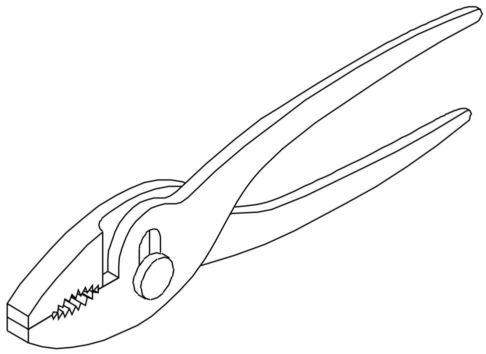


Slip-joint pliers

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



End cutting pliers

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

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 10

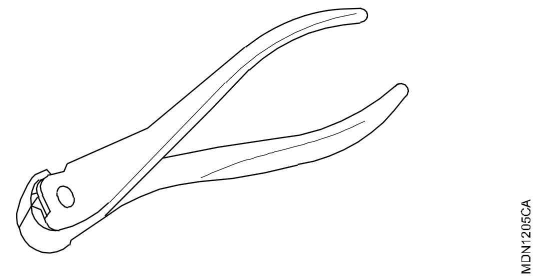
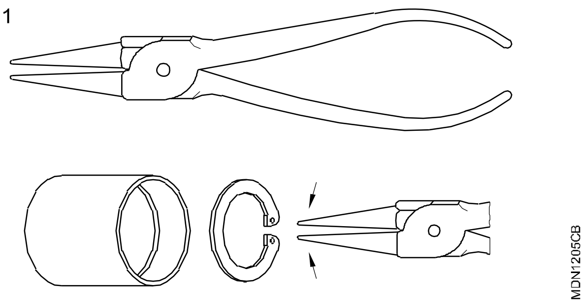


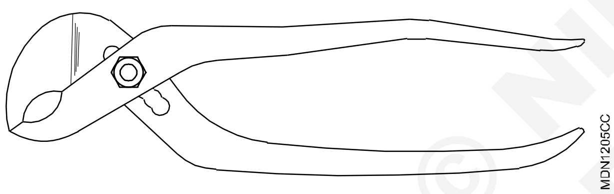
Fig 11



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)

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)

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

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.

Fig 13

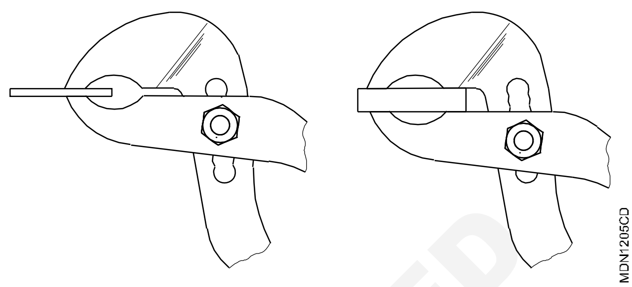


Fig 14

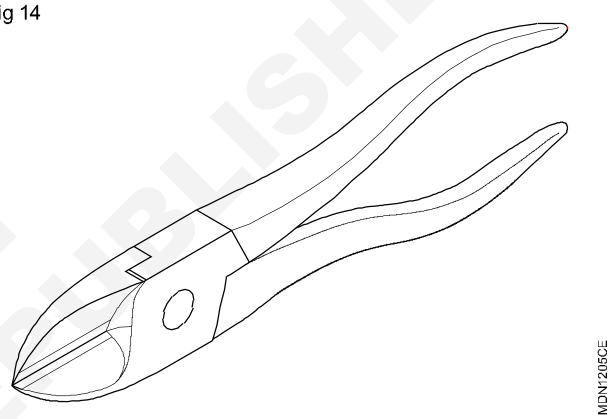
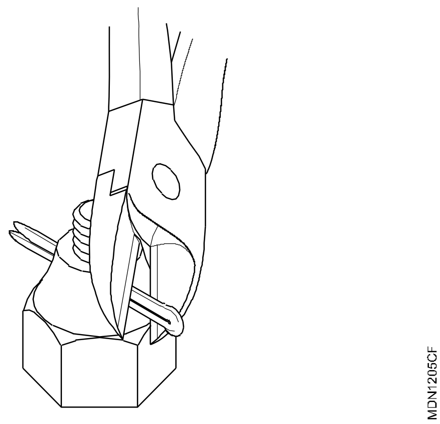


Fig 15



SNIPS (Straight and 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 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)

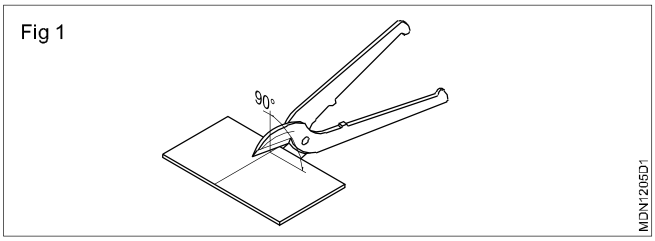
There are several types of snips available for making straight or circular cuts, the most common being straight snips and curved snips.

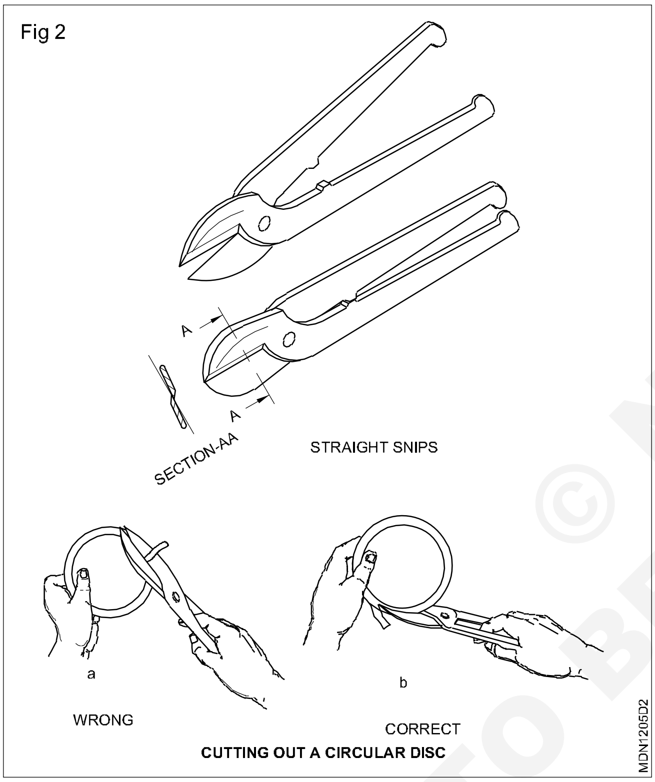
The choice of shears (snips) depends on the shape and type of the cut required.

Straight snips (Fig 1& 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.

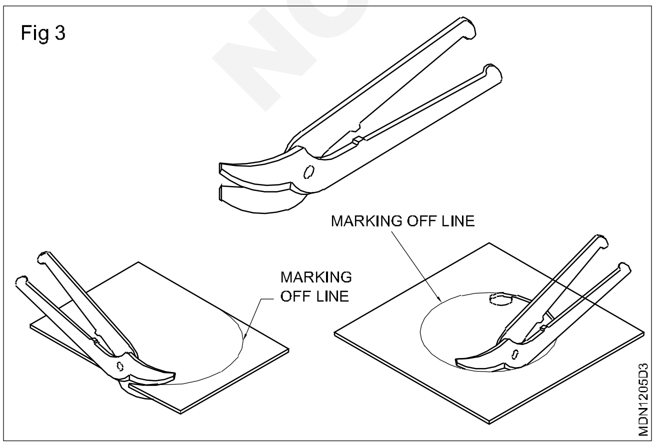
While cutting, the blade of the snips should not cover the marking.





Bent snips (Fig 3)

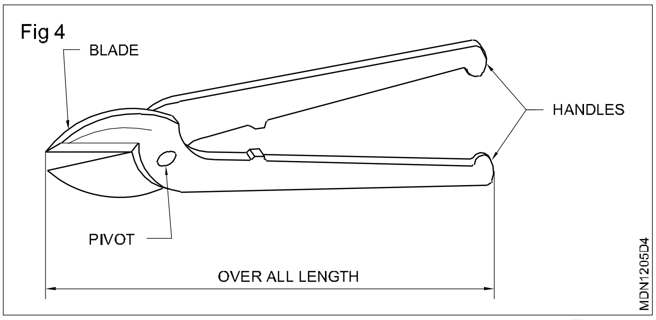
These snips have curved blades for making circular cuts. They are also used for trimming cylindrical or conical work in sheet metal.



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

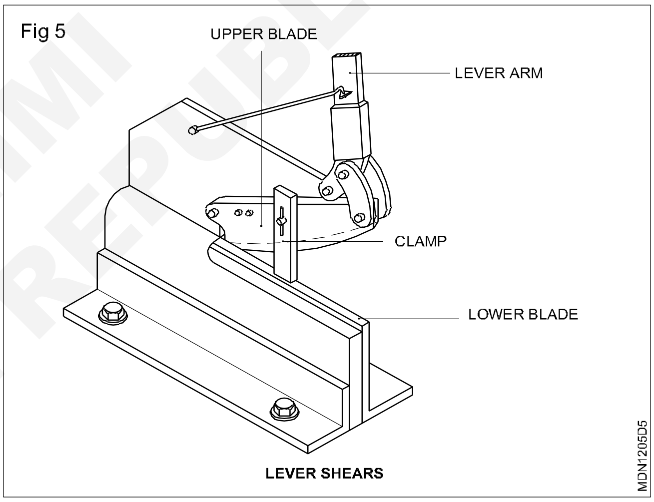
Example

200mm straight snip (Fig 4)



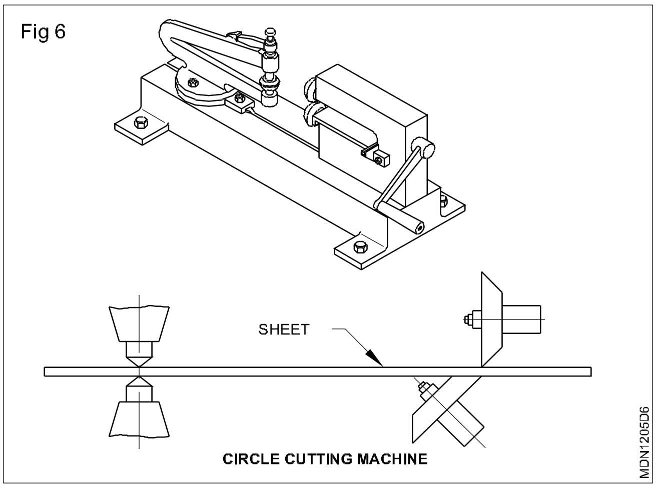
Lever shears (Fig 5): Lever shears are used to cut sheets which cannot be cut with hand shears.

The lever shear possesses a fixed lower blade and a moving upper blade. The sheet being cut is prevented from tilting by a clamping device which can be adjusted to the thickness of the sheet. The knife-edge cutter of the upper blade is curved so that the opening angle at the point of cut remains constant.



Circle cutting and curve cutting machines (Fig 6)

These machines are used to cut circles and curves of the desired shapes. When cutting curves, the sheet must be guided by the hand.



Wrenches

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

Types of wrenches

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

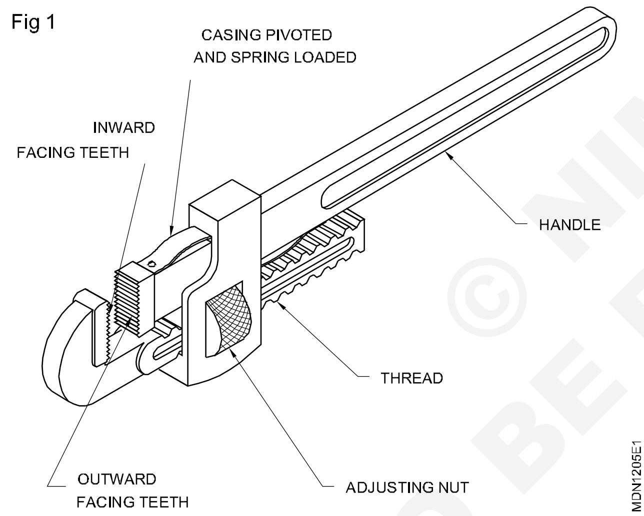
Stillson pipe wrenches (Fig 1 & 2)

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

The parts and their names are shown in the (Fig 1).

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.

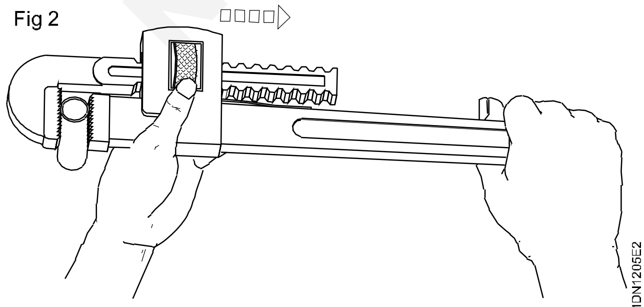
Fig 1



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.

Fig 2



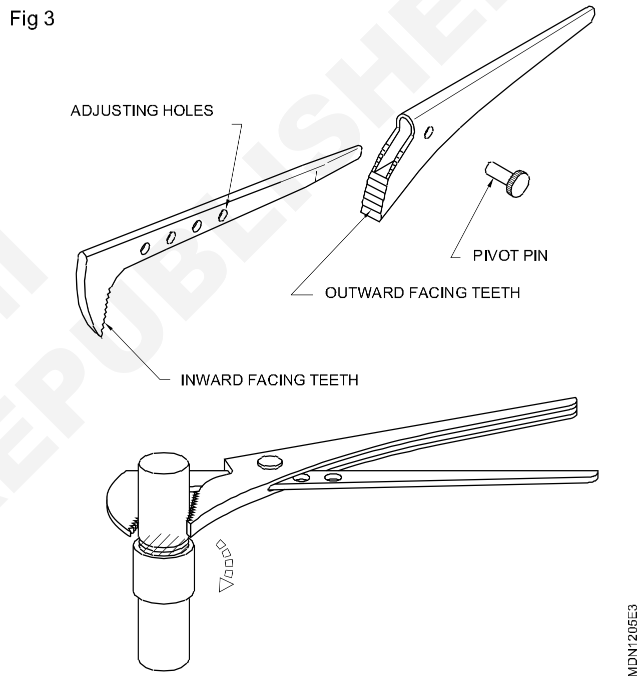
Footprint pipe wrenches (Fig 3)

These are used for gripping and turning pipes and round stock, particularly in confined spaces.

Adjust the size by fitting the removable pin in the hole that allows the pipe to be gripped, with the handles a comfortable distance apart. Thrust the jaws fully on to the pipe. Squeeze the handles firmly. Pull on the folded steel handle to turn the pipe. Stop squeezing and slide the jaws back round the pipe, squeeze and pull again.

File off any burrs raised by the jaws on the pipe.

Fig 3



Tension wrench (Fig 4)

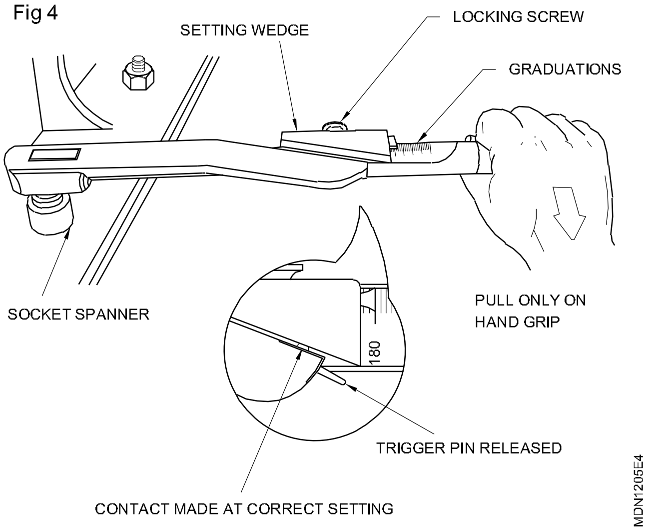
A tension wrench acts as a torque limiting device for turning (rotating) nuts to a predetermined degree of tightness. This avoids breaking the fasteners. It is also essential to avoid warping or springing components held by multiple fasteners that could be unevenly or excessively tightened, cylinder heads of engines, for example.

Some tension wrenches have direct reading indicators that you must watch as you pull the handle to the desired extent. With others, you preset to the desired graduation and pull until you detect a signal which may be an audible click, the release of a trigger pin or an automatic release within the wrench mechanism.

To apply the correct torque with a tension wrench :

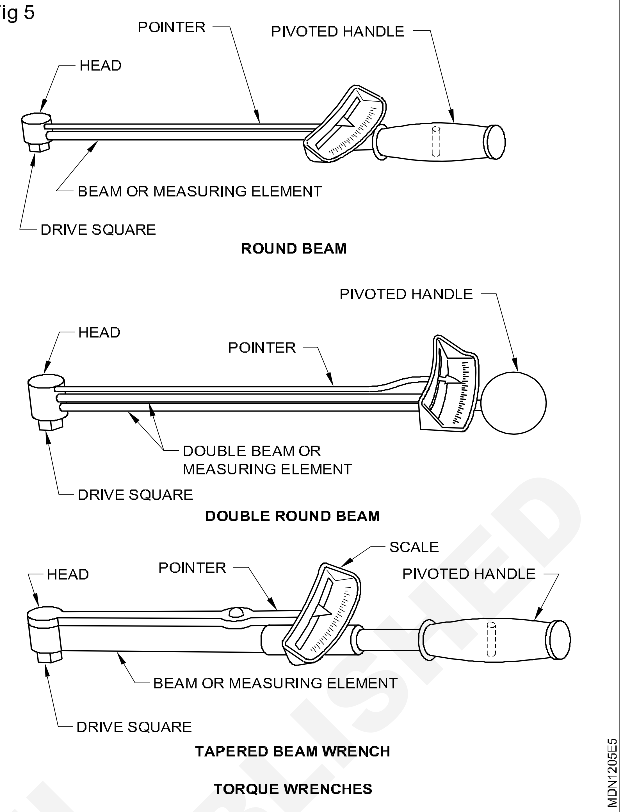
- check that the threads of the nut and the bolt are clean and well formed.
- pull slowly with evenly increasing effort on the hand grip of the handle.

Fig 4



Torque wrench (Fig 5): Torque wrench is used to tighten the bolts/nuts at recommended ended torque. The torque wrench will meausre the torque (twisting force) applied to the fastener. E.g. Cylinder head nuts, bearing cap nuts etc. (N.m; Kg m or Ib-ft)

Fig 5



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**
- **pressurise 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

1 Single thickness flare

2 Double thickness flare

Single thickness flare : It can be made on smaller size copper tubing (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.

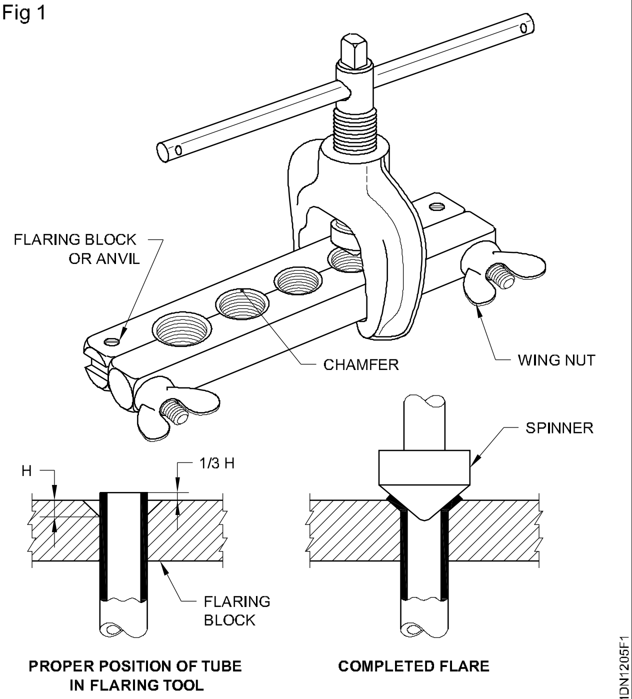
The Fig (2 & 3) shows some defects and correctly made flare. This also shows how defective flare made the fitting mismatched.

Flared tubing fittings : To attach a fitting to soft copper tubing, a flared type connection is generally used.

The following are some of the more common flared type fittings. (Fig. 4 to 6)

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.

Fig 1

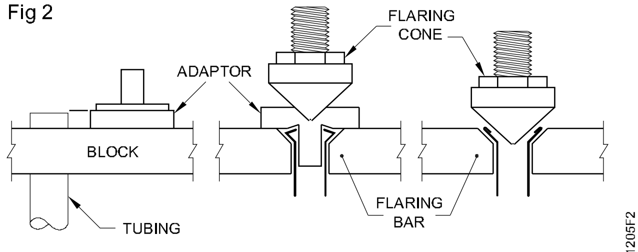


Air pressure from

Air compressor	-	150 PSI
or	-	$10 Kg/cm^2$

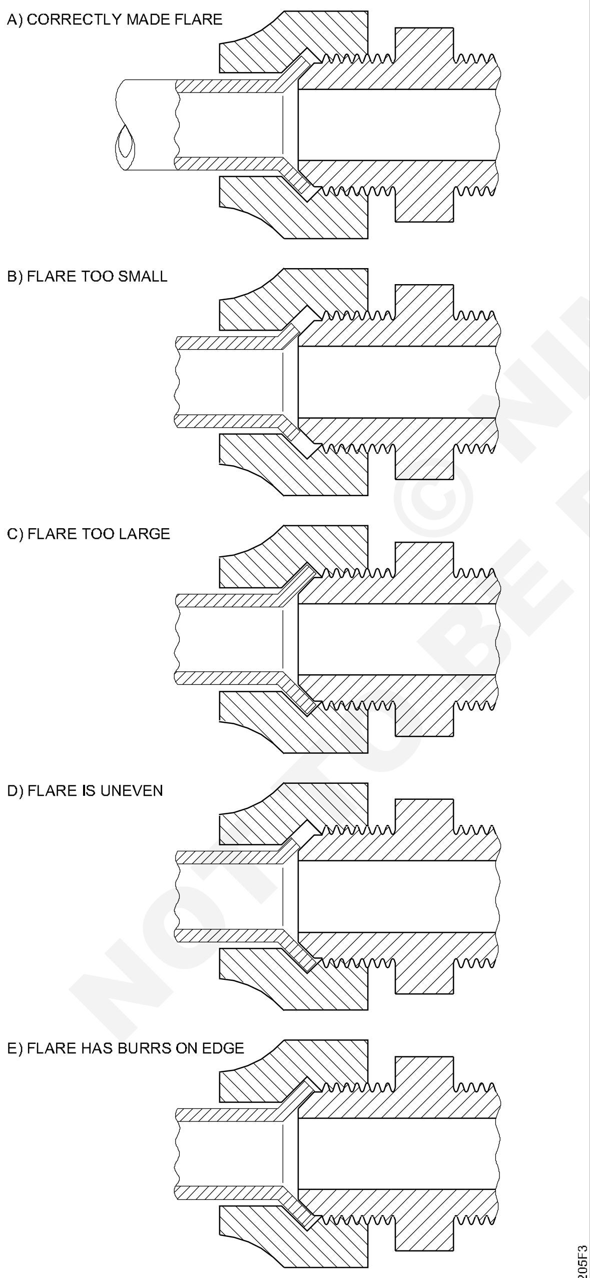
The gas which is employed can be used for testing.

Fig 2



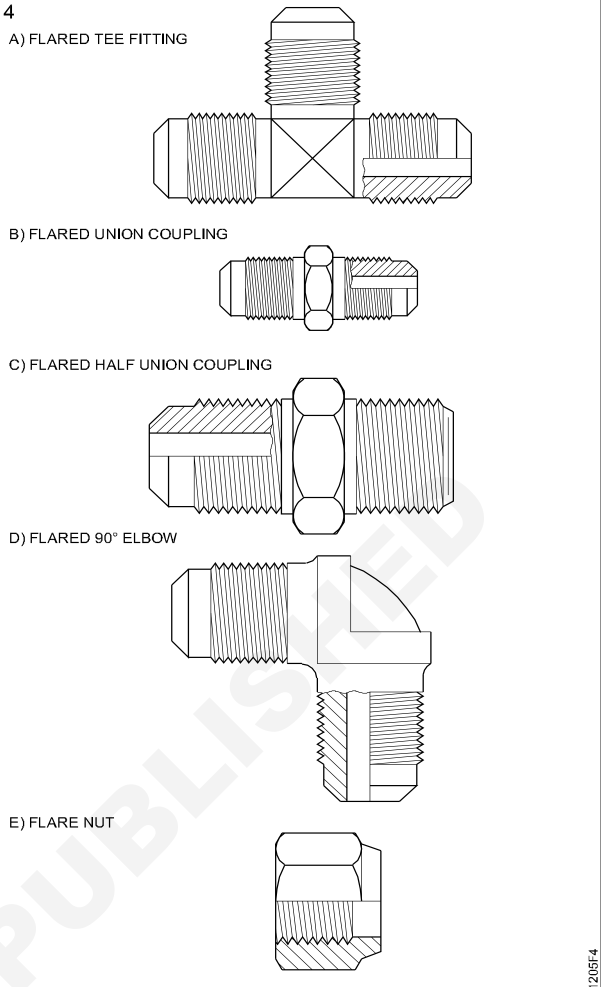
CORRECT PROCEDURE FOR FORMING DOUBLE FLARE

Fig 3



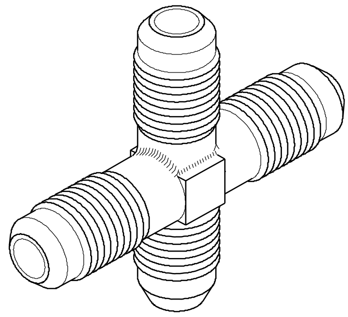
FLARED FITTINGS

Fig 4



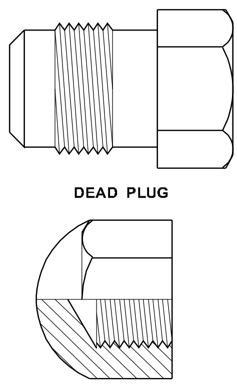
FLARED TYPE FITTINGS

Fig 5



CROSS

Fig 6



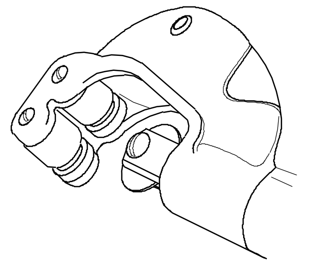
DEAD NUT

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 7)

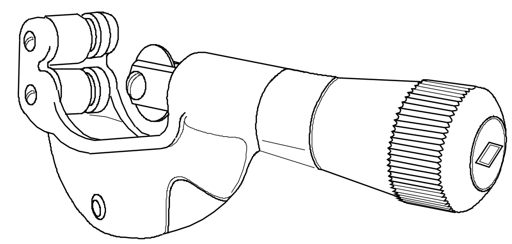
Fig 8



MDN1205F8

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 rights through. (Fig 8)

Fig 7



MDN1205F7

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 legs.

Another classification is based on the power utilised 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 etc.

Hydraulic puller: These pullers eliminate time consuming and unsafe hammering, heating or prying. Damage to part 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 removing engine liner from the cylinder block during engine reconditioning work.

Mechanical puller operation (Fig 1 & 2)

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.

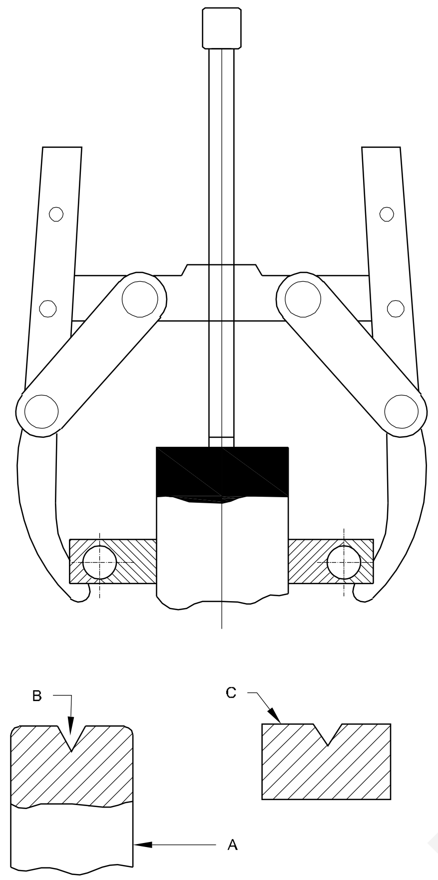
5 Tighten the spindle slightly by turning the spindle nut with proper wrench

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

7 Tighten the strap bolts.

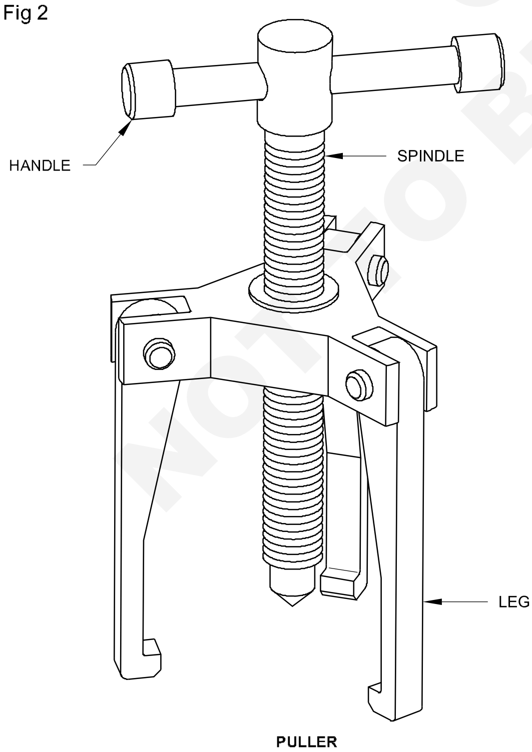
8 Apply pulling force by turning the spindle.

Fig 1



MDN1205G1

Fig 2



MDN1205G2

Post lock puller operation (Manual pullers)

1 Make sure that all items being pulled are supported by means other than the puller. (No loose pieces)

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

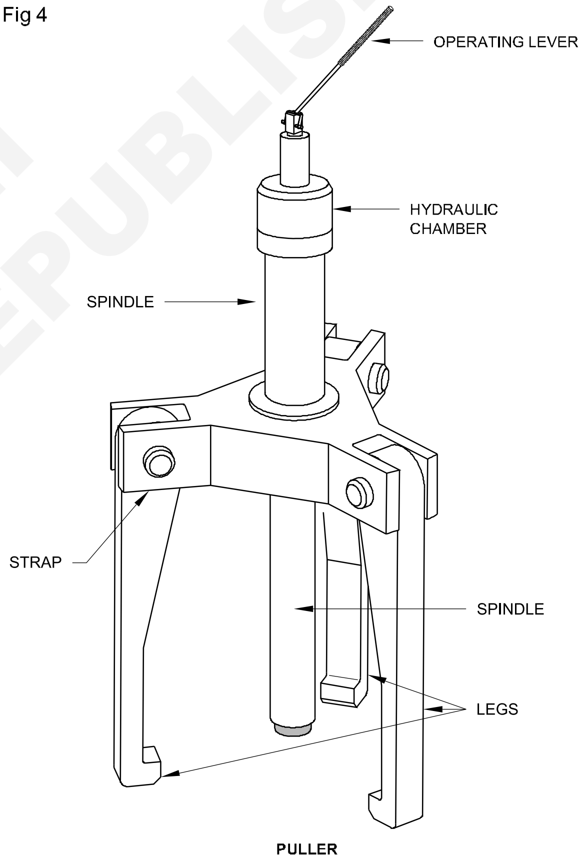
3 To operated the puller, grasp the puller with one hand and turn the T-handle counter-clockwise with the other hand until the jaw opening is big enough to fit over the component to be pulled

4 Turn the T-Handle clockwise with the other hand until the jaw firmly onto the component. (Fig 3A)

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 3B)

6 Turn the T-handle counter-clockwise to remove the puller from the component. (Fig 3C)

Fig 4



MDN1205G4

Hydraulic Puller Operation (Fig 4)

1 Make sure that all items being pulled are supported by a means other than the puller. (No loose pieces)

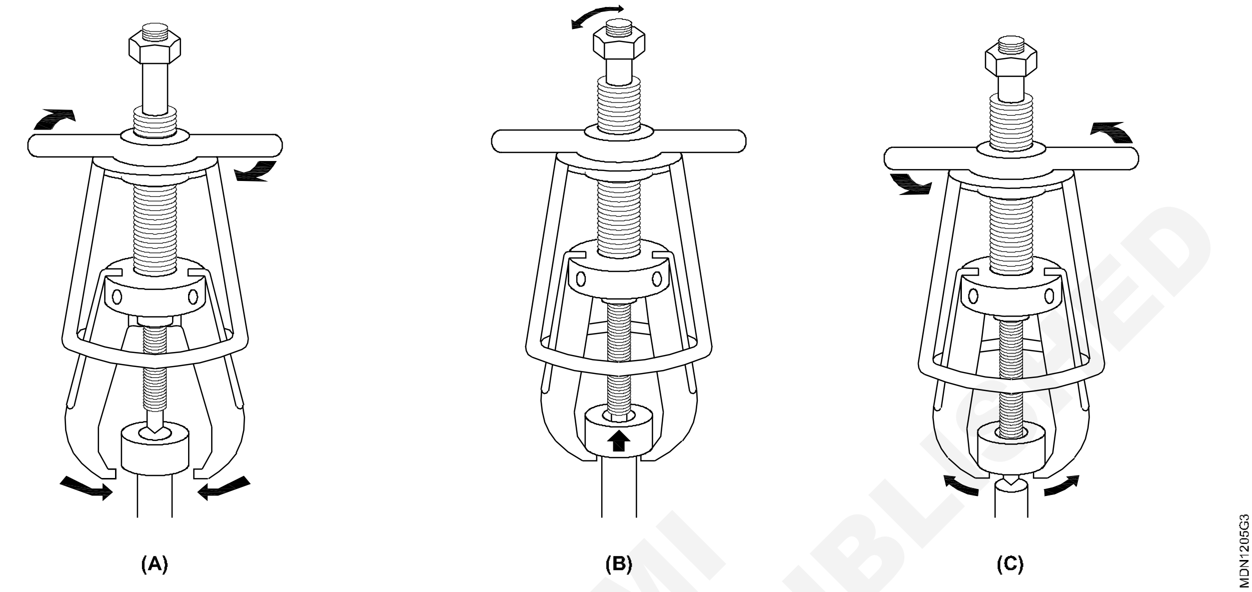
2 Install the cylinder into the puller by threading collar threads clock-wise into the jawhead assembly. Make sure that the puller collar threads are fully engaged in the puller. Attach lift plate to the coupler end of the cylinder. Remove the saddle from the cylinder and insert the ram point into the plunger. Select the ram point that will provide the maximum contact with the shaft.

3 To operate 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 to tighten the jaw firmly onto the component.

5 Make sure that the puller is square with the component to be pulled. Advance the plunger until the ram point contacts the shaft to insure correct alignment. The center point of the puller must be aligned with the center point of the shaft. Continue to advance the plunger slowly to pull the component off of the shaft. Never try to retighten the T-handle during the pulling operation.

Fig 3



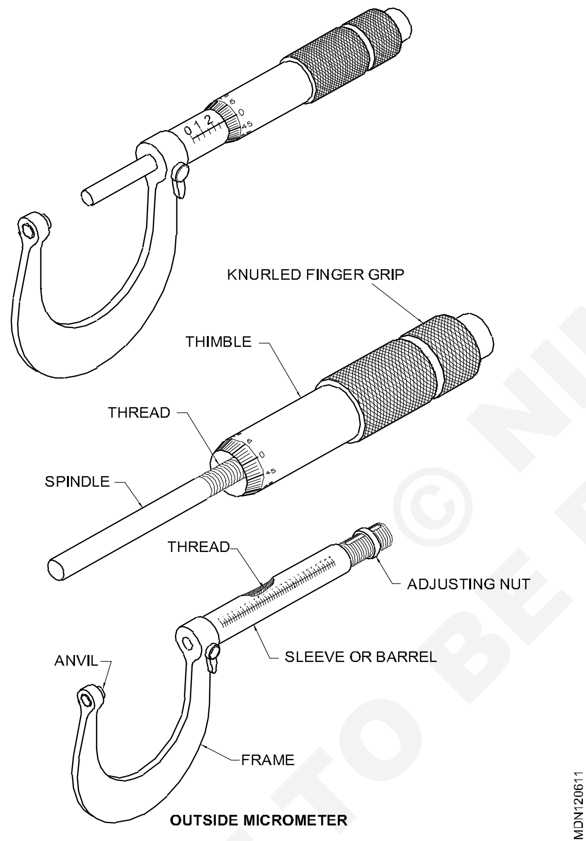
Least count calculation, care and use of micrometer

Scan the QR Code to view the video for this exercise

Objectives : At the end of this lesson you shall be able to
- **name the principal 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.**

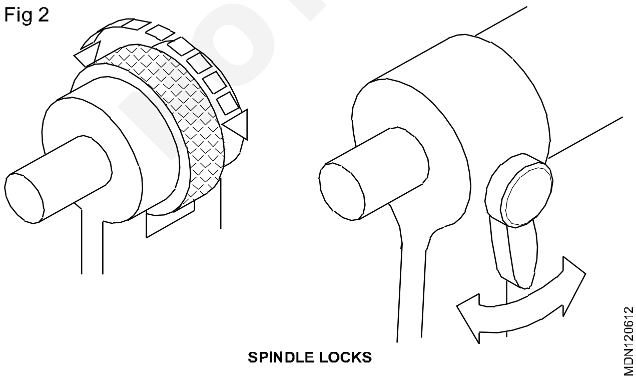
The purpose of a metric micrometer is to read with an accuracy of 0.01 mm of an object. It is available in various sizes. However, the measuring range is limited to the length of the threaded spindle. (Fig 1)

Fig 1



OUTSIDE MICROMETER

Fig 2

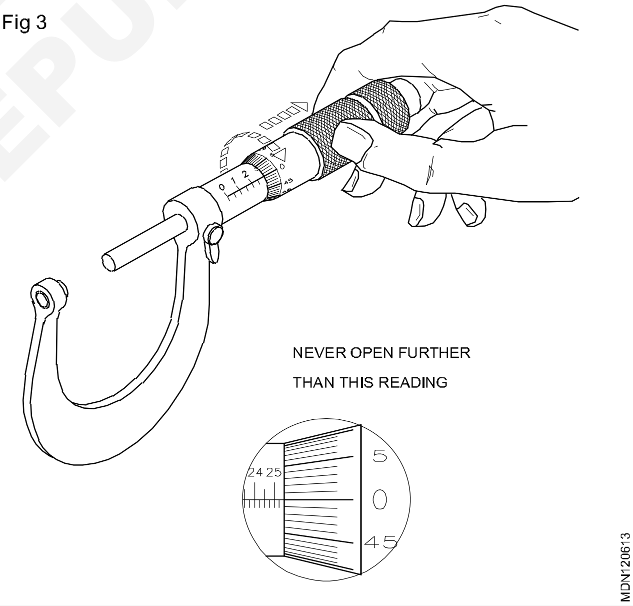


SPINDLE LOCKS

The principal 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 spindle 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 3



The range of micrometers are 0-25 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.

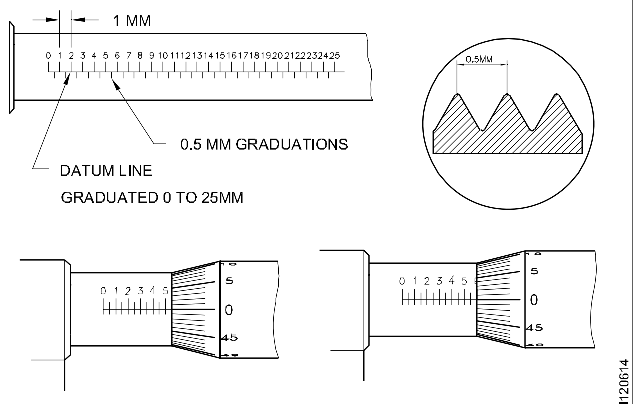
When the face of the anvil and the face of the spindle are in contact, the "0" graduations of the index line and "0" graduation of the thimble coincide with each other.

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

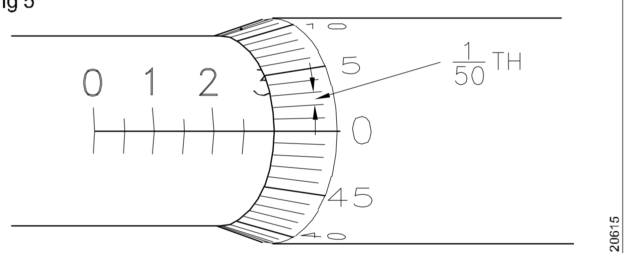
The main scale is graduated in ½ mm. Every 5th mm is shown with the reading. The pitch of the screw thread is accurately maintained to ½ mm.(Fig 4)

Fig 4



NOTE RELATIVE POSITIONS OF SLEEVE GRADUATIONS

Fig 5



THIMBLE GRADUATED INTO 50 PARTS

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)

Determining the reading of a metric micrometer

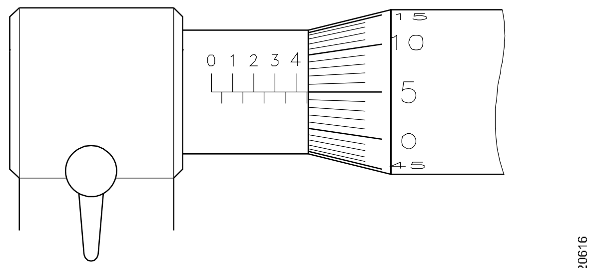
Before using the micrometer for measurement, it is necessary to ascertain that there is no error in the micrometer.

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

Fig 6



EACH MAJOR DIVISION ON BARREL =1 MM READING IS 4 = 4 MM

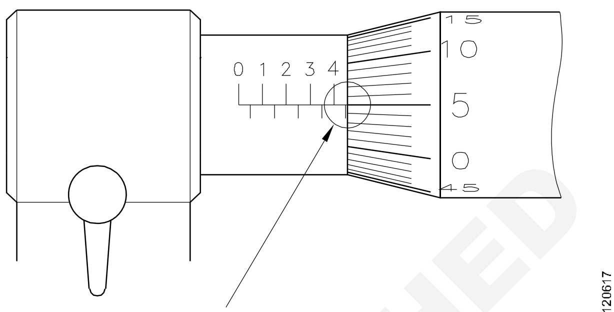
Read on the barrel scale the number of whole millimeters that are completely visible from the bevel edge of the thimble. It reads 4 mm. (Fig 6)

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

The figure reads ½ = 0.5 mm

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

Fig 7



PLUS ADDITIONAL MINOR DIVISIONS. READING IS 1=0.5 MM

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* 0.01 mm = 0.05 mm. The total reading of the micrometer (Fig 8) is;

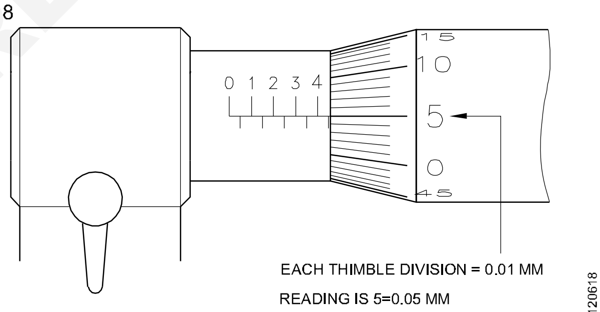
a 4.00 mm +

b 0.50 mm

c 0.05 mm

Total reading 4.55 mm

Fig 8



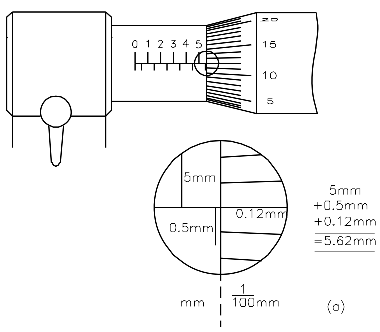
EACH THIMBLE DIVISION = 0.01 MM

READING IS 5=0.05 MM

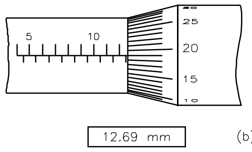
TOTAL READING = 4.55 MM

Some examples of metric micrometer readings and their solution.

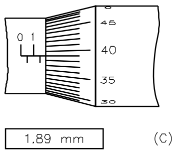
i)	5.00 mm
	0.50 mm
	0.12 mm
Total	5.62 mm



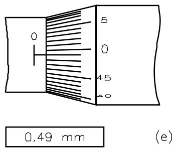
ii) 12.00 mm
0.50 mm
0.19 mm
Total 12.69 mm



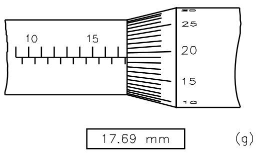
iii) 1.00 mm
0.50 mm
0.39 mm
Total 1.89 mm



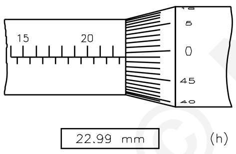
iv) 0.00 mm
0.00 mm
0.49 mm
Total 0.49 mm



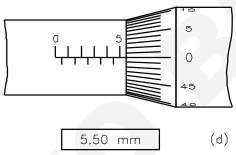
v) 17.00 mm
0.50 mm
0.19 mm
Total 5.50 mm



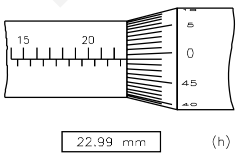
vi) 22.00 mm
0.50 mm
0.00 mm
Total 22.99 mm



viii) 5.00 mm
0.50 mm
0.00 mm
Total 5.50 mm



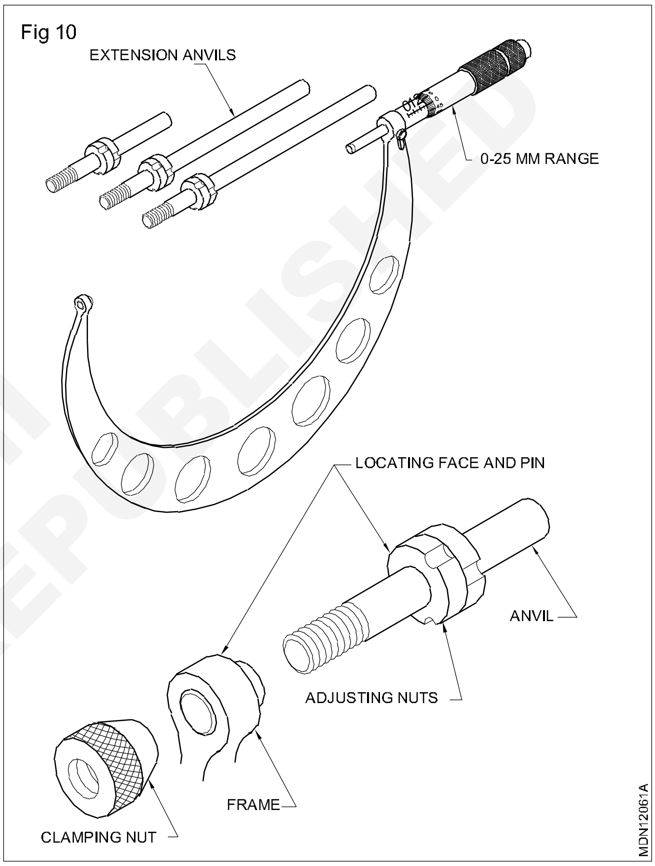
ix) 6.00 mm
0.50 mm
0.20 mm
Total 6.70 mm



Outside micrometers have limited reading capacity as they are dependent upon the length of the spindle which itself is limited and fixed.

A 0-25 mm capacity outside micrometer can read a maximum dimension of 25 mm. 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)



Precision measuring instruments - outside metric micrometer

Objectives: At the end of this lesson you shall be able to
- **hold the micrometer for measurement**
- **set the micrometer on work for measurement**
- **read the measurement.**

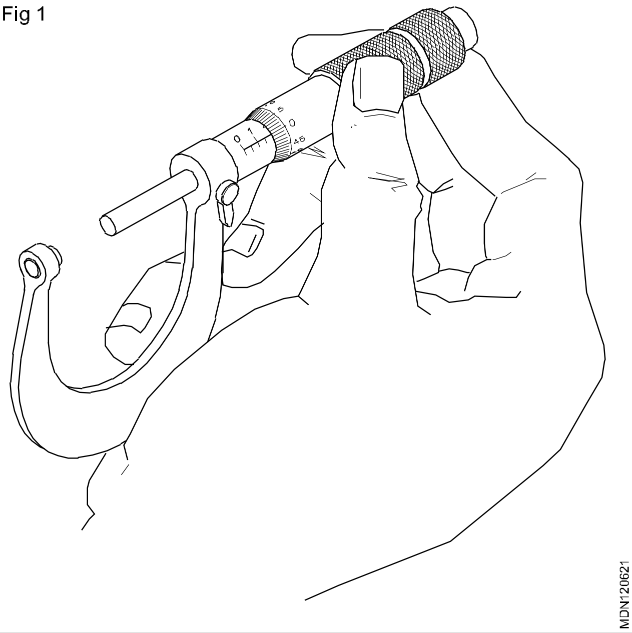
Holding the micrometer for measurement

The micrometer may be held either in one hand or both the hands.

Holding in one hand (Fig 1)

Hold the outside micrometer in your right hand, keeping the graduations on the main scale towards you.

Fig 1



Support the frame on the lower centre of your palm. Use your little or third finger to hold the frame in the palm.

Place the middle finger behind the frame to support it.

Keep the first finger and thumb free to adjust the knurled thimble.

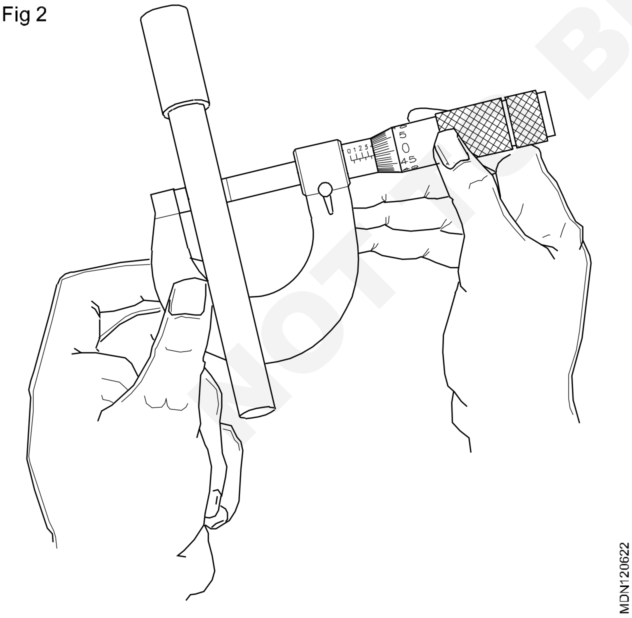
Holding by both the hands (Fig 2)

Sometimes, it may be more convenient to hold the micrometer with both the hands.

Support the frame between the fingers and the thumb of your left hand.

Use the thumb and finger of your right hand to adjust the thimble.

Fig 2

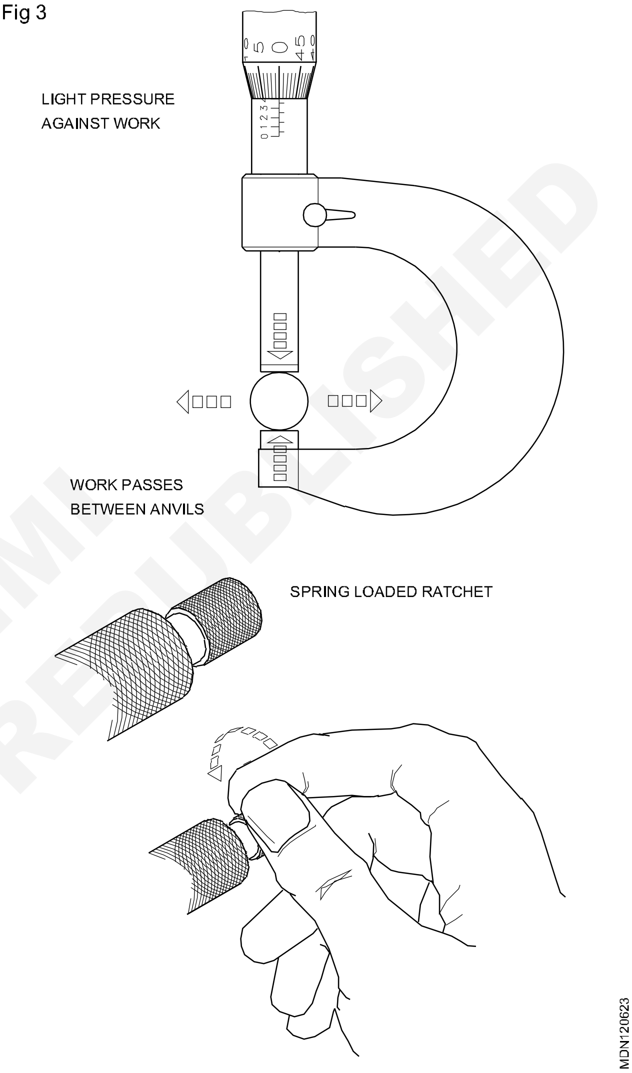


Setting the micrometer on the workplace for measurements (Fig 3): High skills needed for obtaining accurate measurements with the outside micrometer. A wrong setting of the micrometer over the workplace may cause:

- inaccurate reading
- excessive strain on the screw thread
- distortion in the frame.

Fig 3 shows the adjustment of the spindle and anvil over workplace. As you adjust the workplace between the spindle and the anvil, you should feel a light pressure or resistance against the workplace surface. Use the spring loaded ratchet stop to ascertain the feel.

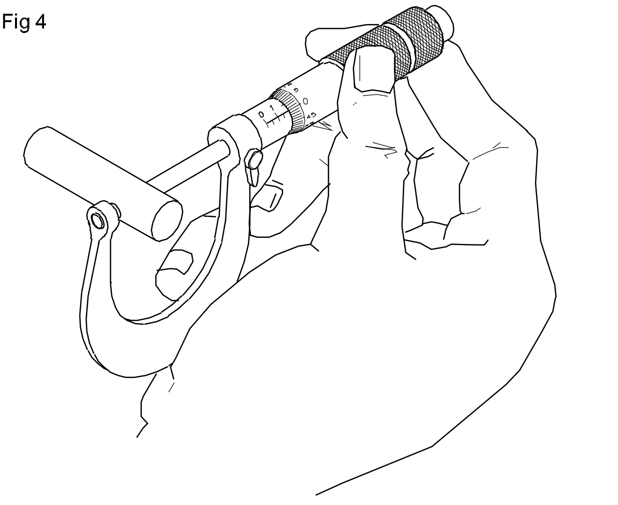
Fig 3



While using only one hand (Fig 4)

- Close the anvil and spindle until you feel them just touching the work
- Move the work slightly between the spindle and the anvil or pass the micrometer over the workplace by moving your wrist
- Make further adjustments of the thimble as required until you obtain the right 'feel'
- When satisfied with the feel, remove the fingers from the thimble
- Turn the micrometer towards you
- read the measurement

Fig 4



Method of reading the micrometer 0-25 range (Fig 5)

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.

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

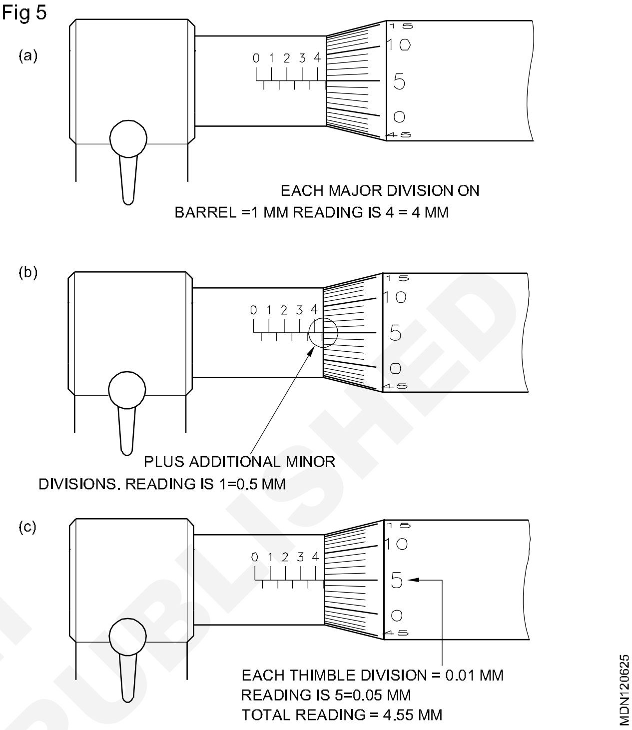
Figure 'b' shows 1 division = 0.5 mm.

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

Fig 5



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.

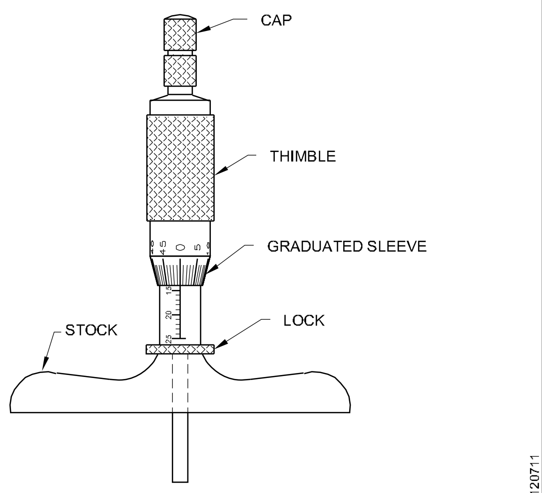
A thimble, which is internally threaded to the same pitch and form, mates with the threaded sleeve and slides over it.

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.

Fig 1



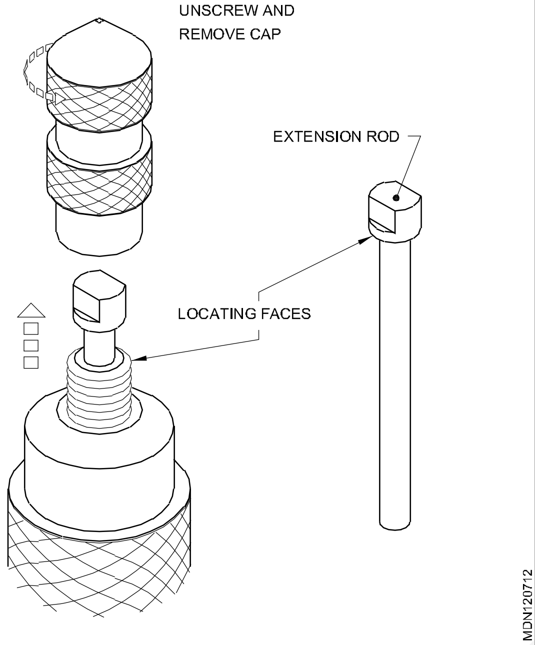
DEPTH MICROMETER

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 3)

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

The zero graduation of the sleeve is on 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 4)

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.

Fig 3

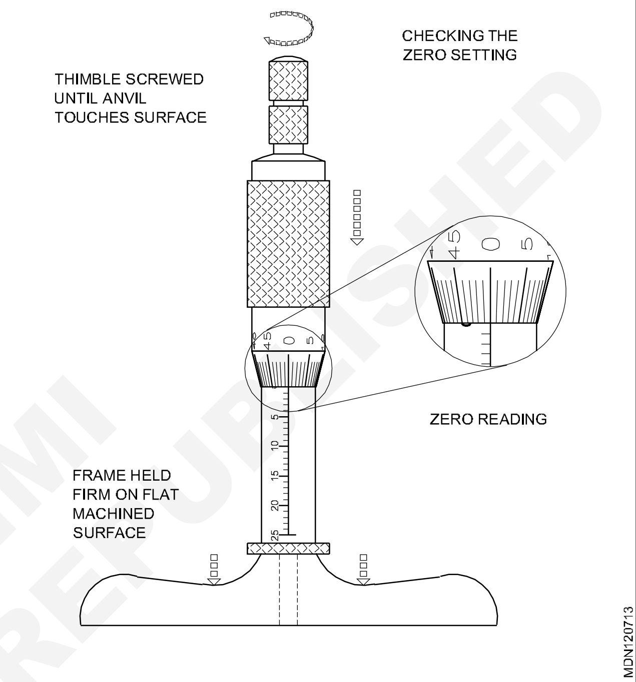
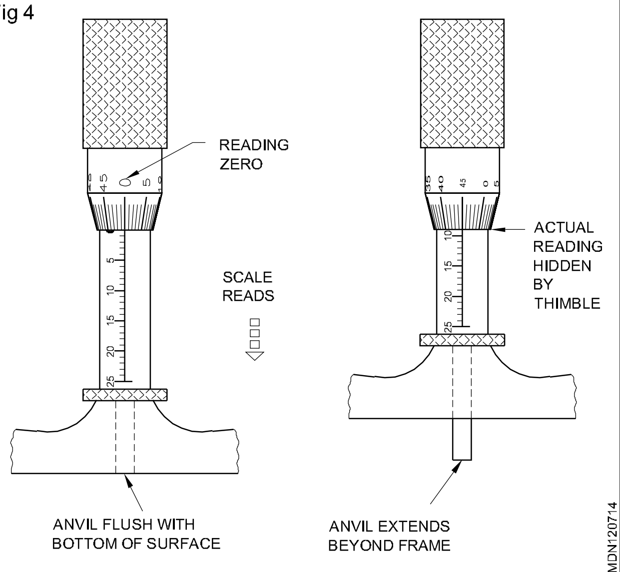


Fig 4



Description least count, calculation, care and use of vernier caliper

Objectives: At the end of this lesson you shall be able to
- **state the principle of vernier**
- **define least count of vernier**
- **derive the least count of vernier scales.**

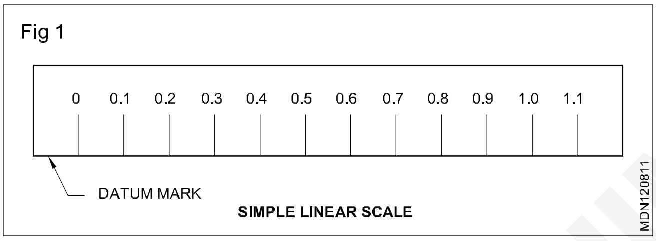
The vernier principle

The basic principle of the vernier is that the smallest unit of size to which a vernier can be read is equal to the difference in the length between the divisions of the two scales.

The magnification on the vernier scale is given by two scales sliding over each other; the eye can detect which divisions on one of them are smaller than those on the other. The eye can detect which of these divisions are in line with each other, and it is this fact which enables us to read a vernier to 0.02 mm accuracy.

Fig 1 show the vernier principle being used to determine the reading. Fig 1 shows the main scale with the datum line marked.

Fig 1



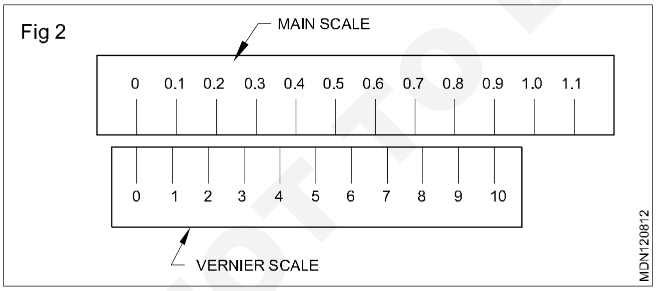
SIMPLE LINEAR SCALE

Fig 2 shows the main scale and vernier scale with graduations. The value of 1 main scale is 0.1 unit. In vernier scale 9 such units are taken and divided into 10 equal parts. Hence the value of 1 vernier scale is

0.9/10=0.09 units

Now, by applying the vernier principle, the smallest unit of size is 1 M.S.D. - 1 V.S.D. (i.e.) 0.1 - 0.09=0.01 unit.

Fig 2



Definition of the least count

The least count is the smallest possible measurement that can be taken with the precision instrument.

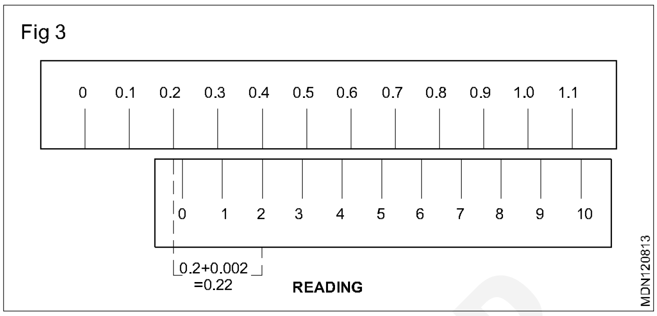
Fig 3 shows the method of reading the vernier scale. The zero of the vernier scale is between 0.2 to 0.3 units

on the main scale and number 2 graduation of the vernier scale is coinciding with the 4th division of the main scale. Thus the reading is 0.2 + 2 * 0.01=0.22.

Fig 4 shows a typical 50 division vernier scale as used in modern metric measurements.

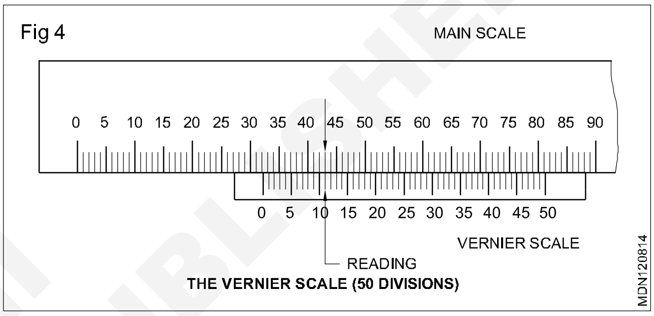
The main scale of this instrument is graduated in mm.

Fig 3



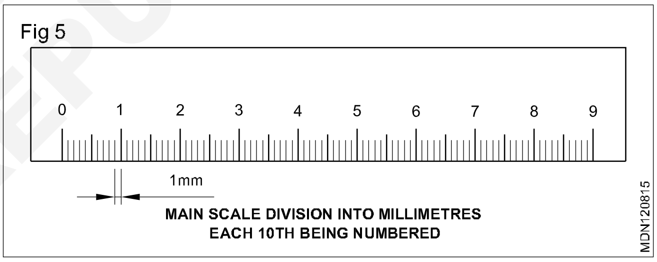
READING

Fig 4



THE VERNIER SCALE (50 DIVISIONS)

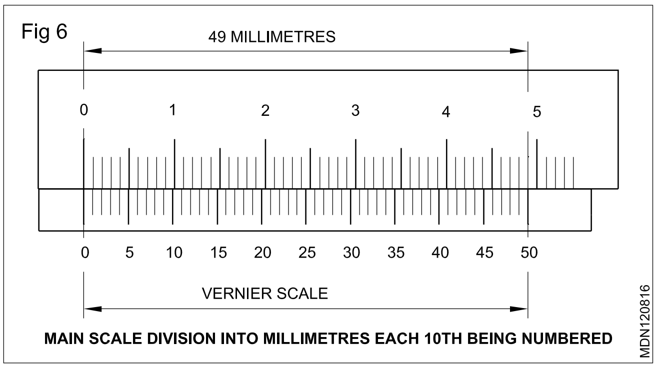
Fig 5



MAIN SCALE DIVISION INTO MILLIMETRES
EACH 10TH BEING NUMBERED

The purpose of a vernier 49 such divisions are … divided into 50 equal divisions. So the value of vernier scale division works out to 49/50 mm (Fig 6).

Fig 6



MAIN SCALE DIVISION INTO MILLIMETRES EACH 10TH BEING NUMBERED

Least count is 1 main scale division - 1 vernier scale division (Fig 7).

which is $1\text{mm} - \frac{49}{50}\text{mm} = \frac{50-49}{50} = \frac{1}{50} = 0.02\text{ mm}$

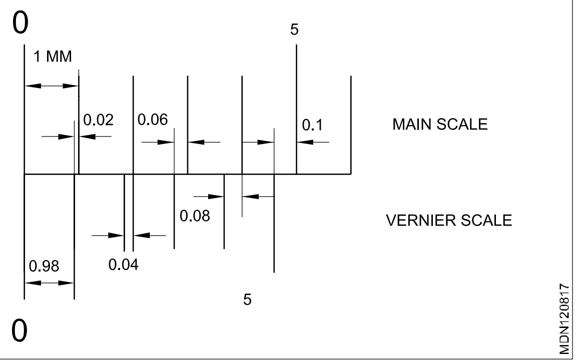
In that case of 150 mm capacity vernier calipers the main scale is graduated in ½ mm instead of in 1 mm. For the purpose of the vernier scale 24 such divisions are taken and divided into 25 equal divisions. So the value of 1 vernier scale division is

$$\frac{1}{2} \times \frac{24}{25} = \frac{12}{25} \text{mm}$$

Least count = 1 M.S.D. - 1 V.S.D.

$$\frac{1}{2}\text{mm} - \frac{12}{25}\text{mm} = \frac{25 - 24}{50} = \frac{1}{50} = 0.02\text{mm}$$

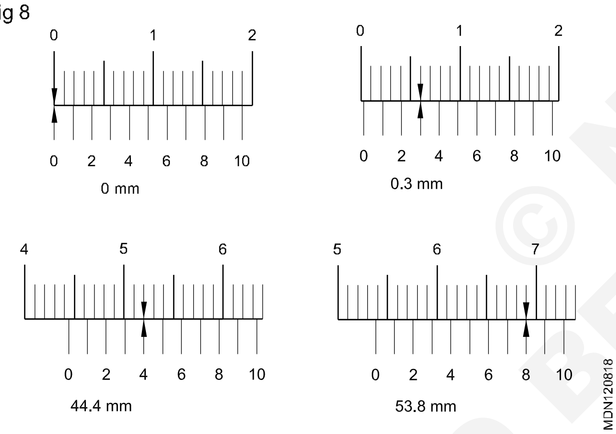
Fig 7



Measurement of reading (Fig 8)

It is 0 mm as 'O' of vernier scale and 'O' of the main scale if that coincide.

Fig 8



Measurement of reading (Fig 9 & 10)

'O' of vernier is to the right of the main scale and lies between 'O' and 1st division of the main scale. The 3rd division of the vernier scale coincides with a division on the main scale.

Hence measurement is 0 mm + 3 * 0.1 mm = 0.3 mm.

Fig 9

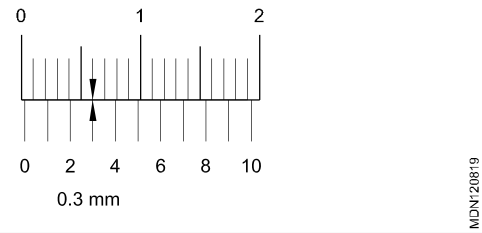
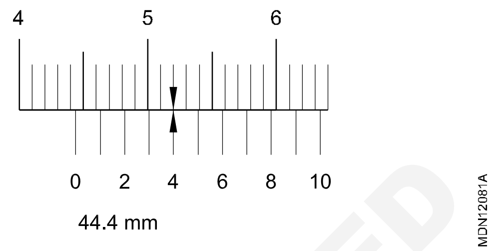


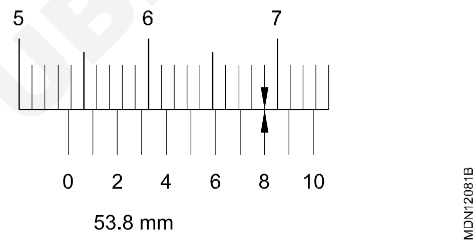
Fig 10



Measurement of reading (Fig 11)

'O' of the vernier scale lies between the 44th and 45th divisions of the main scale and the 4th division of the vernier scale coincides with a division of the main scale. Hence the measurement is 44 mm + 4 * 0.1 mm = 44.4

Fig 11



Measurement of reading

'O' of the vernier scale lies between the 53rd and 54th divisions on the main scale, and the 8th division of the vernier scale coincides with a division on the main scale. Hence measurement is 53 mm + 8 * 0.1 mm = 53.8 mm.

The least count of the vernier caliper used for the above readings is 0.1 mm.

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 the 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 `

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

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 value of 1 main scale division - value of 1 vernier scale division = 1mm - 0.98mm = 0.02mm.

Advantages

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

This application of the universal vernier caliper is taking external, internal and depth measurements is shown in Fig 2.

Disadvantages

Accuracy of reading depends on the skill of the operator.

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 mainscale reading.

Fig 1

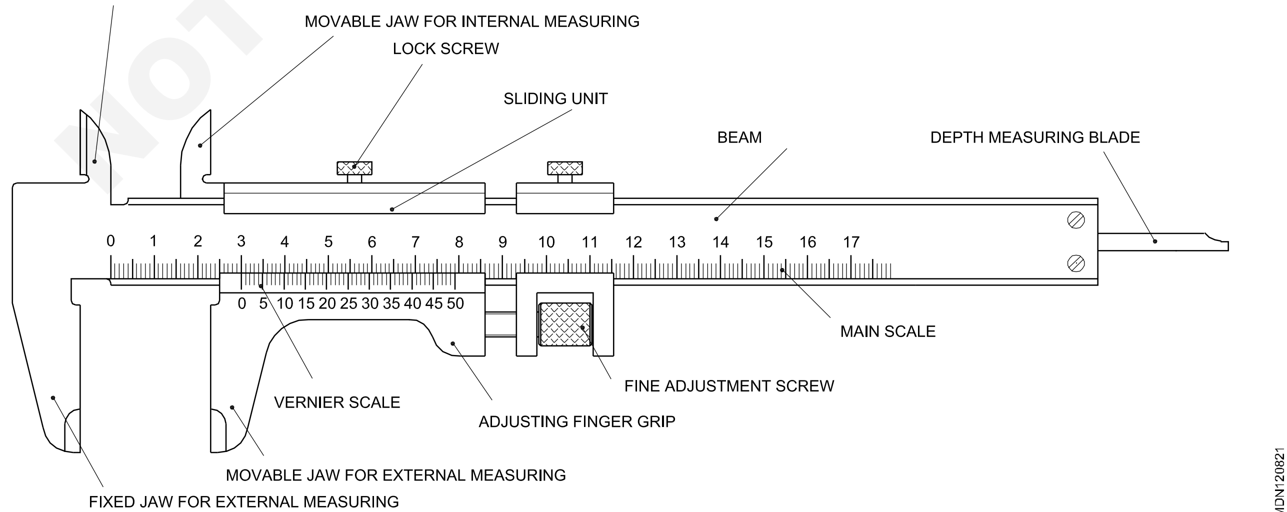
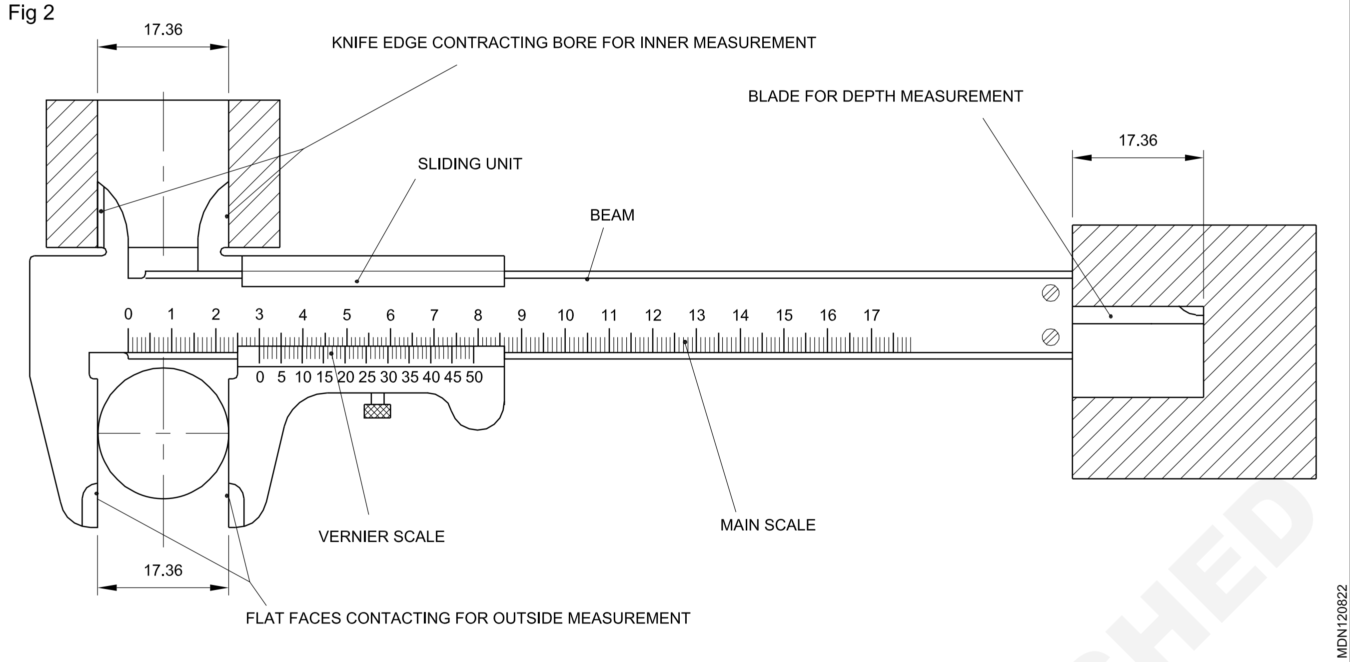


Fig 2



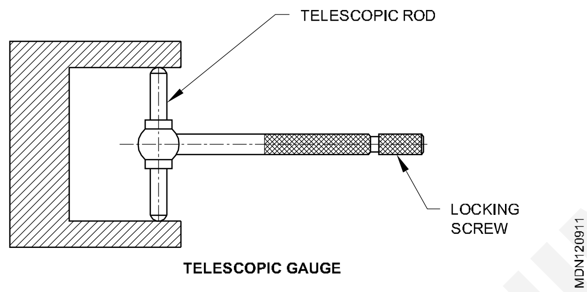
17.36
KNIFE EDGE CONTRACTING BORE FOR INNER MEASUREMENT
BLADE FOR DEPTH MEASUREMENT
17.36
SLIDING UNIT
BEAM
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
0 5 10 15 20 25 30 35 40 45 50
VERNIER SCALE
MAIN SCALE
17.36
FLAT FACES CONTACTING FOR OUTSIDE MEASUREMENT
MDN120822

Telescopic gauge

Objectives: At the end of this lesson you shall be able to
- **name the parts of telescopic gauge**
- **measure with a telescopic gauge and transfer the reading to an 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 telescopic 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.

Fig 1



TELESCOPIC GAUGE

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 is 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.

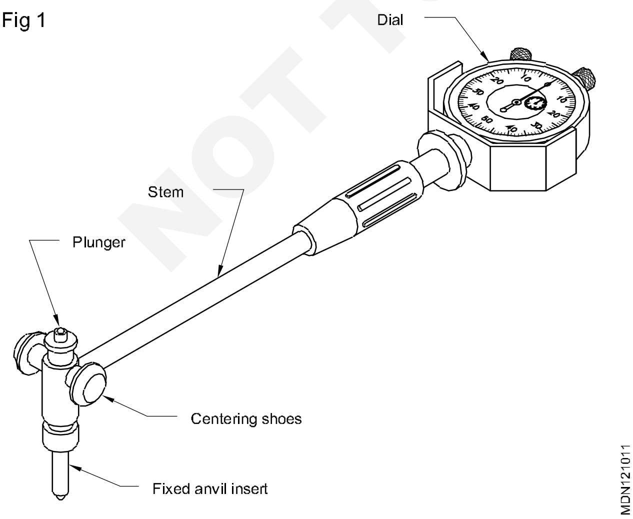
Bore dial gauge

- **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 bore dial 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

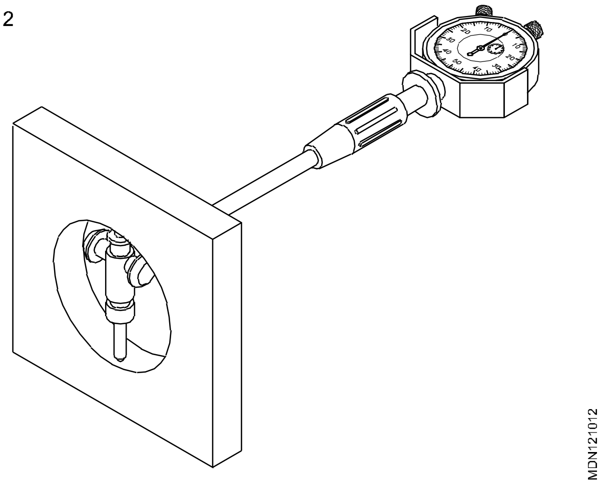
This actuates the movement of the dial for reading the measurement.

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.

Fig 2



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 3

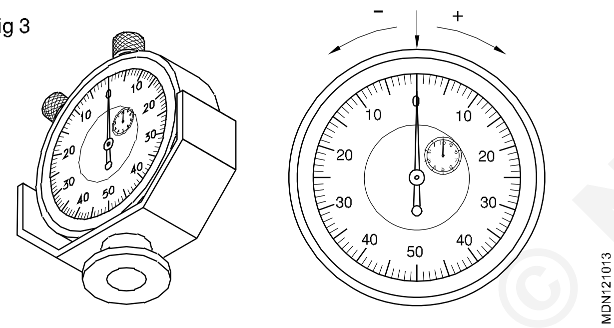
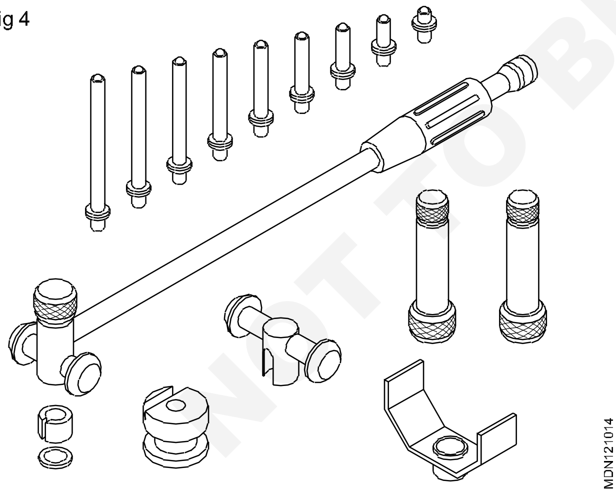


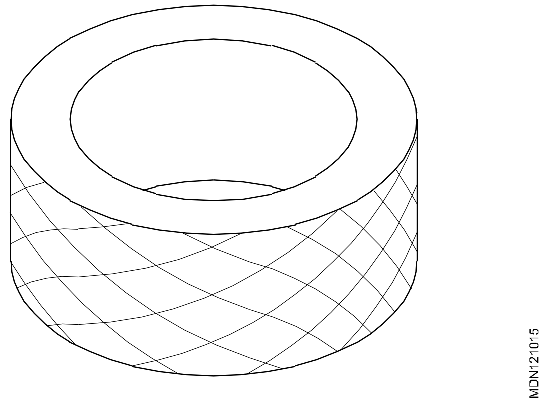
Fig 4



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.

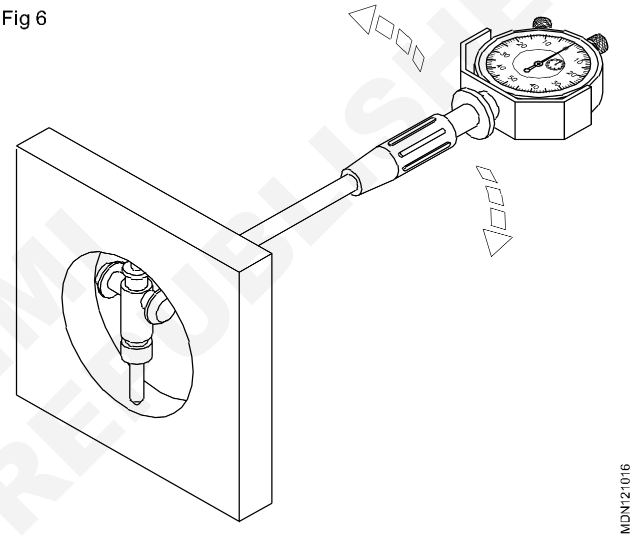
The dial gauge should be set to zero before taking measurement. Setting rings are available for zero setting. (Fig 5)

Fig 5



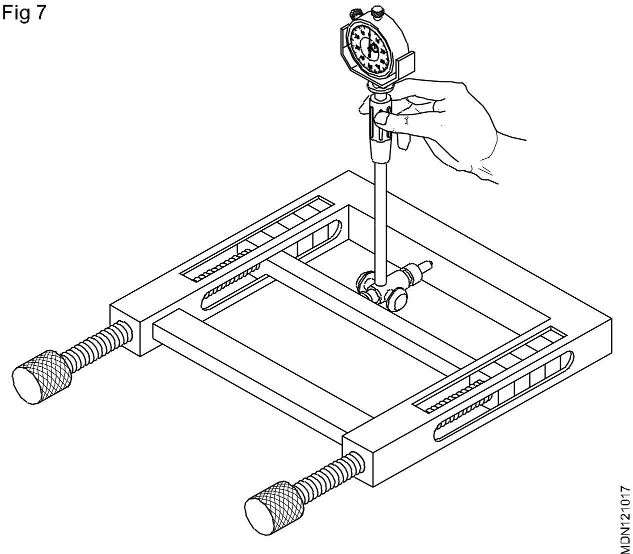
While taking measurements press the spring-loaded end (plunger) as it enters into the setting device or in the bore being measured. Slightly rock and steady the device for keeping the measuring faces in position. (Fig 6)

Fig 6



Slip gauges fixed in a setting fixture can also be used for zero setting. (Fig 7)

Fig 7

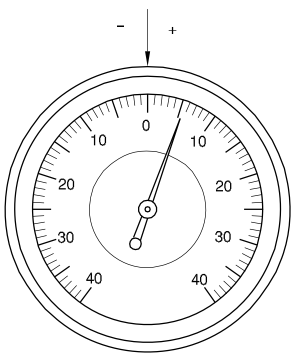


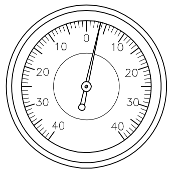
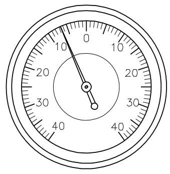
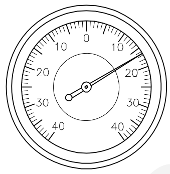
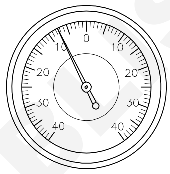
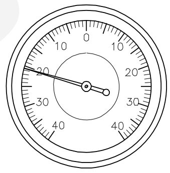
Reading the dial indicator (Fig 8)

When taking the reading, first check the measuring range and the subdivisions of the scale. The indicator in the figure has a range of 0.8mm and is graduated 0-40 in both directions. Thus the value of each division is 0.01 mm.

The indicator shows positive deviations in the clockwise direction and negative deviations in the anticlockwise direction.

Fig 8



Classroom assignment			
Basic measurement		**Value measured**	
30.0 mm		29.97 - 29.98	☐
		30.02 - 30.03	☐
		30.03 - 30.04	☐
		30.04 - 30.05	☐
23.0 mm		22.92 - 22.93	☐
		22.93 - 22.94	☐
		22.94 - 22.95	☐
		22.96 - 22.97	☐
47.8 mm		47.86 - 47.87	☐
		47.88 - 47.89	☐
		47.92 - 47.93	☐
		47.96 - 47.97	☐
53.0 mm		52.92 - 52.93	☐
		52.93 - 52.94	☐
		53.96 - 53.97	☐
		53.97 - 53.98	☐
65.0 mm		64.75 - 64.76	☐
		64.79 - 64.80	☐
		64.83 - 64.84	☐
		64.87 - 64.88	☐

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)

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 indicator4s are in use. They are the

1 Plunger type (Fig 2)

2 Lever type. (Fig 3,4 & 5)

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.

Fig 1

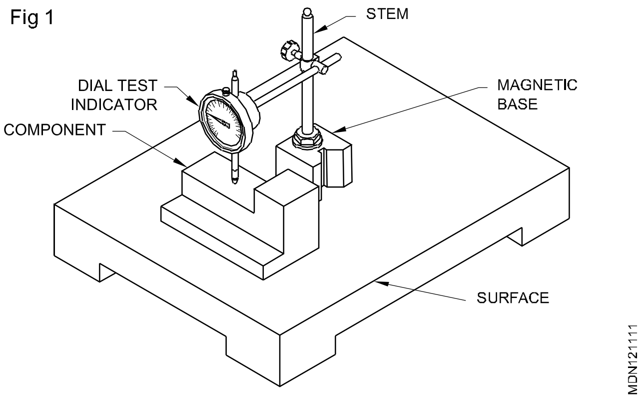
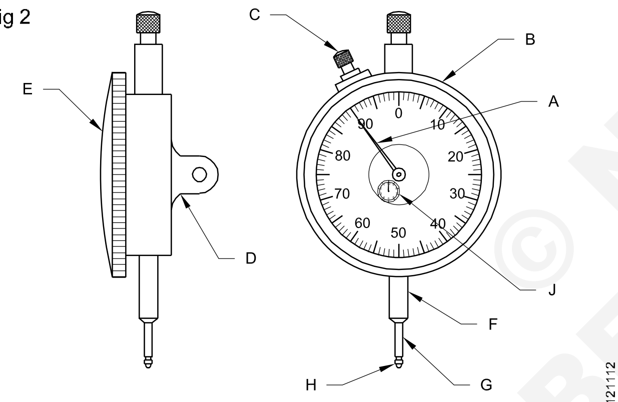


Fig 2



PLUNGER TYPE

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.

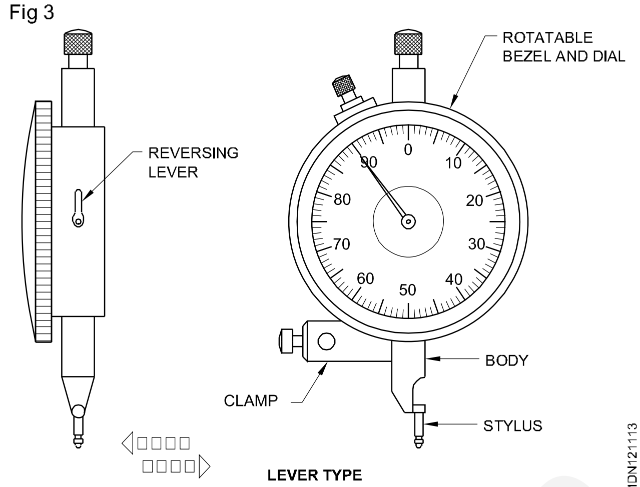
This can be conveniently mounted on a surface gauge stand, and can be used in places where the plunger type dial test indicator application is difficult.

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.

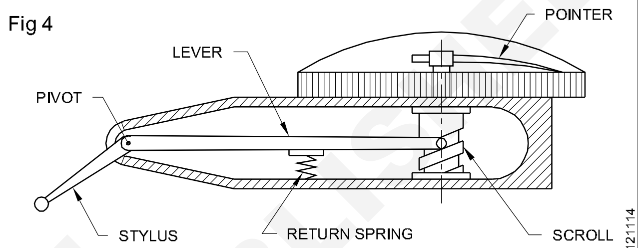
Many dial test indicators read plus in the clockwise direction from zero, and minus in the anticlockwise direction so as to give plus and minus indications.

Fig 3



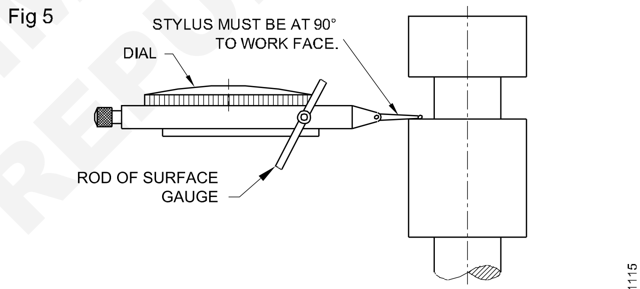
LEVER TYPE

Fig 4



MECHANISM OF THE LEVER TYPE DIAL TEST INDICATOR

Fig 5



WORK PIECE WITH RECESS INACCESSIBLE TO PLUNGER TYPE DIAL INDICATOR

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 6 & 7)

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 6

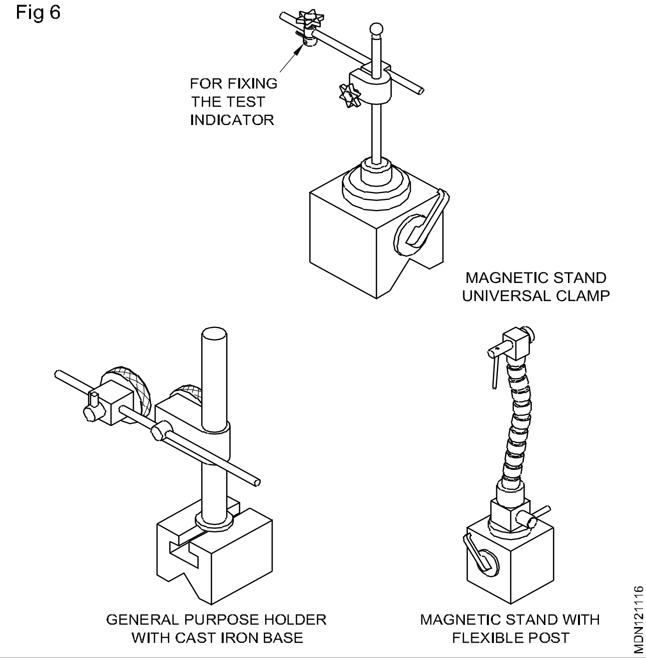
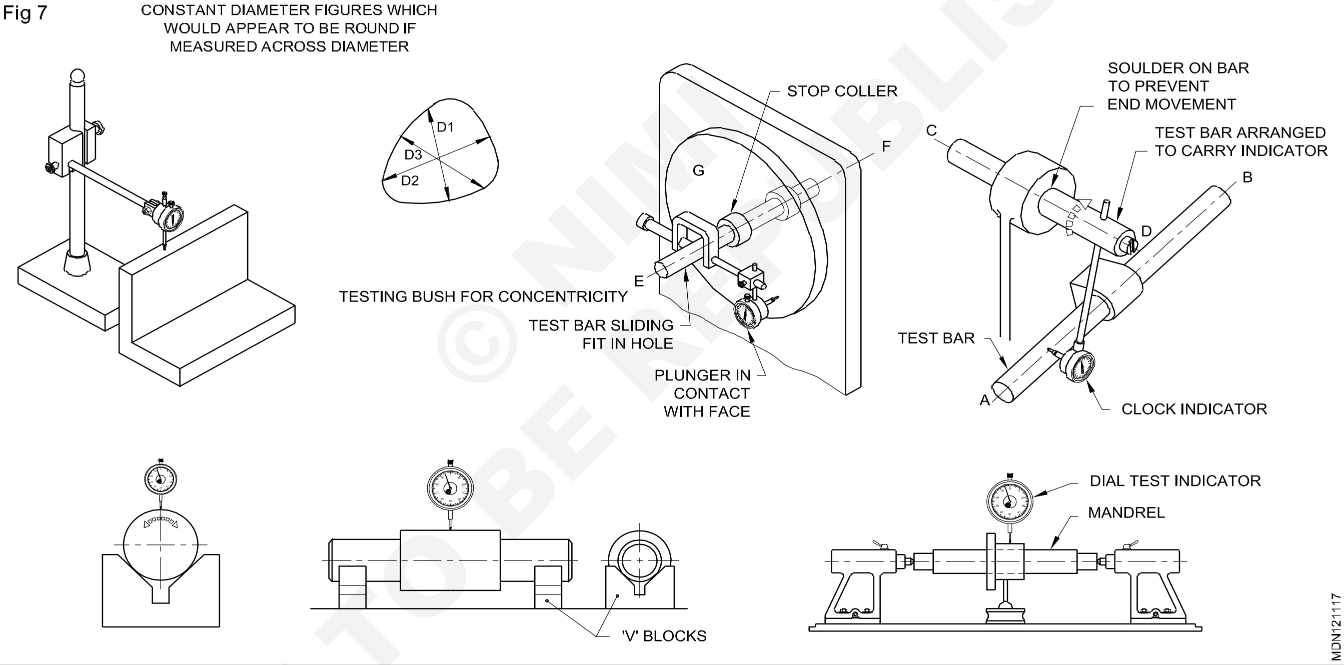


Fig 7



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**
- **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)

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 provided with feet to prevent distortion under their own weight.

Fig 1

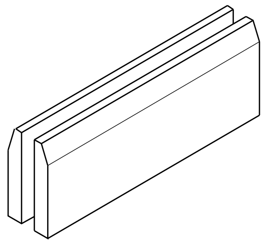
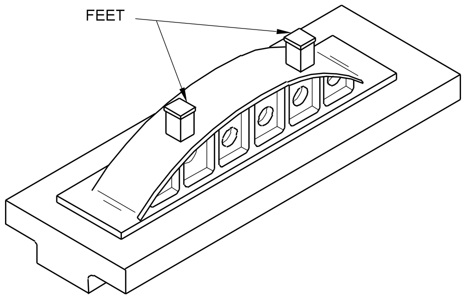


Fig 2

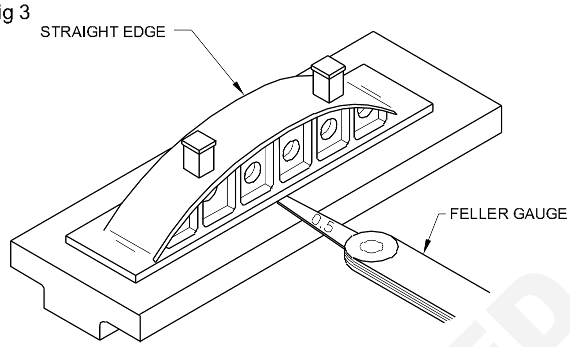


Use of straight edges

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



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**
- **state the different types and uses of feeler gauges.**

Features

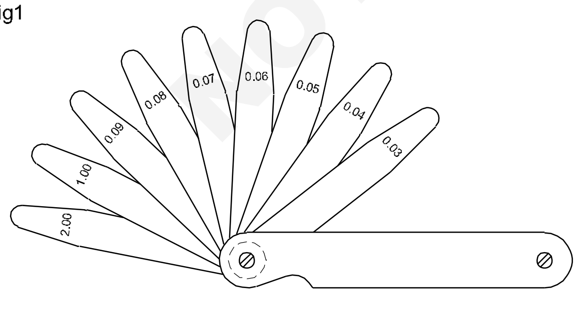
A feeler gauge consists of a number of hardened and tempered steel blades of various thicknesses mounted in a steel case.

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

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.

Fig1



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.

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&3)
- to check and measure the bearing clearance, and for many other purposes where a specified clearance must be maintained.

Fig 2

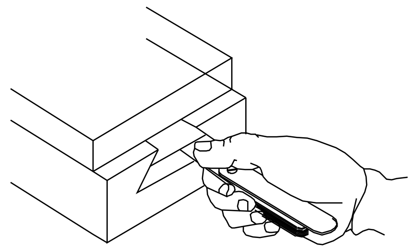
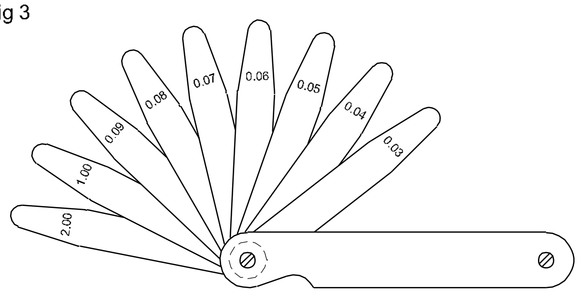


Fig 3



Wire gauge (Fig 4): The plug wire gauge is a thickness gauge using wires of varying diameter instead of thin flat strips of steel. It is used for checking spark plug gap.

Types of feeler gauge

1 Universal master gauge

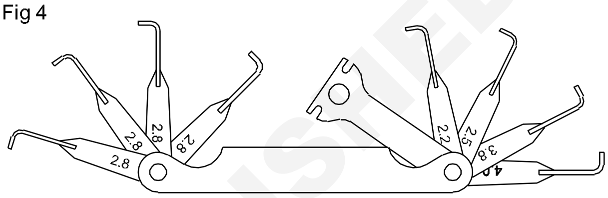
2 Standard feeler gauge

3 Ignition and wire gauge

Classification of feeler gauge

- Universal master gauge containing 25 leaves
- Standard feeler gauge containing 10 leaves
- Go and No-Go type feeler gauge containing 15 step-grand leaves
- Overhead valve feeler gauge containing 16 offset blades
- Ignition feeler gauge containing 12 leaves
- Piston gauge containing and leaves
- Spark plug wire gauge containing electrode bender and 8 wire gauge

Fig 4



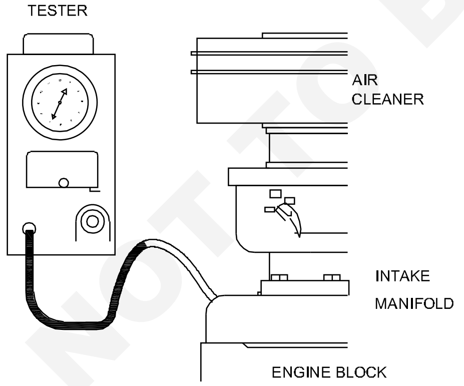
WIRE GAUGE SET FOR CHECKING SPARK PLUG GAP

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 steady high vacuum reading indicate an absence vacuum leak in the system (i.e) valves and rings are in good sealing.
- Fairly steady vacuum reading indicate vacuum leak in the system (i.e) valves 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 and set tyre pressure.**

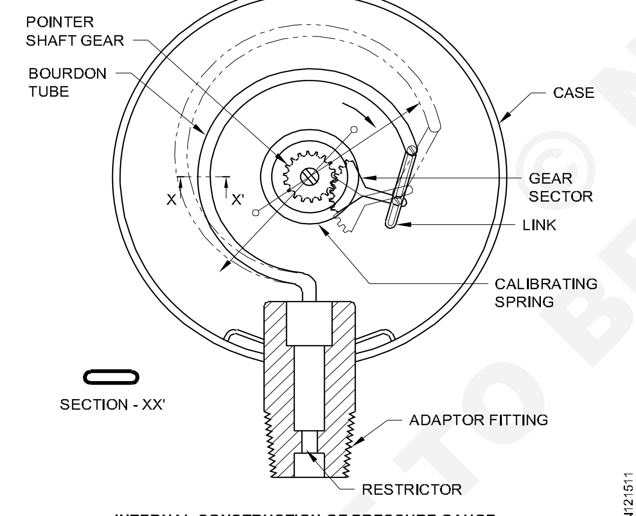
Pressure gauge: It is used to check the pressure of tyre unit. Bourdon tube pressure gauges (Fig 2) made by stainless steel. A pressure rise in bourdon tube makes it tend to straighten. This movement will pull on the link which will turn the gear sector counter clockwise. The pointer shaft will then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

Special features

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

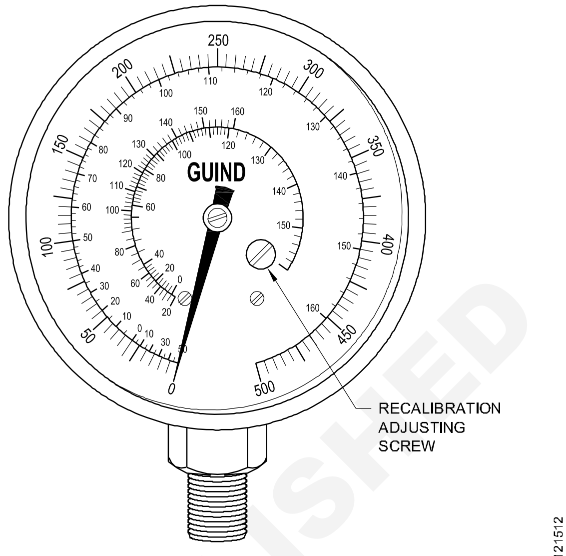
The pressure gauge hose has a adapter, which depresses the valve pin of tyre and compressed air get into the tube of the gauge. The pressure is indicated in the dial. Compare the pressure to the recommended pressure by the manufacturer. If it is less, refill the tyre with compressed air by operating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

Fig 1



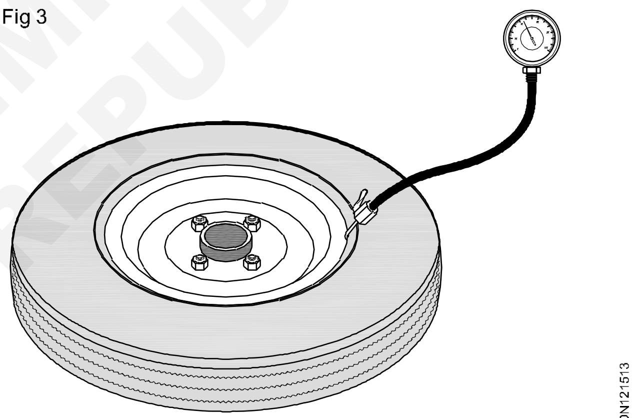
INTERNAL CONSTRUCTION OF PRESSURE GAUGE

Fig 2



PRESSURE GAUGE

Fig 3



Rivets - types and uses

Objectives : At the end of this lesson you shall be able to
- **state what is riveting**
- **state the uses of a rivet**
- **name the features of a rivet**
- **name the different types of rivets.**

Riveting (Fig 1)

Riveting is a method of making permanent joints. For riveting, the plates to be joined are drilled or punched The head on the other end is formed after assembling the parts.

The main features of rivets used in self-piercing riveting are:

- Shank diameter and rivet length
- Shape of rivet head and tail design
- Rivet material and hardness

Type of crating/plating

Types of rivets

1 Solid/round rivets

2 Semi tubular rivets

3 Blind rivets

4 Oscar rivets

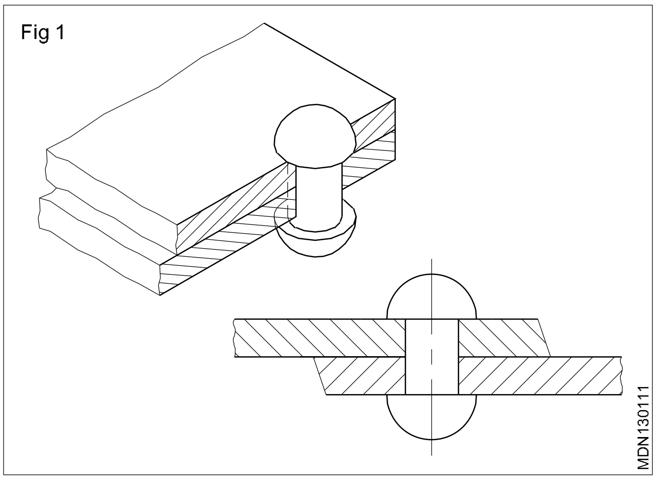
5 Drive rivets

6 Flesh rivets

7 Friction-lock rivets

8 Rivet alloys shear strength and driving conditions

9 Self-piercing rivets



Rivet proportions

Objectives : At the end of this lesson you shall be able to
- **determine the hole sizes for different diameters of rivets**
- **choose the rivet diameters according to the thickness of the plates/sheets**
- **calculate the length for different diameter rivets and plate sizes.**

In order to produce efficient and good quality riveted joints the following aspects are important.

The size of the hold drilled for inserting the rivets.

The diameter of the rivet in proportion to the thickness of the plates/sheets to be joined.

The length of the rivet according to the type of the rivet and the thickness of the plates/sheets.

The size of the rivet and hole

The size of the hole to be drilled is according to the diameter of the rivet used.

A formula generally used for determining the diameter of a solid rivet is

D.Min = T

to D.Max = 2T

The actual value used will depend upon the actual joint features and service conditions.

The size of the hole has to be slightly larger than the nominal diameter of the rivet (Table 1)

For hot working, rivets will have holes with more clearance than for cold working.

Length of rivets

The length of a rivet is the shank length. This will vary according to the thickness of the plates to be riveted and the type of the rivet head.

A formula generally used in the shop floor is

Length of snap-head rivets (Fig 1)

L = T + 1.5 D

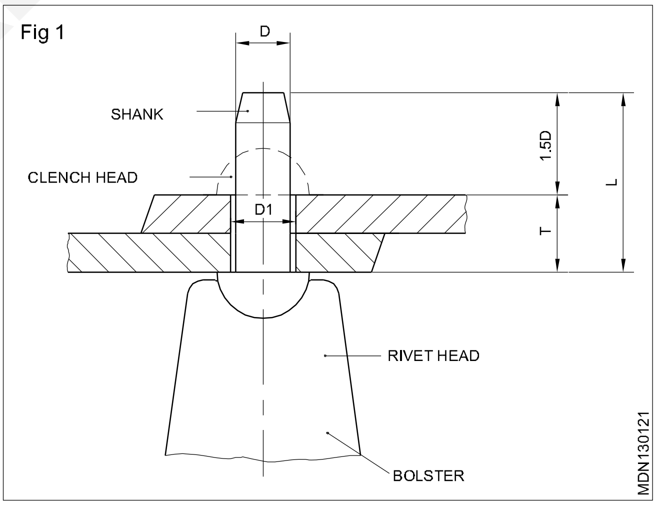


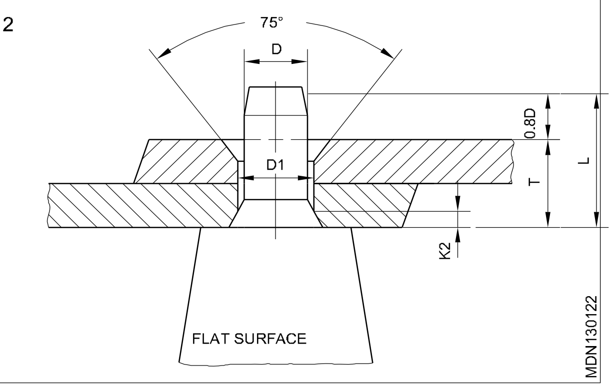
Table 1

Hole diameter for rivets

Rivet nominal dia	2	3	4	5	6	8	10	12	15	15-40
Hole dia	2.2	3.2	4.2	5.3	6.3	8.5	11	13	16.5	Holes largethan the nominal dia by 1.5. to 2.0mm

Length of countersunk head rivets (Fig 2)

Fig 2



L	=	T + 0.6 D
L	=	shank length
T	=	total thickness of the number of plates used
D	=	rivet diameter
D1	=	hole diameter

The rivets are then inserted and closed by force so that they completely fill the hole and form a rigid joint.

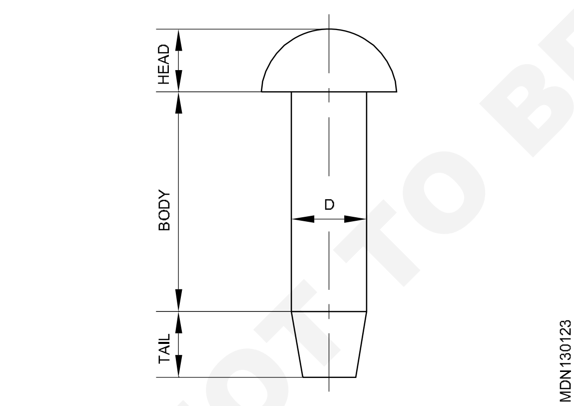
Uses

Rivets are fasteners used for joining metal sheets and plates in fabrication work such as bridges, ships. cranes. structural steel work, boilers, aircraft etc.

Parts (Fig 3): The following are the parts of a rivet;

- Head
- Body
- Tail

Fig 3



Materials

In riveting, the rivets are secured by deforming the shank to form the head. These are made of ductile materials.

Examples

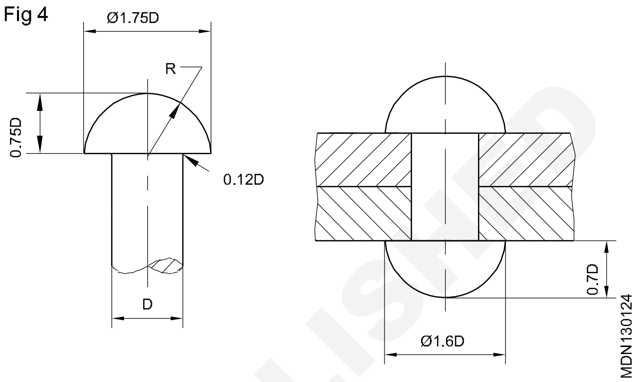
Low carbon steel, brass, copper and aluminium.

Rivet head-shapes

Snap-head (Fig 4)

This rivet is most commonly used for structural works. The opposite end of the rivet is shaped similar to the head.

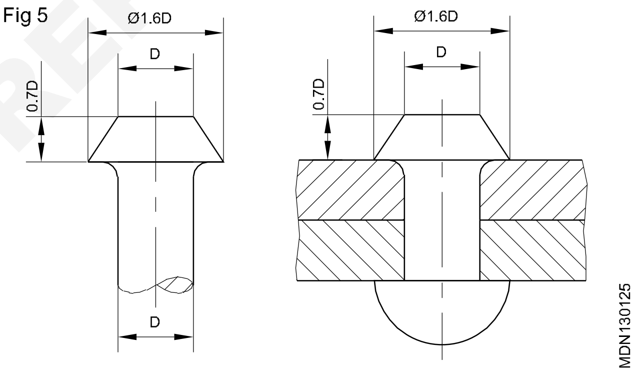
Fig 4



Pan head (Fig 5)

It is a very strong rivet. The opposite end is usually finished to the snap-head shape. Pan head rivets are used in heavy construction.

Fig 5



Riveted joints

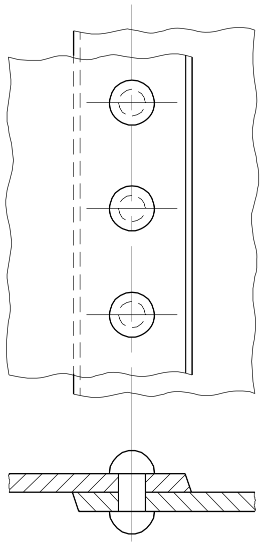
Objectives : At the end of this lesson you shall be able to
- **name the different types of riveted joints**
- **state the features of different types of riveted joints**
- **distinguish between chain riveting and zigzag riveting.**

In construction and fabrication work different types of riveted joints are made. The commonly used joints are;

- Single riveted lap joint
- Double riveted lap joint
- Double riveted (zigzag) lap joint
- Single strap butt joint
- Double strap butt joint

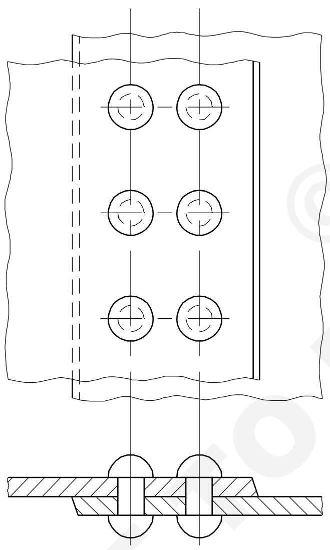
Single riveted lap joint (Fig 1): This is the simplest and most commonly used type of joint. This joint is useful for joining both thick and thin plates. In this, the plates to be joined are overlapped at the ends and single row of rivets is placed in the middle of the lap.

Fig 1



Double riveted lap joint (Fig 2): This type of joint will have two rows of rivets. The overlap is large enough to accommodate two rows of rivets.

Fig 2



Double riveted (Zigzag) lap joint (Fig 3): This provides a stronger joint than a single lap joint. The rivets are placed either in a square formation or in a triangular formation. The square formation of rivet placement is called CHAIN riveting. The triangular formation of rivet placement is called zigzag riveting.

Single strap butt joint (Fig 4): This method is used in situations where the edges of the components are to be joined by riveting.

A separate piece of metal called STRAP is used to hold the edges of the components together.

Double strap butt joint (Fig 5 & 6): This joint is also used for joining the edges of components together. This is stronger than the single strap butt joint. This joint has two cover plates placed on either side of the components to be assembled.

When a single or double straps are used for riveted butt joints, the arrangement of rivets may be:

- Single riveted, i.e. one row on either side of the butt
- Double or triple riveted with chain or zigzag formation.

Fig 3

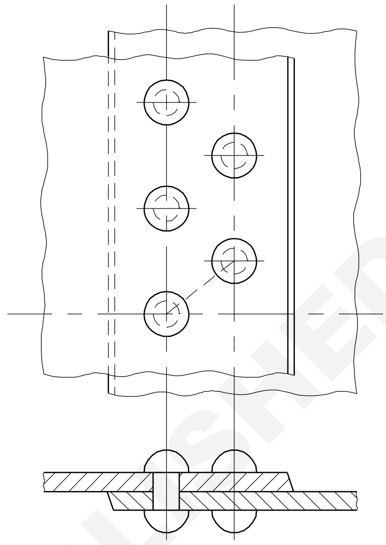


Fig 4

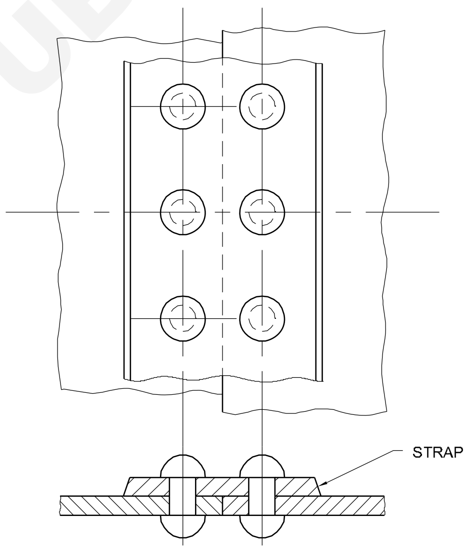


Fig 5

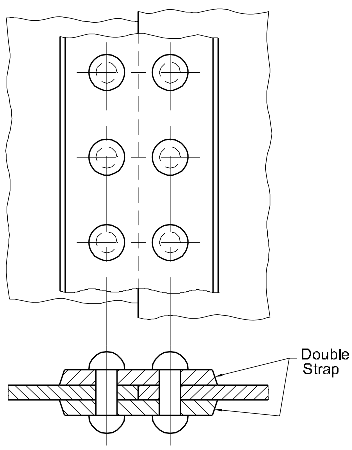
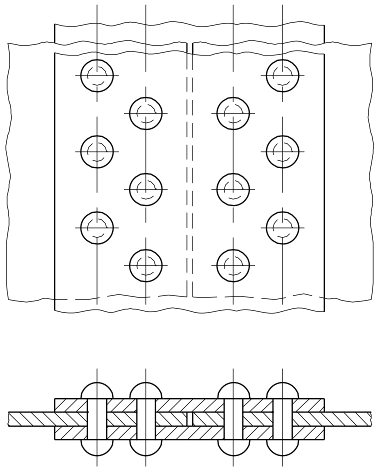


Fig 6



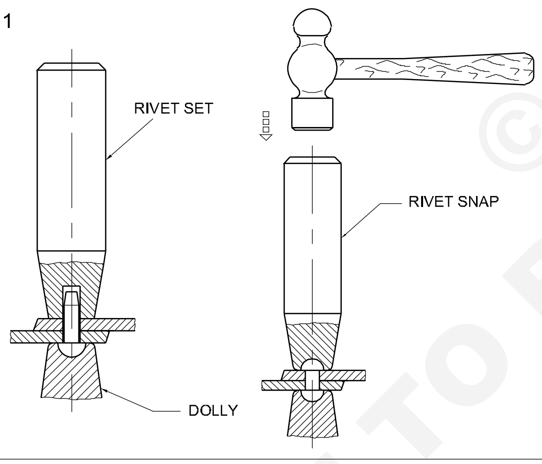
Tools for hand riveting

Objectives : At the end of this lesson you shall be able to
- **name the different tools used for hand riveting**
- **state the uses of different hand riveting tools.**

The following tools are used for making efficient riveted joints.

Rivet set (Fig 1): A rivet set is used for bringing the plates closely together after inserting the rivet in the hole. This is required while riveting thin plates or sheets with small rivets.

Fig 1



Dolly: This is used to support the head of the rivet which is already formed and also to prevent damage to the shape of the rivet head.

Snap: The rivet snap is used to form the final shape of the rivet during riveting. Snaps are available to match the different shapes of rivet heads.

Combined rivet set (Fig 2): This is a tool which can be used for setting and forming the head.

Drift (Fig 3): This is used to align the holes to be riveted.

Hand riveter (Fig 4): This has a lever mechanism which exerts pressure between the jaws when the handle is pressed.

This is useful for riveting copper or aluminium rivets, interchangeable anvils can be provided.

Fig 2

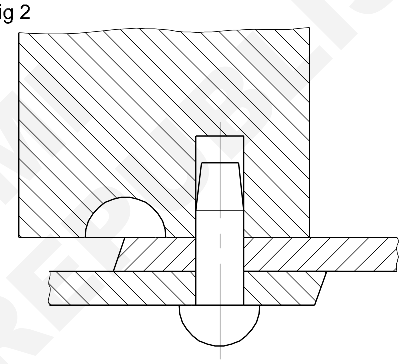


Fig 3

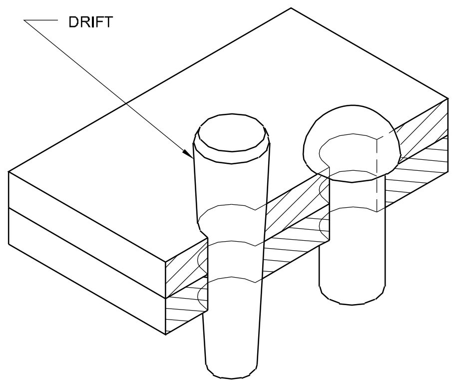
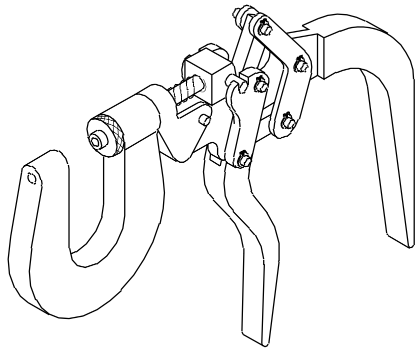
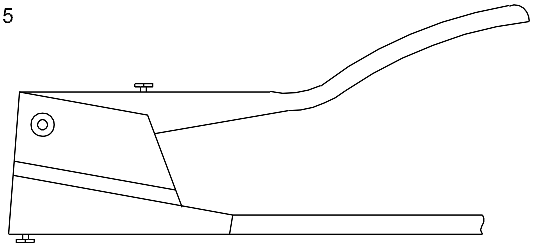


Fig 4



Pop riveter (Fig 5): This is used for riveting pop rivets by hand. The trigger mechanism squeezes the rivet and separates the mandrel of the rivet. In this method, as the mandrel is being separated from the rivet, the head is formed on the other end.

Fig 5



Spacing of rivets in joints

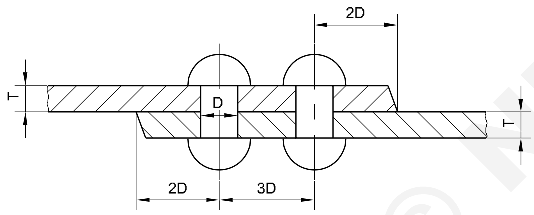
Objectives : At the end of this lesson you shall be able to
- **determine the distance between the rivet and the edge of the joint.**
- **state the effect on the joints when the rivets are too close or too far from the edge**
- **determine the pitch of rivets in joints**
- **state the effect of too close and too far a pitch of rivets in joints**.

The spacing of the rivet holes depends upon the job. Given below is a general approach in determining this.

Distance from the edge to the centre of the rivet (Fig 1)

The space or distance from the edge of the metal to the centre of any rivet should be at least twice the diameter of the rivet.

Fig 1



The purpose of this is to prevent the splitting of the edges. The maximum distance from the edge should not be more than ten times the thickness of the plate.

Too much distance from the edge will lead to GAPING.

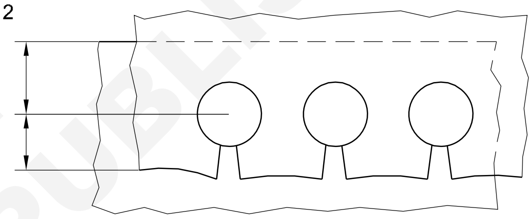
Pitch of rivet

The minimum distance between rivets should be three times the diameter of the rivet (3D)

This distance will help to drive the rivets without interference.

Too closely spaced rivets will tear the metal along the centre line of the rivets.(Fig 2)

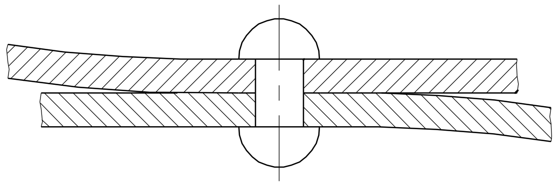
Fig 2



The maximum distance between the rivets should not exceed twenty four times the thickness of the metal.

Too far a pitch will allow the sheet/plate to buckle between the rivets. (Fig 3)

Fig 3

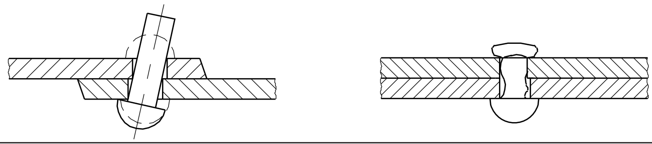
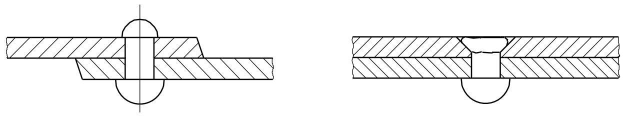
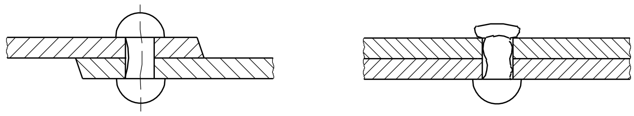
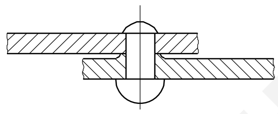
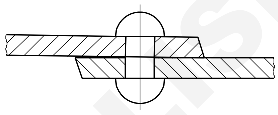
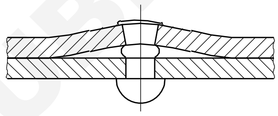
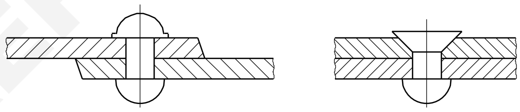
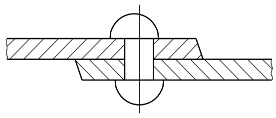


Defects in riveted joints

Objectives : At the end of this lesson you shall be able to
- **relate riveting defects with their causes.**

While making riveted points certain precautions are to be exercised to avoid defects in the joints.

A few common causes and defects and resistant effects in riveting are given below:

Causes of riveting defects	Resultant effect
Holes wrongly aligned	
Rivet too short	
Hole too large	
Burrs in drilling	
Burrs between plates	
Rivet not set correctly	
Rivet length too long	
Head formed out of centre	

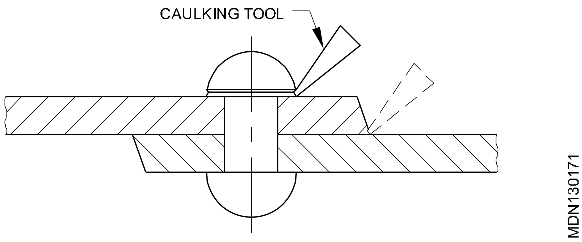
Caulking and fullering

Objectives : At the end of this lesson you shall be able to
- **state the purpose of caulking and fullering**
- **distinguish between caulking and fullering processes.**

In order to provide a leak-proof joint in the construction of fluid containers, caulking and fullering are carried out after riveting.

Caulking (Fig 1)

Fig 1



Caulking is an operation of closing down the edges of the plates and heads of the rivets to form a metal-to-metal joint.

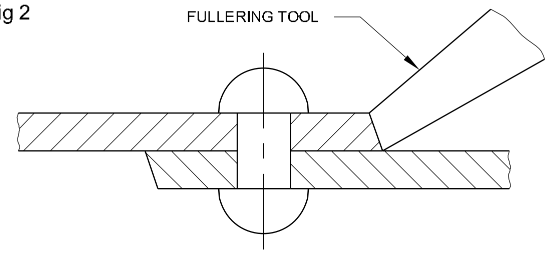
The edge of the rivet head is tightly pressed and expanded on the plate by a caulking tool which looks like a flattened cold chisel.

Fullering (Fig 2)

Fullering is an operation of pressing the whole surface of the edge of the plate. It is done by a fullering tool.

When the caulking tool is about as thick as the plate, it is called a fullering tool.

Fig 2



The whole surface of the edge of the first plate is tightly pressed on the second plate.

A better fluid-tight joint is achieved by fullering.

Caulking is done on the edges of the plates as well as on the edges of the rivet heads. But fullering is done on the edges of the plate only. To facilitate caulking and fullering on the plates, the edges of the plates are bevelled about 80° to 85°.

The strength of riveted joints

A riveted joint is only as strong as its weakest part and it must be borne in mind that it may fail in one of the following four ways.

Shearing of the rivet

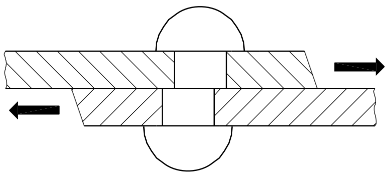
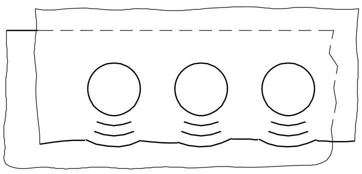
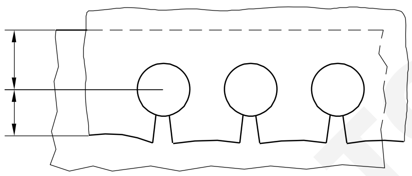
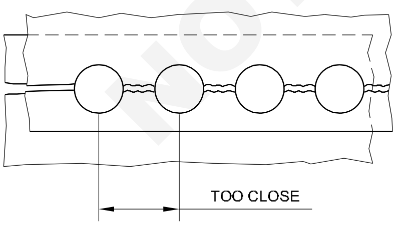
Crushing of the metal

splitting of the metal

Rupture or tearing of the plate

These four undesirable effects are illustrated in the table below:

Table

Riveted Joint	Effects	Causes	Prevention
	Shearing of the rivet	Diameter of the rivet too small compared with the thickness of the plate. The diameter of the rivet must be greater than the thickness of the plate in which it is to be inserted.	Select the correct diameter rivet to suit thickness of the plate.
	Crushing of the metal	Diameter of the rivet too large compared with the thickness of the plate. The rivets when driven tend to bulge and crush the metal in front of them.	Select the correct diameter rivet for the thickness of the metal plate.
	Splitting of the metal	Rivet holes punched or drilled too near the edge of plate. Metal is likely to fail by splitting in front of the rivets.	Drill or punch the rivet at the correct distance from the edge and use the correct lap allowance for the diameter of the rivet.
	Tearing of the plate	Plates weakened by rivete holes being too close together. Plate tend to rupture along the centre line of the rivets	Punch or drill rivet holes at the correct spacing or ‘pitch. In addition remove all burrs from the holes before final assembly.

Bolts, studs and nuts

Objectives : At the end of this lesson you shall be able to
- **state the situations in which bolts and nuts are used**
- **state the advantages of using bolts and nuts**
- **name the different types of bolts**
- **state the applications of the different types of bolts**
- **state the situations in which studs are used**
- **state the reason for having different pitches of threads on stud ends.**

Scan the QR Code to view the video for this exercise

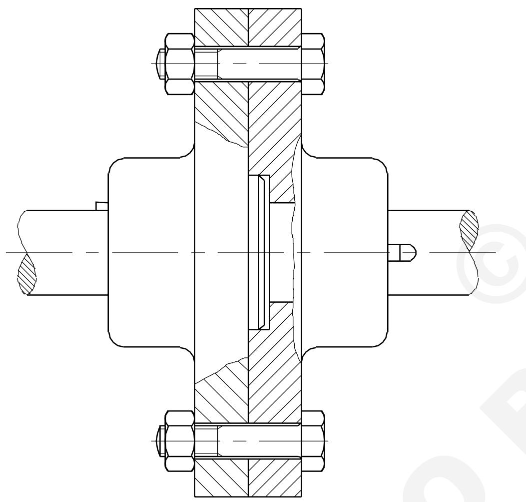
Bolts and nuts (Fig 1)

These are generally used to clamp two parts together.

When bolts and nuts are used, if the thread is stripped, a new bolt and nut can be used. But in the case of a screw directly fitted in the component. When threads are damaged, the component may need extensive repair or replacement.

Depending on the type of application, different types of bolts are used.

Fig 1

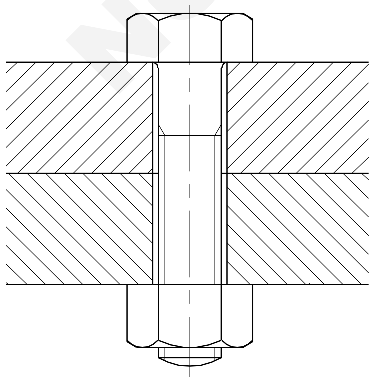


MDN121521

Bolts with clearance hole (Fig 2)

This is the most common type of fastening arrangement using bolts. The size of the hole is slightly larger than the bolt (clearance hole)

Fig 2



MDN121522

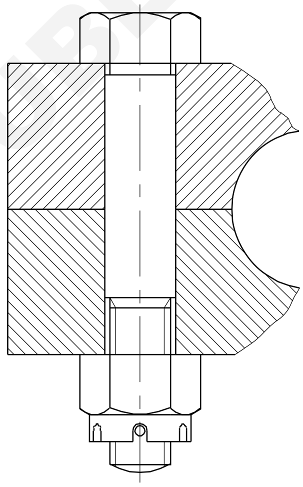
Slight misalignment in the matching hole will not affect the assembly.

Body fit bolt (Fig 3)

This type of bolt assembly is used when the relative movement between the workpieces has to be prevented. The diameter of the threaded portion is slightly smaller than the shank diameter of the bolt.

The bolt shank and the hole are accurately machined for achieving perfect mating.

Fig 3



BODY FIT BOLT

MDN121523

Anti-fatigue bolt (Fig 4)

This type of bolt is used when the assembly is subjected to alternating load conditions continuously. Connecting rod big ends in engine assembly are examples of this application.

The shank diameter is in contact with the hole in a few places and other portions are relieved to give clearances.

Studs (Fig 5)

Studs are used in assemblies which are to be separated frequently.

When excessively tightened, the variation in the thread pitch allows the fine thread or nut end to slip. This prevents damage to the casting.

Fig 4

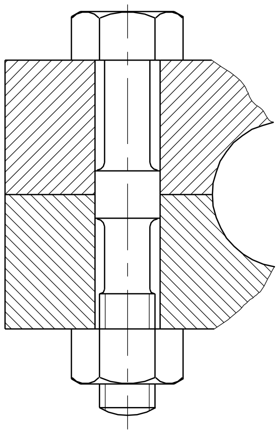
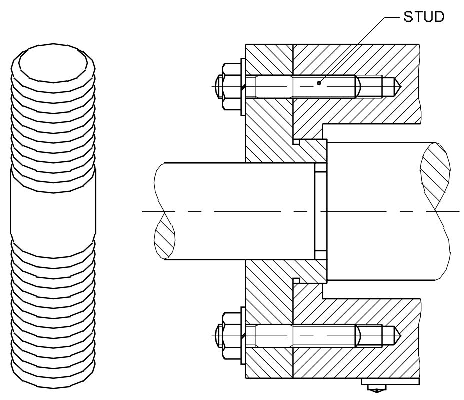


Fig 5



Designation of bolts as per B.I.S. specifications

Hexagon head bolts shall be designated by name, thread size, nominal length, property class and number of the Indian Standard.

Example

A hexagon head bolt of size M10, nominal length 60mm and property class 4.8 shall be designated as:

Hexagon head bolt M10x60 - 4.8-IS: 1363 (Part 1)

Explanation about property class

The Part of the specification 4.8 indicates the property class (mechanical properties). In this case it is made of steel with minimum tensile strength = 40kgf/mm2 and having a ratio of minimum yield stress to minimum tensile strength = 0.8.

NOTE

Indian standard bolts and screws are made of three product grades - A,B, & C, `A' being precision and the others of lesser grades of accuracy and finish.

While there are many parameters given in the B.I.S. specification, the designation need not cover all the aspects and it actually depends on the functional requirement of the bolt or other threaded fasteners.

For more details on the designation system, refer to IS: 1367, Part XVI 1979.

Locking devices

Objectives : At the end of this lesson you shall be able to
- **state what is a locking device**
- **name the effect, if proper locking devices are not employed**
- **name the various types of locking devices**
- **state the uses of the commonly used locking devices.**

Locking devices: A locking device is used to lock the threaded fasteners to prevent them from loosening. Due to vibration in the moving part, there is a tendency for the threaded fastener to get slack and to slip off. Then the assembled part will get loose and cause damages. Some examples are given below to illustrate the importance of the locking device.

In the case of a micrometer, the lock-nut avoids the Movement of the spindle after taking the reading. In the case of boilers and gas cylinders, locking of the nut avoids the leakage of steam or gas.

In Automotives the lock-nut avoids the loosening of the assembled part.

Classification of lock-nuts: Lock-nuts are classified into two categories.

1 Positive locking device

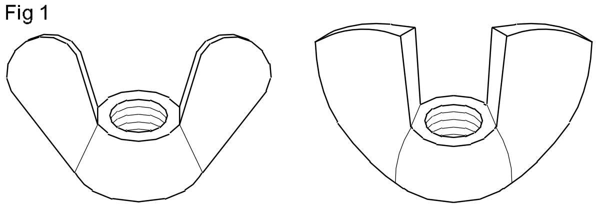
2 Frictional locking device

These nuts have special provision in the form of slots for fixing split pins for locking the nuts.

Slotted nuts are hexagonal shaped throughout. In the case of castle nuts, the top part of the nut is cylindrical in shape.

Wing-nuts (Fig 1): Wing-nuts are used in light duty assembly which require frequent removal and fixing. These are available as hot forged/cast (Type A) and cold forged (Type B).

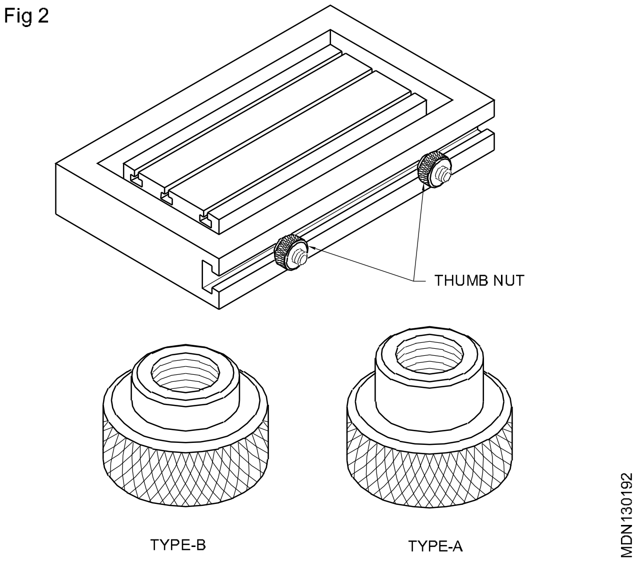
Fig 1



Thumb-nut (Fig 2)

These are used in places where frequent adjustments are required and mere finger tightening enought. They are available in two types - Types A & Type B.

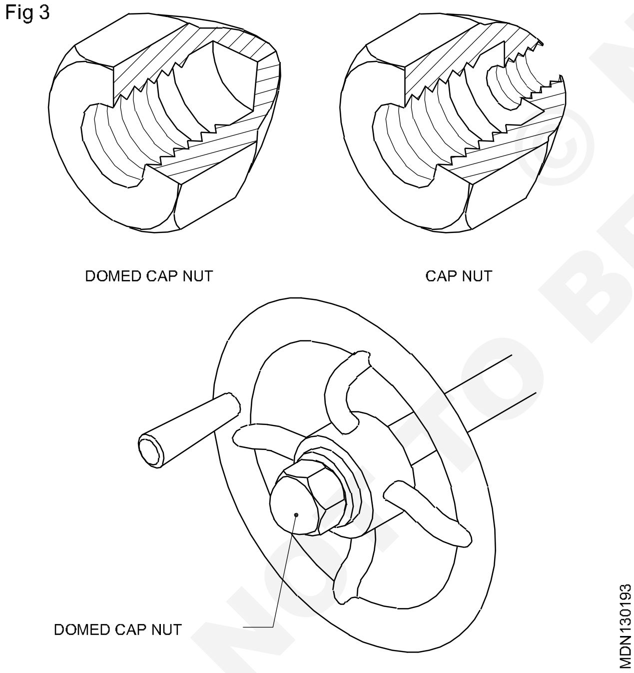
Fig 2



Cap nut (Fig 3)

These are used to protect the bolt end threads from damages and also as a protector for safe working. They serve to provide a decorative appearance.

Fig 3



Hexagonal nuts with collar (Fig 4): These nuts have a machined collar on one end. This provides additional bearing surface in assembly. The collar acts like a washer and is useful where frequent tightening and loosening is necessary.

Hexagonal weld nuts (Fig 5): These are nuts used for welding on the plate work. These nuts have:

- a spigot ring which fits in the hole of the plate
- three projections to provide a uniform contact on the surface, that is to be welded
- a countersunk hole on one end to protect the thread during welding.

Castle nuts (Fig 6) are widely used in automotives and locomotive engines to avoid sudden shock and vibration.

Fig 4

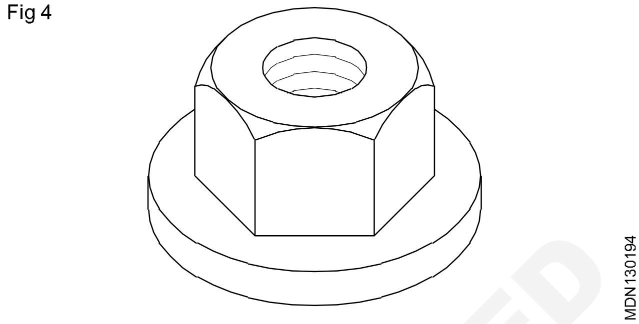


Fig 5

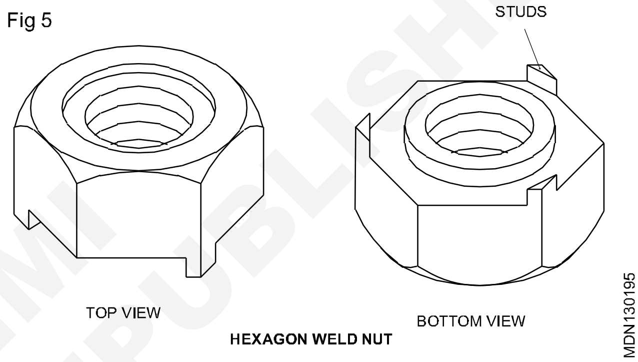
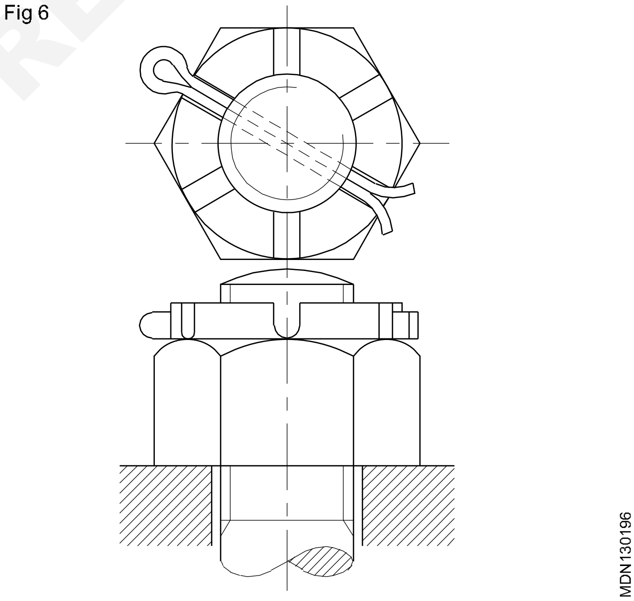


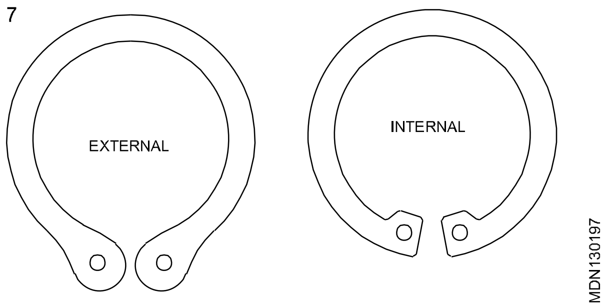
Fig 6



Circlip (Fig 7)

These are widely used to retain the component on a shaft or in a bore. Seating of these circlips in a slot by using a special type of pliers facilitates rapid assembly and disassembly.

Fig 7

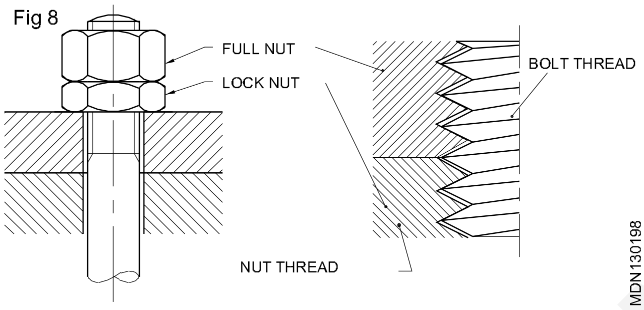


Chuck nut (Fig 8)

This nut is used along with one ordinary nut as shown in the figure.

A chuck nut is also called a lock-nut. The two nuts are thus locked or wedged tightly against each other and against the bolt. This will prevent slackening.

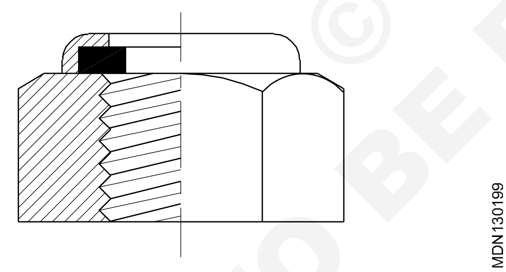
Fig 8



Self-locking nut (Fig 9)

Self-locking nut will have a nylon insert to prevent the loosening of the nut from shock, vibration and temperature.

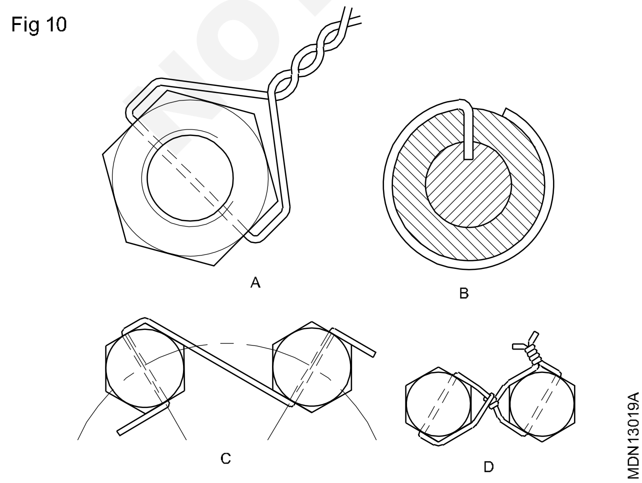
Fig 9



Wire lock (Fig 10)

Wire locks are used for light engineering works. The wire is passed through the groove.

Fig 10



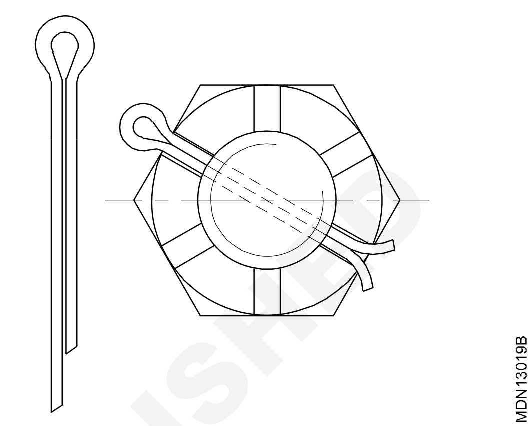
Nut applied with a sealant

These locking devices are for permanent locking in light works.

Split pin (Fig 11)

A split pin is made from a steel wire of semicircular cross section, bent as shown in the figure. It is inserted in a hole drilled in the bolt so that it exerts pressure on the top face of the nut to prevent it from turning.

Fig 11

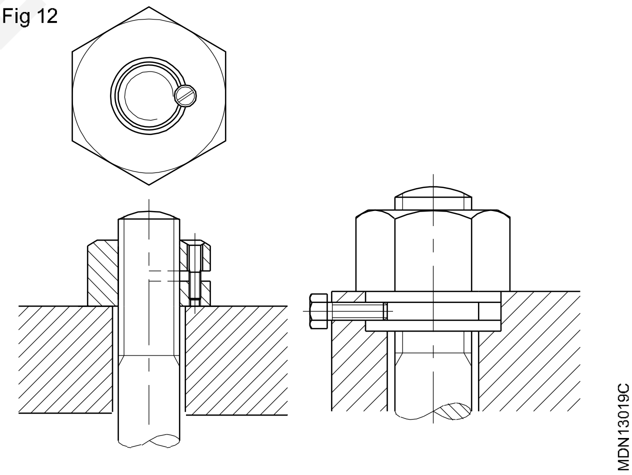


Sawn nut (Wiles nut)

In this locking device, a slot is cut half way across the nut. A screw is fitted with a clearance hole on the top part and a matching thread on the lower part of the nut. Tightening of the nut provides positive locking for the nut.

Positive locking device (Fig 12): Frictional locking device

Fig 12



Positive locking device (Fig 13)

In the positive locking device, the locking action is positive. This locking device is difficult to fit and may take more time. But it is very essential to use this type of locking device in critical joints where failure could cause serious accidents.

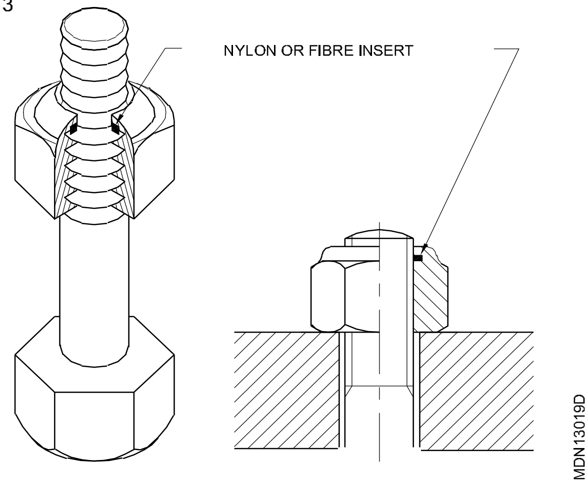
Eg. Clutches, brakes, controls etc.

The positive locking devices are:

- standard hexagonal nut, cross-drilled and pinned
- standard slotted nut

- standard castle nut
- hexagonal nut and locking plate
- wiring bolt heads.

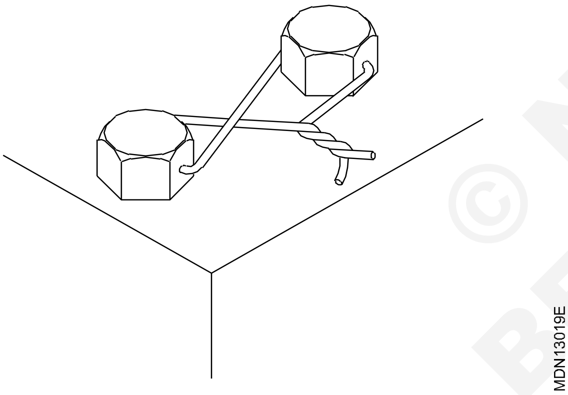
Fig 13



Frictional locking devices (Fig 14): These lock nuts are easy to fit and less time consuming. The frictional locking devices are;

- lock-nut (chuck nut)
- wedge lock bolt
- spring washer
- simmonds lock-nut.

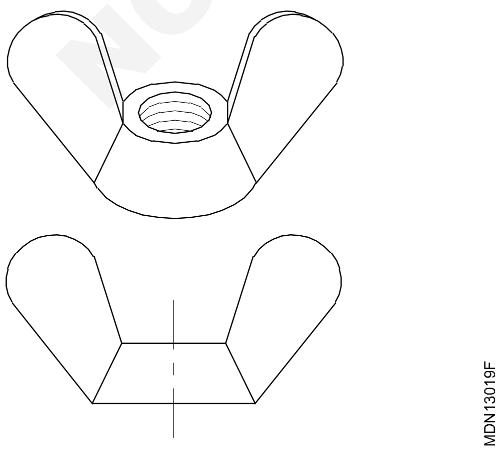
Fig 14



Commonly used locking devices

Wing-nut (Fig 15): A wing-nut is used where frequent adjustment or removal is necessary. It can be loosened or tightened rapidly without the need of a wrench. These nuts are manufactured with the same material as is used for the bolts.

Fig 15

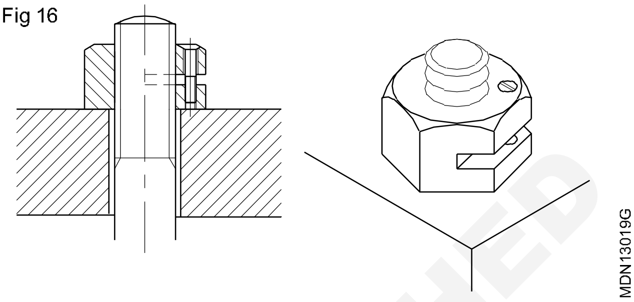


Thumb-nut: A thumb-nut is used where the movement of the spindle is to be locked, as in a micrometer. Stopping the movement of the spindle is necessary for taking a correct reading.

Locking ring: A locking ring is used in taper nose spindles of lathes to lock the chuck.

Castle nut (Fig 16): Slots are cut in a cylindrical collar provided on the top of the nut, thus overcoming the disadvantage of the slotted

Fig 16



Slotted and castle nut with a split pin: The position of the nut can be locked using the split pin.

Split pins are designated by the nominal size, nominal length, the number of the Indian Standard and the material. (Fig 17 & 18)

The nominal length is the distance from the underside of the eye to the end of the short leg.

Fig 17

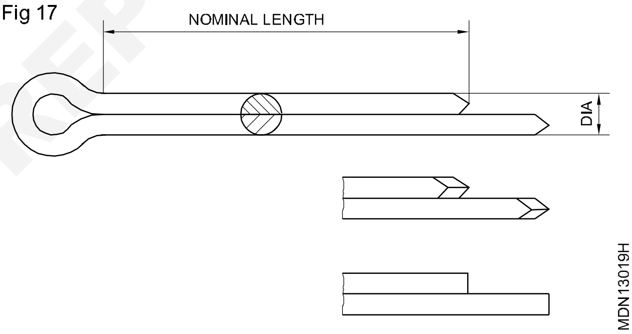
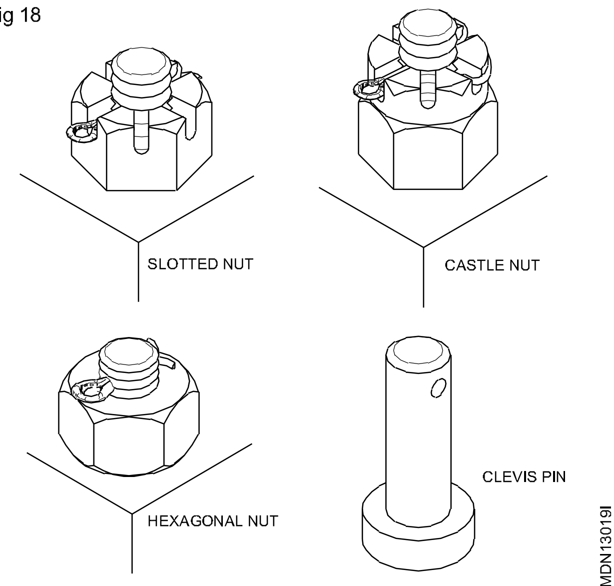


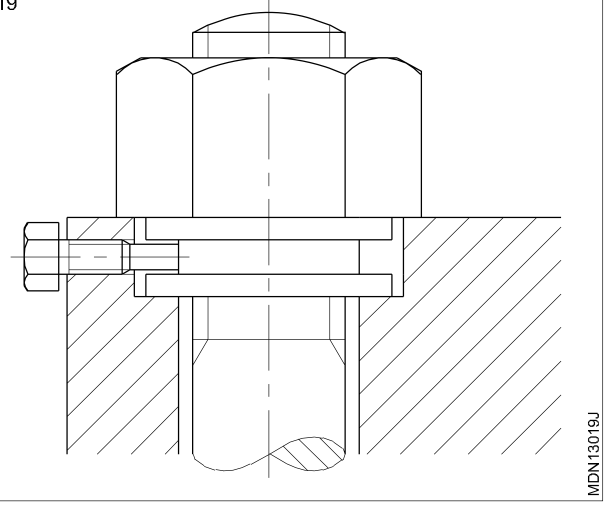
Fig 18



Split pins are used for locking slotted nuts, castle nuts, hexagonal nuts, clevis pins etc. and are used in different ways.

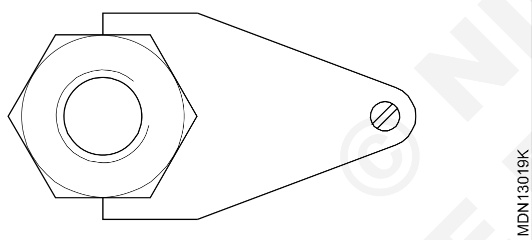
Grooved nut (Penning nut) (Fig 19): This is a hexagonal nut with the lower part made cylindrical. On the cylindrical surface there is a recessed groove in which a set screw is used to lock the nut.

Fig 19



Locking plate (Fig 20): For preventing the nut from loosening, locking plates are fixed on the outside of the hexagonal nut.

Fig 20



Lock washers with lug (Fig 21): In this arrangement of locking, a hole is drilled for accommodating the lug.

The movement of the nut is prevented by folding the washer against the nut.

Tab washers (Fig 22): Tab washers can be used for locking the nuts which are located near an edge or corner.

Fig 21

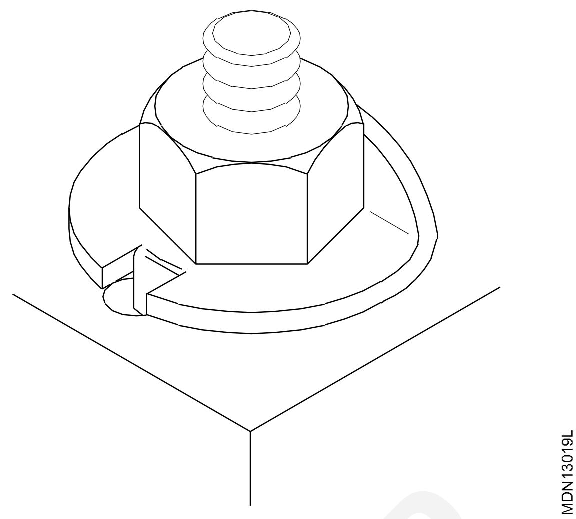
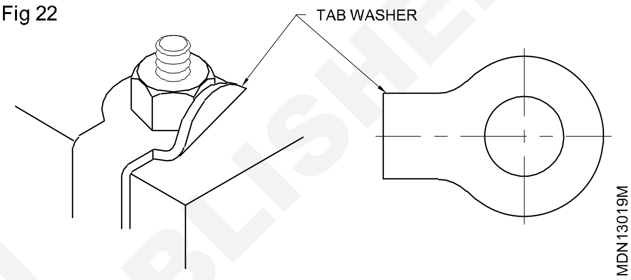
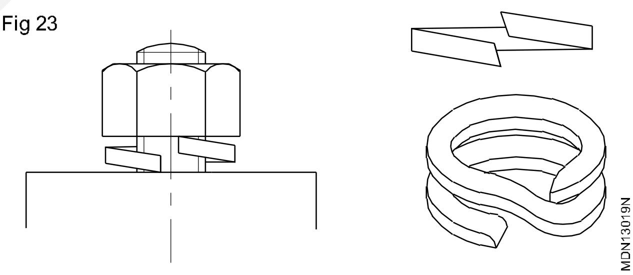


Fig 22



Spring washer (Fig 23): Spring washers are available with single or double coils. These are placed under a nut in the assembly as washers. The stiff resistance offered by the washer against the surface of the nuts serves to prevent loosening.

Fig 23



Keys and splines

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

Keys and splines

Keys are used for transmitting torque from a rotating shaft to a hub/wheel or from a hub/wheel to the shaft. (Fig 1)

Keys of different types are used depending on the requirements of transmission.

Hollow saddle key

One face of this key has a curvature to match with that of the shaft surface. It has a taper of 1 in 100 and is driven in through the keyway. (Fig 2)

The hub is held on the shaft due to friction. This key is useful only for light duty transmission.

Flat saddle key: This key has a rectangular cross-section.

For fitting this key in the assembly a flat surface is machined on the shaft. (Fig 3). The key is placed between the flat surface of the shaft and the keyway on the hub. This is considered to be stronger than the hollow saddle key. This is not suitable for heavy duty transmission.

Fig 1

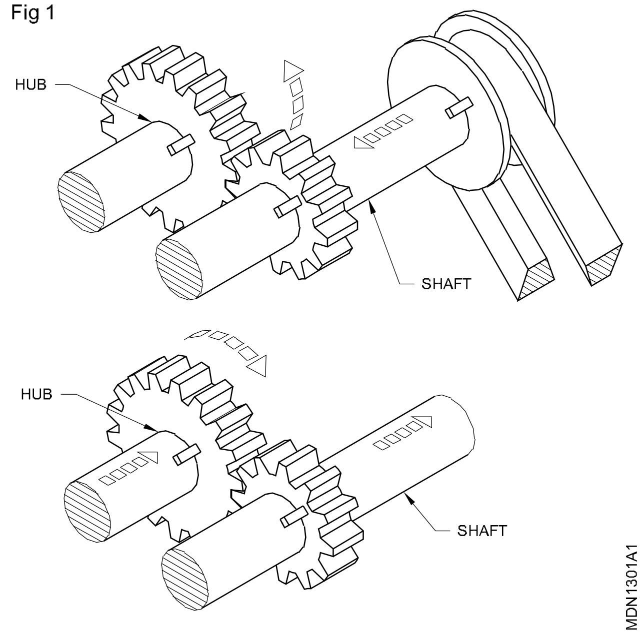


Fig 2

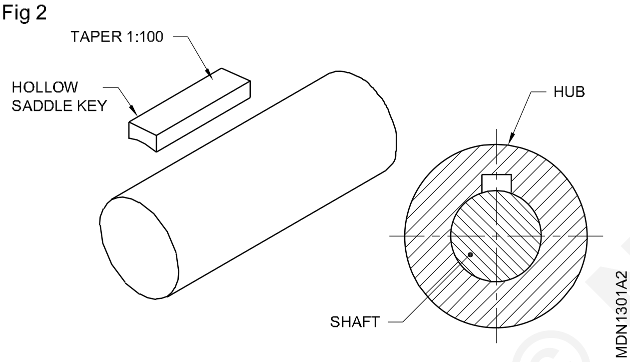
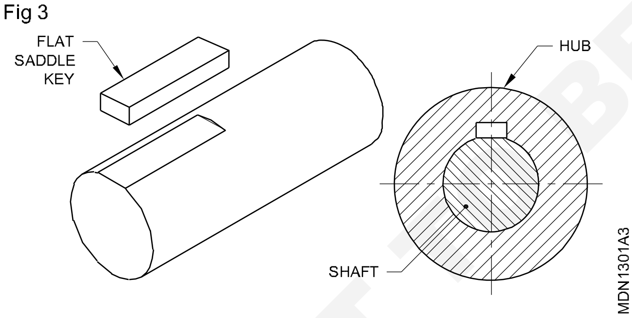
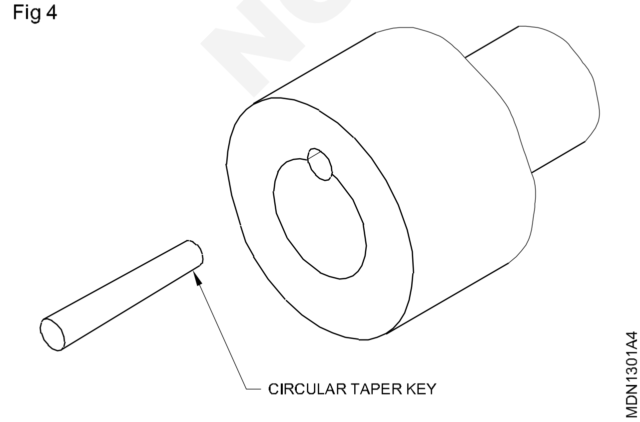


Fig 3



Circular taper key (Fig 4)

Fig 4



In this case both the shaft and the hub have semicircular keyways cut on them. (Fig 4) The taper key is driven in while assembling. This key is suitable only for light transmission.

Sunk key (Fig 5 & 6)

This key has a rectangular cross-section and its fits into the keyway cut on both the shaft and the hub. Sunk keys are either parallel or tapered.

Fig 5

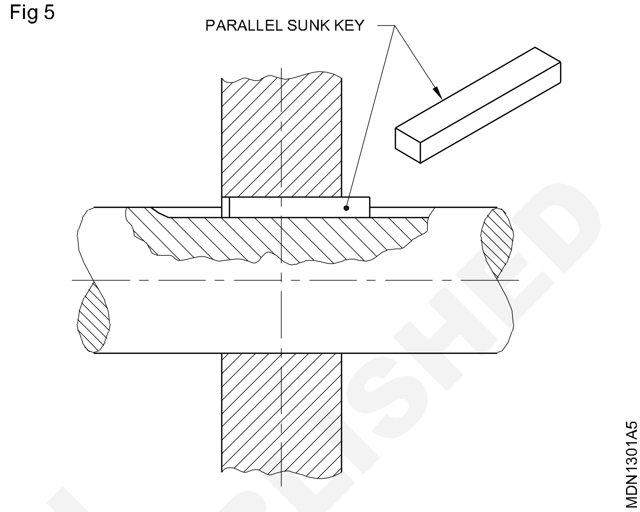
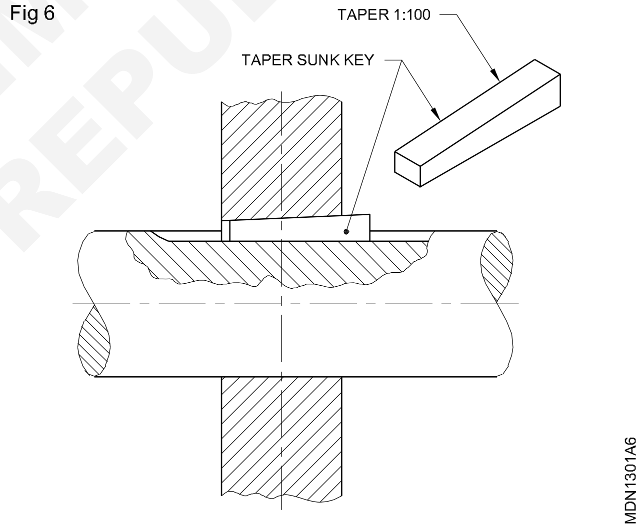


Fig 6



Gib-head key (Fig 7)

This is another type of sunk key. This has a gib-head to assist in fixing and removing the keys. (Fig 7a and b)

Feather key (Fig 8)

This is a parallel key with rounded ends. This is useful when the hub/pulley has to slide axially on the shaft to some distance. (Figs 8a,b and c) This key may be either tightly fitted in the keyway or screwed in.

Woodruff key (Fig 9)

This is semicircular key and it fits on to the shaft on which matching recesses are cut. The top portion of the key projects out and fits in the keyway cut on the hub. (Fig 9)

This key is particularly useful on tapered fittings of shafts.

Splined shaft and serrated shaft

Splined shafts along with splined hubs are used particularly in the motor industry. The splined hub can also slide along the shaft, wherever necessary. (Fig 10a and 10b)

In certain assemblies, serrated shafts are also used for transmission. (Figs 11a and 11b)

Fig 7

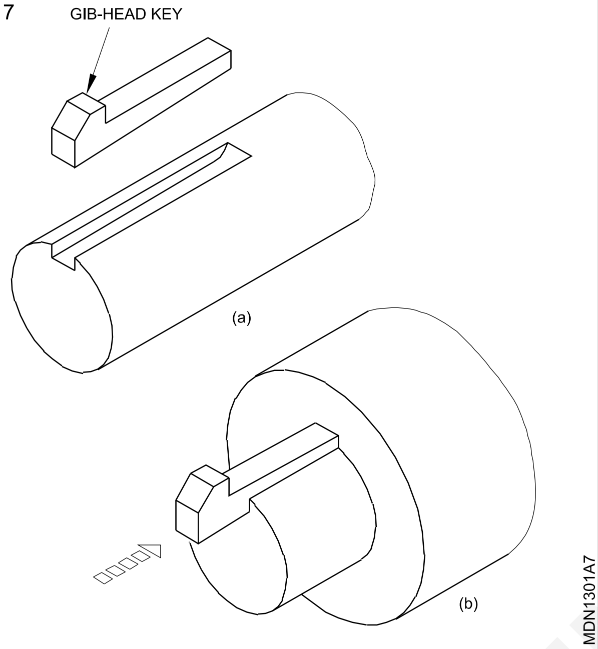


Fig 8

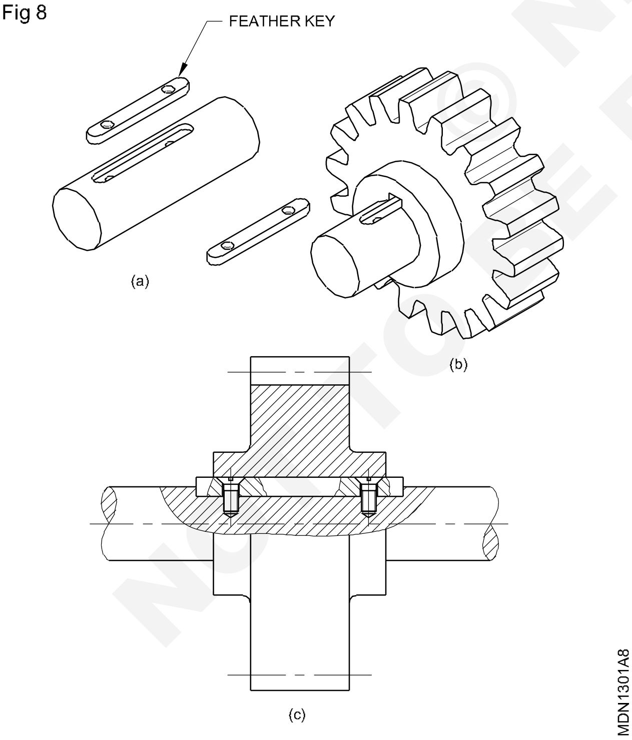


Fig 9

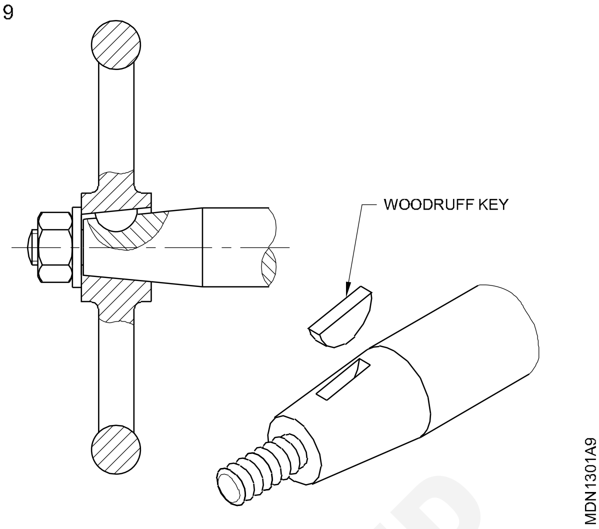


Fig 10

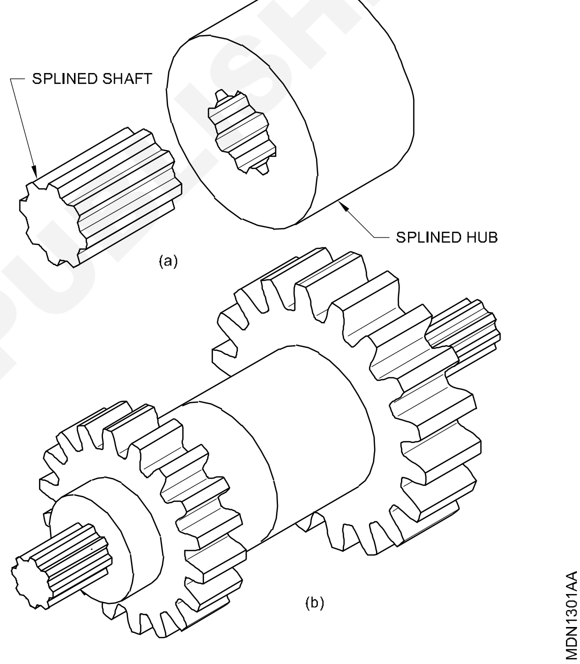
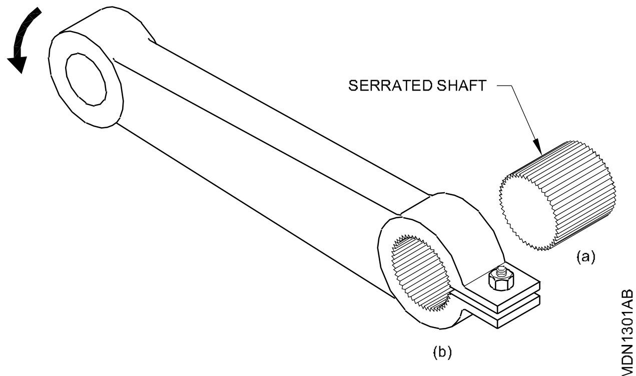


Fig 11



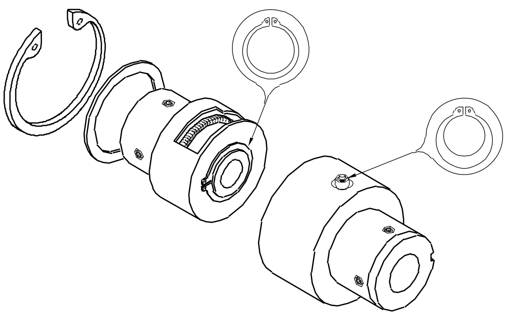
Circlips

Objectives : At the end of this lesson you shall be able to
- **state the functions of circlips**
- **state the different types of circlips**
- **state the advantages of circlips over other fastening devices**
- **state the material used for circlips.**

Circlips are fastening devices used to provide shoulders for positioning or limiting the movement of parts in an assembly (Fig 1) Circlips are also called `Retaining rings.

The rings are generally made of materials having good spring properties so that the fastener may be deformed elastically to a considerable degree and still spring back to its original shape. This permits the circlips to spring back into a groove or other recess in a part or they may be seated on a part in a deformed conditional so that they grip the part by functional means. Circlips are manufactured from spring steel with high tensile and yield strength.

Fig 1



MDN1301B1

Types: There are two types.

1 **Internal circlips (Fig 2):** This type of rings are assembled in holes, bores or housing.

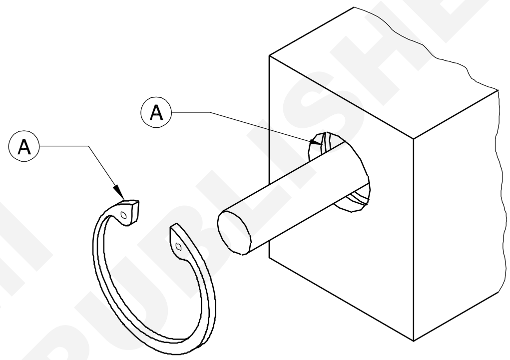
2 **External circlip (Fig 3):** This type of rings are installed on shafts, pins, studs and similar parts.

Both types offer a number of advantages over other types of fasteners.

- Their cost is relatively low when compared with other types of fasteners.
- Their use often results in savings in raw material and simplified machining operations for other parts in the assembly.
- One circlip often can replace two or more parts.
- Assembly toolings developed for circlips usually permit very rapid assembly of the fasteners, even by unskilled workers.

Material: Because retaining rings depend for their function largely on their ability to be deformed elastically during assembly and disassembly, the materials must have good spring properties. Circlips are manufactured from spring steel with high tensile and yield strength.

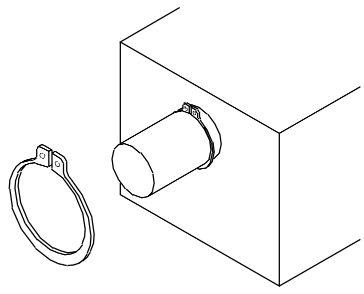
Fig 2



INTERNAL CIRCLIP

MDN1301B2

Fig 3



EXTERNAL CIRCLIP

MDN1301B3

Washers - Types and Uses

Objectives : At the end of this lesson you shall be able to
- **state the purpose of washers**
- **name the types of washers**
- **state the uses of each type of washers**
- **specify the washers as per B.I.S.**

Purpose: It is a common practice to provide washers under the nuts in bolted joints.

Washers help to (Fig 1)

- increase the frictional grip
- prevent loosening of nuts due to vibration
- prevent damage to the work piece and
- distribute force over a larger area.

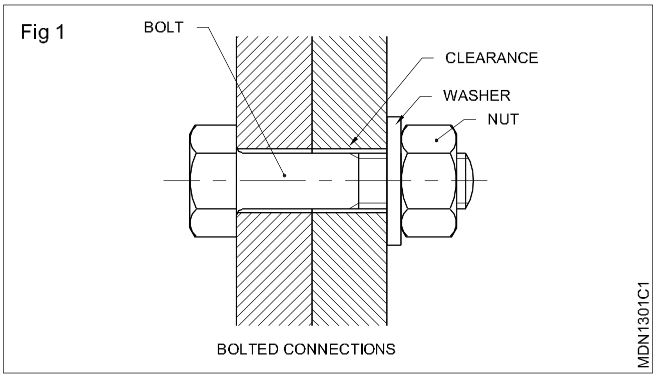


Fig 1

Types of washers: There are different types of washers available. They are;

- plain or flat washers
- taper washers
- spring washers
- tab washers
- toothed lock washers.

Plain or flat washers (Fig 2): These washers are used for bolting assemblies with flat surfaces. The diameter thickness and the bore diameter are proportional to the diameter of the bolt. (I.S. 2016) Plain washers are available as machined or punched washers.

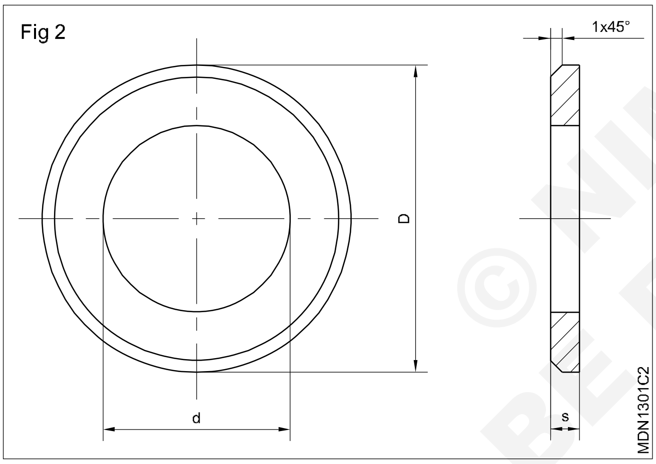


Fig 2

Machined washers (Fig 3): These washers are used for assemblies using machined components. These washers are available with chamber on one side or on both sides. They are heat treated and ground.

Punched washers: These do not have chamfers and are commonly used in structural fabrication work.

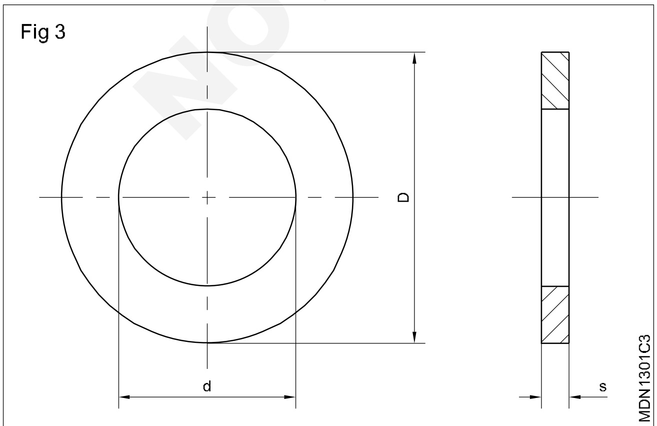


Fig 3

Tapered washers (Figs 4 & 5): These are used in structural assemblies with tapered surfaces like the inside of beams, channels etc. These washers help bolt head or nut to seat square to the hole.

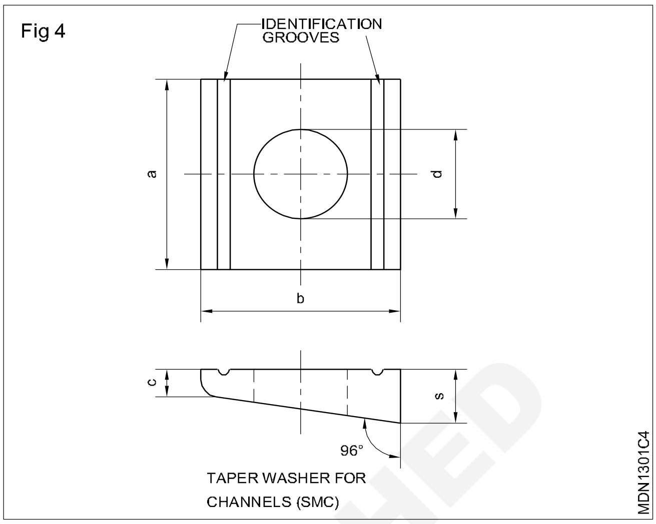


Fig 4

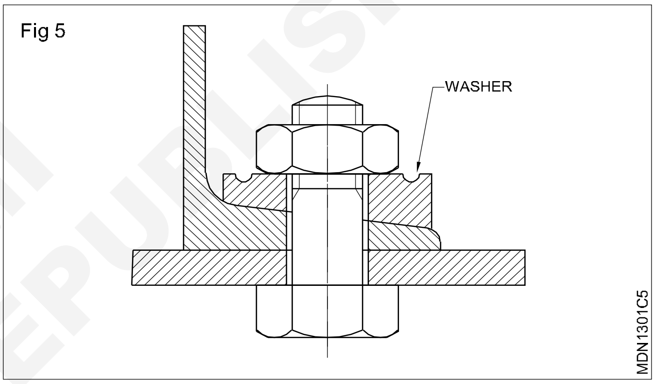


Fig 5

Spring washers (Figs 6 & 7): Spring washers are used under the nuts to prevent slackening of the nuts due to vibrations. They are made of spring steel, and when compressed they create tension between the bolt and the nut.

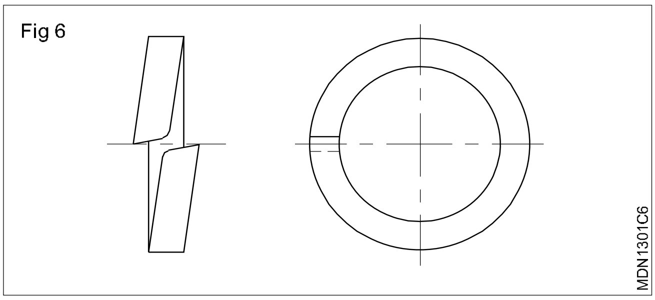


Fig 6

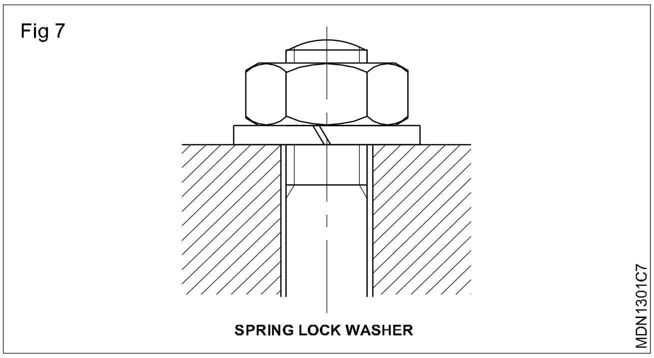
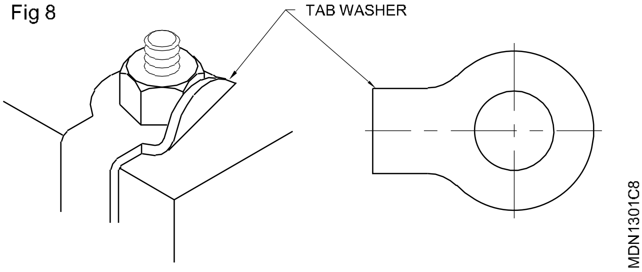


Fig 7

Tab washers (Fig 8): These washers are used for locking the nuts.

Fig 8



Toothed lock washers (Fig 9): These washers have serrations, cut and twisted. When placed between the nut and the assembly, this washer exerts friction on both the contacting surfaces. This prevents the nuts from slackening.

Specifications

The Indian standard Is:2016-1967 designates a washer by name, type size and number of the standard and material.

Example

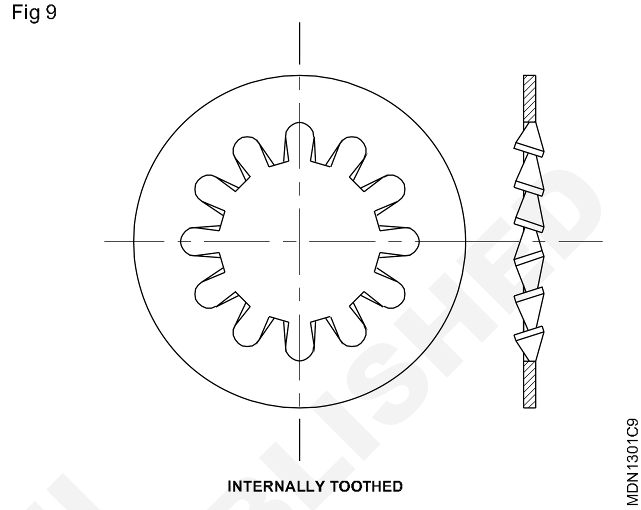
A machined washer of size 10.5 mm made of brass shall be designated as machined washer 10.5 IS:2016 Brass.

Note

For detailed specification of different types of washers refer to the following IS specifications.

Taper washer	- IS: 5374 and IS: 5372
Tab washer	- IS: 8068
Toothed lock washer	- IS: 5371
Plain washer	- IS: 2016

Fig 9



Different types of screws, nuts, studs and bolts

Objectives : At the end of this lesson you shall be able to
- **name the different types of machine screws used in heavy duty assembly**
- **name the different types of machine screws used in light assembly work**
- **state the uses of different types of machine screws**
- **name the different types of set screws.**

Machine screws are used when a nut cannot be used in the assembly and the component in the assembly has a threaded hole to receive the screws (Fig 1)

Types of machine screws (Heavy duty)

Hexagon head screws

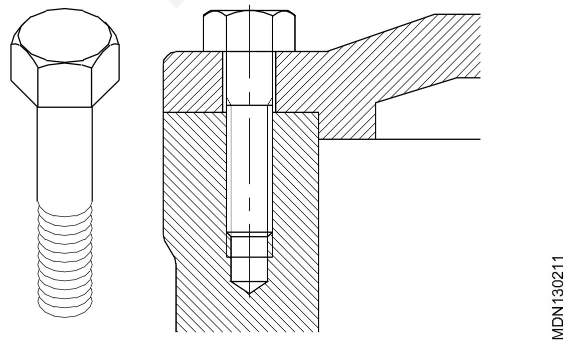
Hexagon socket head cap screws

Square head countersink head screws

These are heavy duty screws.

Hexagon head screws: These are used when the projection of the screw head will not be an obstruction in the assembly (Fig 1)

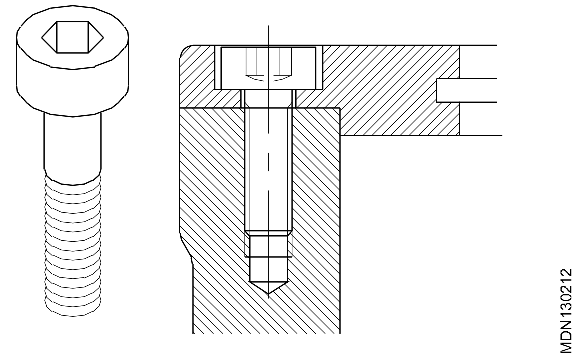
Fig 1



Hexagon socket head cap screws

These are used when the projection of the screw head above the surface is to be avoided. (Fig 2) The Indian Standard specification head socket cap screws cover the range from 1.6 mm to 36mm.

Fig 2



Hexagon head screws and hexagon socket head screws are made of steel. Hexagon head screws used in electrical work are made of brass.

Countersink head screws

There are four types of countersink head screws in common use.

They are:

- slotted countersink head screws (Fig 3)
- cross-recessed countersink head screws (Fig 4)
- slotted raised countersink head screws (Fig 5)
- cross recessed, raised countersink head screws (Fig 6)

Fig 3

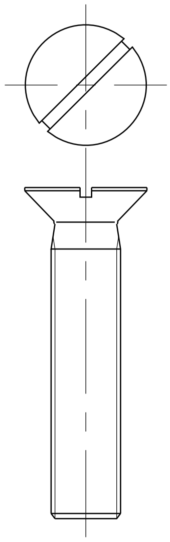


Fig 4

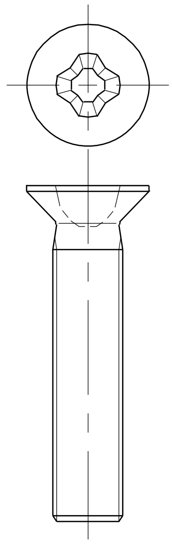


Fig 5

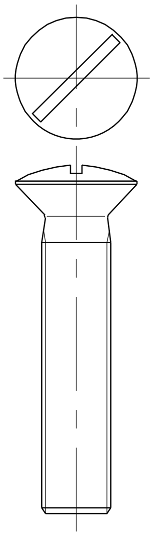
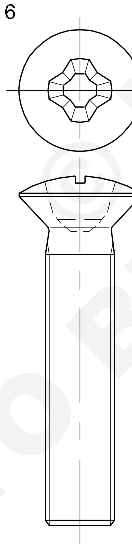


Fig 6

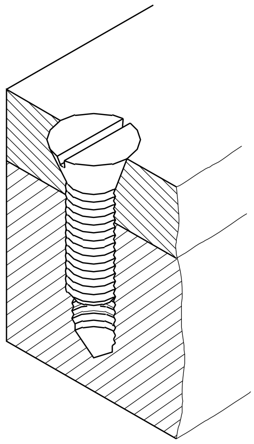


Countersink screws are capable of aligning the matching component correctly with the threaded hole. (Fig 7)

The projection of the screw head above the assembly is also avoided. B.I.S. specification covers the following ranges of countersink head screw sizes in different types.

- Slotted countersink head screws M1 - M20
- Cross-recessed countersink head screws M1.6 to M10.
- Slotted raised countersink head screws M1 to M20.
- Cross-recessed raised countersink head screws M1.6 to M10.

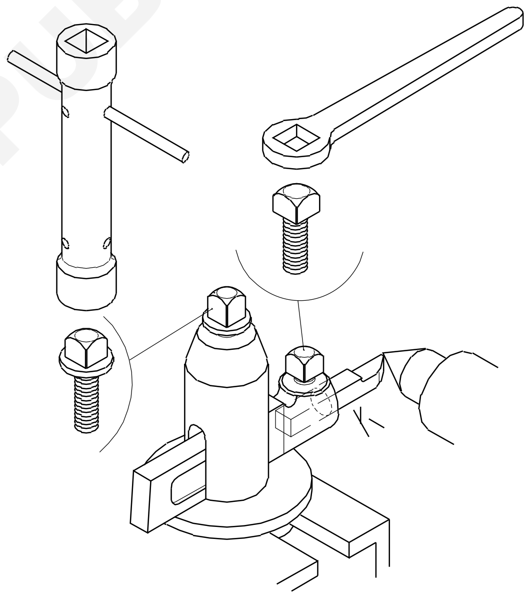
Fig 7



Square head screws (Fig 8)

Square head screws are used in places where there is frequent removal and refitting of the assembly. These screws are tightened to a higher torque using a wrench. (Fig 8) Square head screws are also available with a collar. In this there is a washer at the base which is an integral part of the head. The purpose of this collar is to protect the work-surface from damages due to constant use of wrenches.

Fig 8



Other types of machine screws used in light assembly work are:

Pan head (Fig 9) ; Cheese head (Fig 10)

Raised cheese head (Fig 11) ; Round head (Fig 12)

These screws are also available with slotted head or as cross-recessed.

The screws used for light duty are normally available up to 10mm thread diameter.

These screws are made of steel, stainless steel or brass. These screws are either plain finished, zinc-coated or chrome-plated.

Fig 9 Fig 10

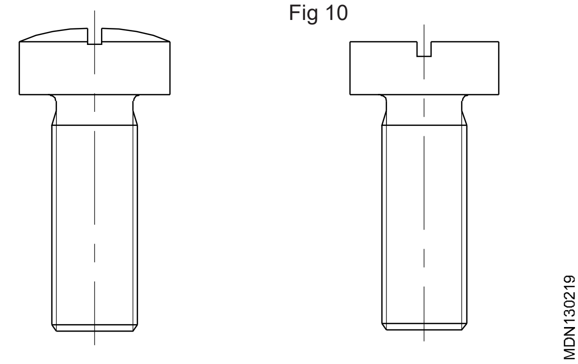
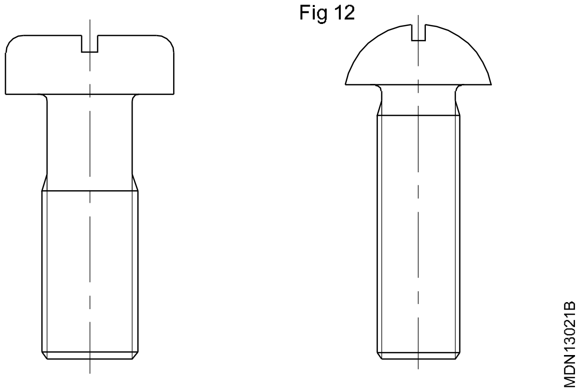


Fig 11 Fig 12



Set screws and grub screws

Hexagonal socket set screws (Fig 13): These are headless socket screws available with different points for various functional requirements. (Fig 14)

These points either allow to bite into the metal or tighten without damage to the work-surface. They are used to fasten pulleys, collars etc. to the shafts. They are used for higher strength applications where space is limited.

Fig 13

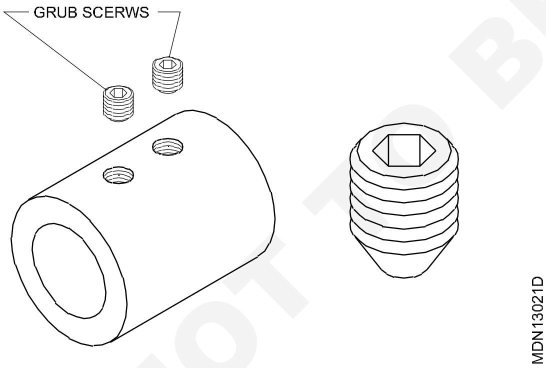
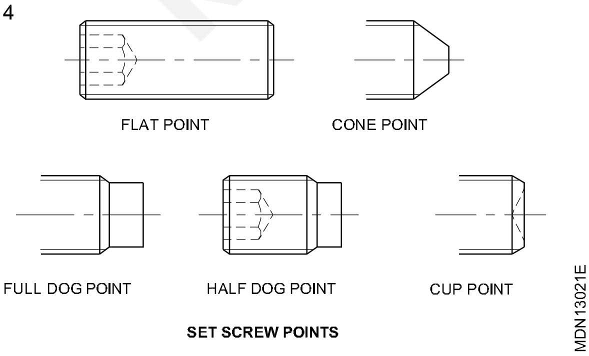


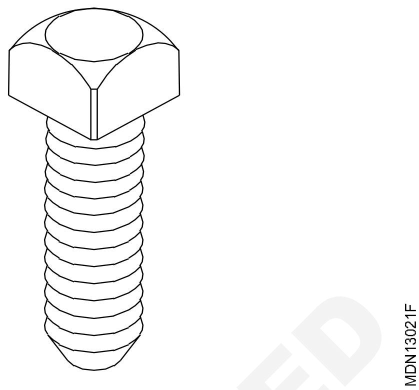
Fig 14



Square set screws (Fig 15): These set screws have similar applications as hexagon socket set screws but have square heads projecting above the work-surface.

These are useful when the assembly needs frequent disassembly and setting.

Fig 15



Grub screws: Grubs have similar application as hexagon socket set screws but are used for light holding.(Fig 16)

Grub screws are also available with different types of points (Fig 17)

Fig 16

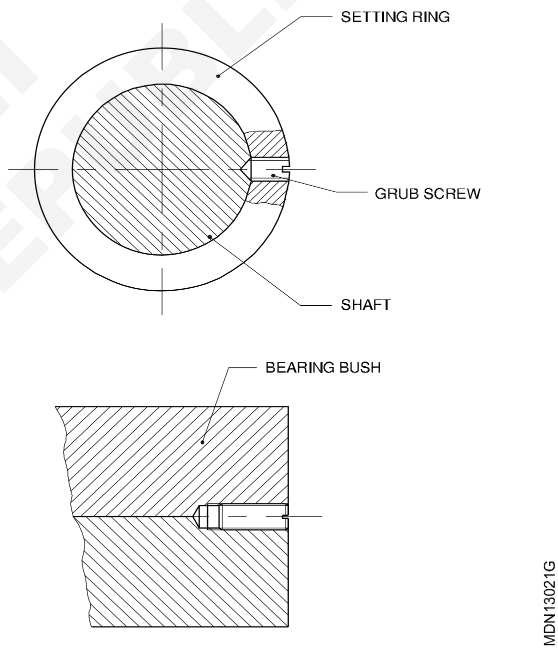
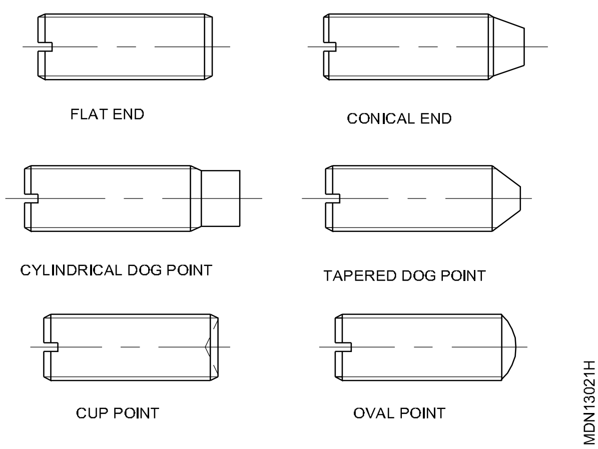


Fig 17



Thumb screws

Objectives : At the end of this lesson you shall be able to
- **state the types of thumb screws**
- **state the uses of thumb screws**
- **designate thumb screws as per B.I.S. specification.**

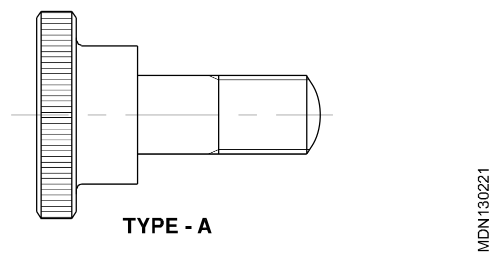
Thumb screws are used in places where fixing and removal of components are frequent. Tightening and loosening of the assembly is finger tight only.

Types

As per the Indian standard specification IS:3726-1972 there are five types of thumb screws.

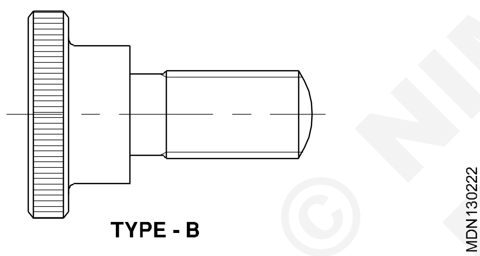
Type-A Thumb screws partially threaded (Fig 1)

Fig 1



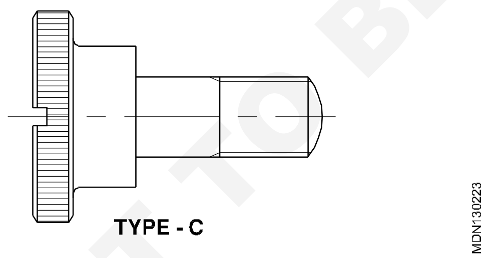
Type-B Thumb screws fully threaded (Fig 2)

Fig 2



Type-C Slotted thumb screw partially threaded (Fig 3)

Fig 3



Type-D Slotted thumb screw fully threaded (Fig 4)

Type-E Flat thumb screws (Fig 5)

Fig 4

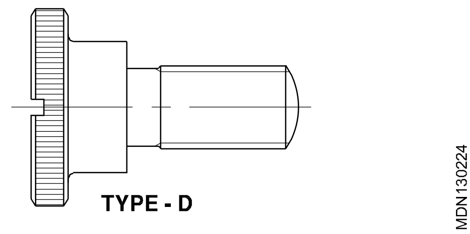
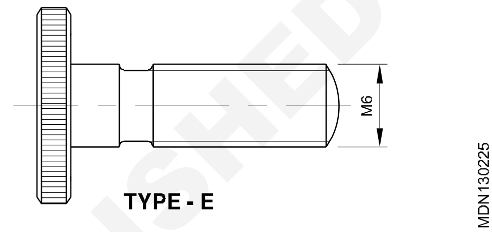


Fig 5



The type of thumb screw selected depends on the actual requirement in the assembly.

Sizes

Thumbs screws are available in the following sizes as per B.I.S.

M1.6, M2, M2.5, M3, M4, M5, M6, M8 and M10.

Designation of thumb screws

Thumb screws shall be designated by the nomenclature, type, thread size, nominal length, the number of Indian Standard and the symbol for mechanical properties.

Example

A thumb screw of Type `A', size M6, nominal length 12mm and of property class 4.6 shall be designated as:

Thumb screws A M6 x 12 IS: 3726-4.6

When brass or any other non-ferrous metal is used for the manufacture of thumb screws, the word Brass or the name of the non-ferrous metal used will replace the property class number in the designation.

Types of nuts

Objectives : At the end of this lesson you shall be able to
- **name the common types of nuts**
- **state the features and uses of the common types of nuts.**

Different types of nuts are used depending on the requirement of the assembly.

Hexagonal nuts (Fig 1 & 2)

This is the most commonly used type of nut in structural and machine tool construction.

Hexagonal nuts are available in different thicknesses. Thin nuts are used as lock-nuts.

Square nut (Fig 3)

Square bolts are provided with square nuts. In bolts for coaches mostly square nuts are used.

Fig 1

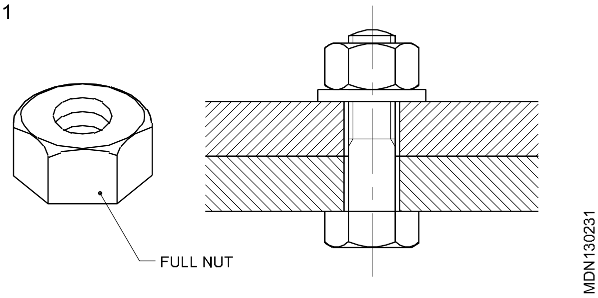


Fig 2

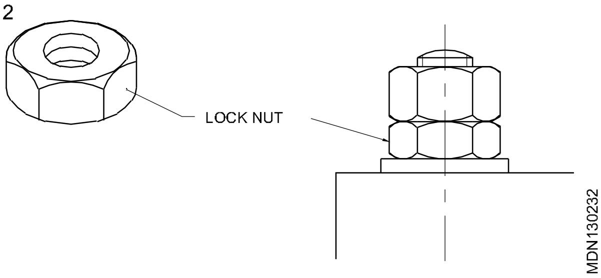
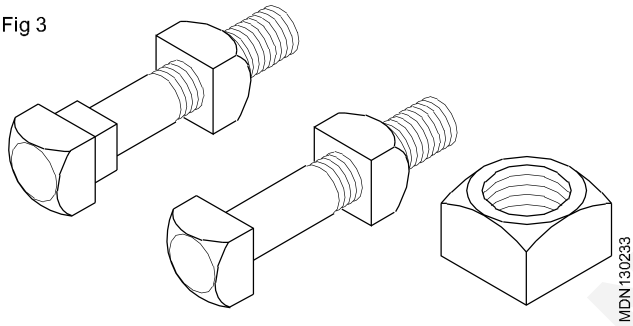


Fig 3



Self-locking nuts (Simmonds lock-nut)

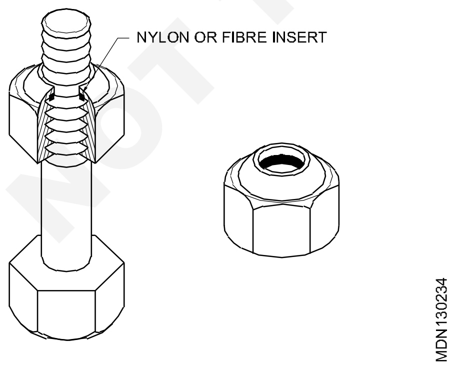
This nut has an internal groove cut in which a fiber or nylon ring is inserted. This ring holds the nut tightly on the bolt and serves as a locking device.

Self-locking nuts are not used with studs.

T-nuts: T-nuts are used along with studs on machine tools for fixing/holding devices or workpieces.

Slotted and castle nuts (Fig 4)

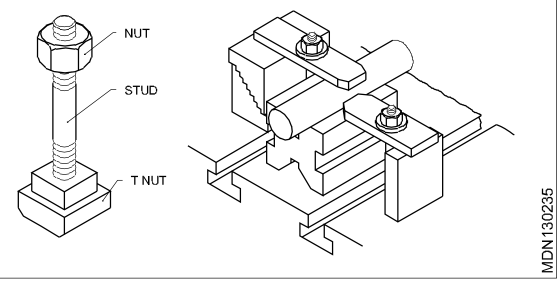
Fig 4



Round nuts (Fig 5)

Round nuts of different types are available for special applications.

Fig 5



Slotted round nut (Figs 6 to 10)

Slotted round nut for hook wrench.

Round nut with set pin holes on sides

Round nut with holes in the face.

Fig 6

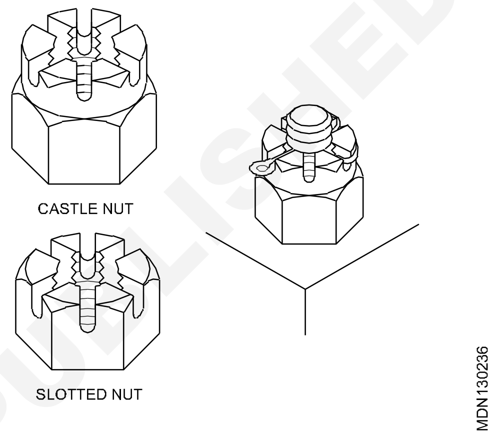


Fig 7

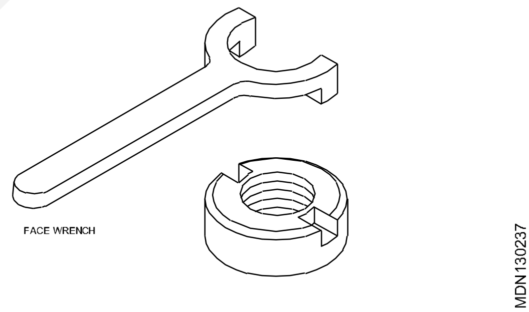


Fig 8

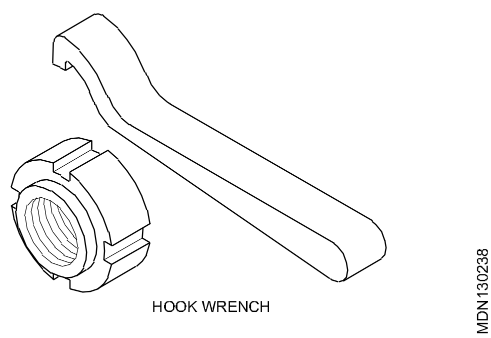


Fig 9

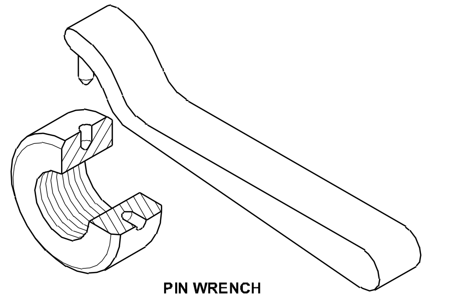
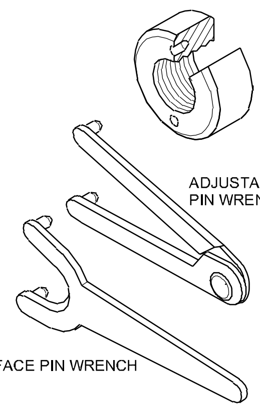


Fig 10



Methods of removing broken studs

Objectives : At the end of this lesson you shall be able to
- **state the reasons for breakage of studs**
- **state the different methods for removing broken studs.**

The stud is used in the place of a bolt. Where hole cannot be had for the bolt to pass through or to avoid the use of an unnecessarily long bolt. Studs are generally used to fix up cover plates or to connect cylinder covers to engine cylinders.

Reasons for breakage of stud/bolt

Excessive torque is applied while screwing the stud into the hole/tightening the nut.

Threads are corroded excessively.

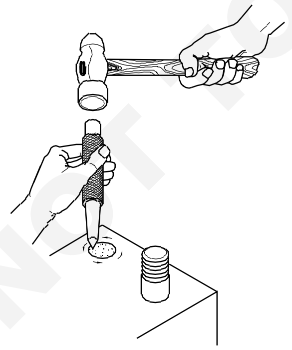
Matching threads are not of proper formation.

Threads are seized.

Methods of removing broken studs

Prick punch method (Fig 1): If the stud is broken very near to the surface, drive it in an anticlockwise direction, using a prick punch and hammer to remove it.

Fig 1



Filing square form (Fig 2): When the stud is broken a little above the surface, form a square on the projecting portion to suit a standard spanner. Then turn it anticlockwise using a spanner to remove stud.

Using square taper punch (Fig 3): Broken studs can also be removed by drilling a blind hole (hole diameter equal to half of stud diameter) and driving a square taper punch into the hole as shown Fig 3. Turn the punch using a suitable spanner in an anticlockwise direction to unscrew the stud.

Fig 2

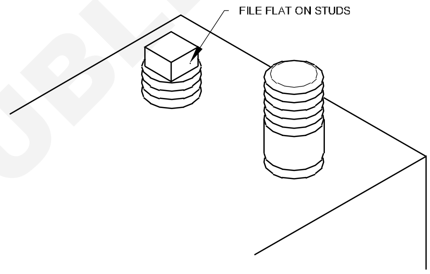
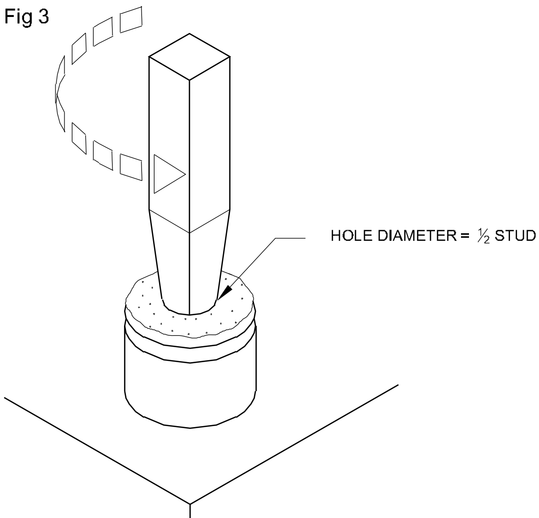


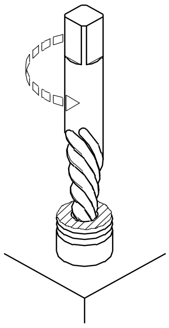
Fig 3



Ezy-out method (Fig 4)

Ezy-out or a stud extractor is a hand tool, some what similar to the form of a taper reamer but it has left hand spiral. It is available in a set of 5 pieces. The recommended drill size is punched on each ezy-out.

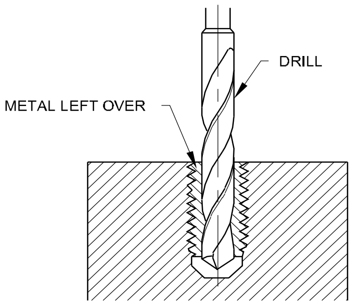
Fig 4



Drilling the hole, the recommended ezy-out is set on and turned in an anticlockwise direction by a tap wrench. As it is rotated it penetrates into the hole increasing its grip and in the process the broken stud gets unscrewed.

Making drill hole (Fig 5)

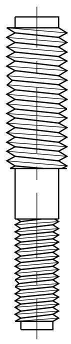
Fig 5



Correctly find out the centre of the broken stud and drill a hole nearly equal to the core diameter of the stud down the centre so that the threads only remain (Fig 5). Remove the thread portion by the point of a scriber in the form of broken chips. Re-tap the drill hole to clear the threads.

If all other methods fail drill a hole equal to the size of the stud size or a little over and tap the hole with an oversize tap. Now a special oversize stud as shown in figure 6 is to be made and fitted in position. (Fig 6)

Fig 6



OVERSIZE SPECIAL STUD TO SUIT THE TAPPED HOLE

Screw pitch gauge

Objectives: At the end of this lesson you shall be able to
- **state the purpose of a screw pitch gauge**
- **state the features of a screw pitch gauge.**

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 mm. The pitch of the blade is stamped on each blade. The standard and range of the pitches are marked on the case. (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)

Fig 1

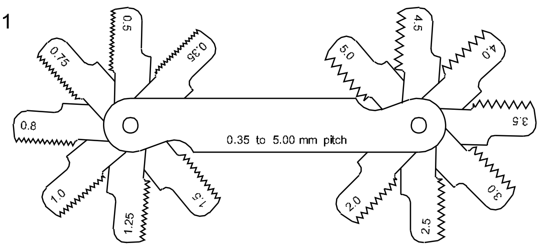
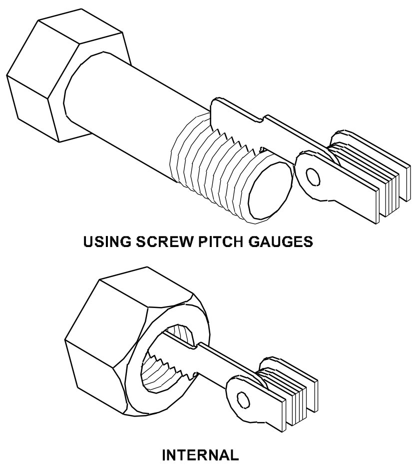


Fig 2



USING SCREW PITCH GAUGES

INTERNAL

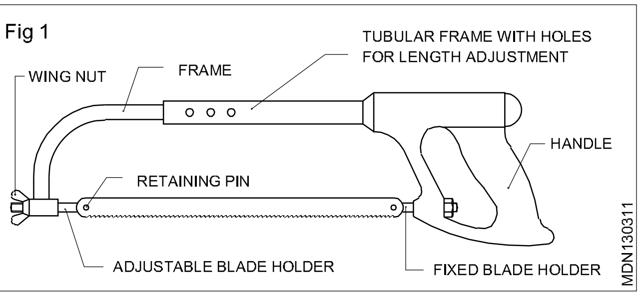
Hacksaw frame and blade

Objectives : At the end of this lesson you shall be able to
- **name the parts of a hacksaw frame**
- **specify hacksaw frames**
- **state the different types of hacksaw blades and their uses.**

The hand hacksaw is used along with a blade to cut metals of different sections. It is also used to cut slots and contours.

The parts are idenfified in the (Fig 1)

Fig 1



Types of hacksaw frames

The two different types of hacksaw frames are solid frame and adjustable frames.

Solid frame

Only a particular standard length of blade can be fitted to this frame.

Adjustable frame (Flat type)

Different standard lengths of blades can be fitted to this frame.

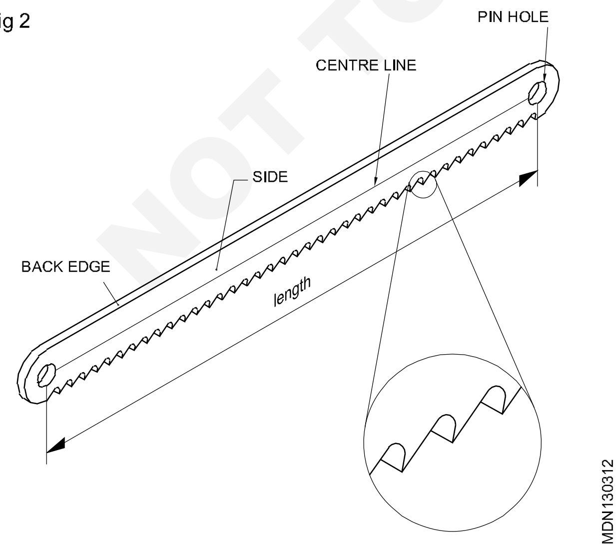
Adjustable frame (Tubular type)

This is the most commonly used type. It gives a better grip and control, while sawing.

For proper working. It is necessary to have frames of rigid construction.

Hacksaw blades (Fig 2)

Fig 2



A hacksaw blade is a thin narrow steel band with teeth and two pin holes at the ends. It is used along with a hacksaw frame. The blade is made of either low alloy steel (LAS) or high speed steel (HSS) and is available in standard lengths of 250 mm and 300 mm.

Types of hacksaw blades: Two types of hacksaw bladws are available - all hard blades and flexible blades.

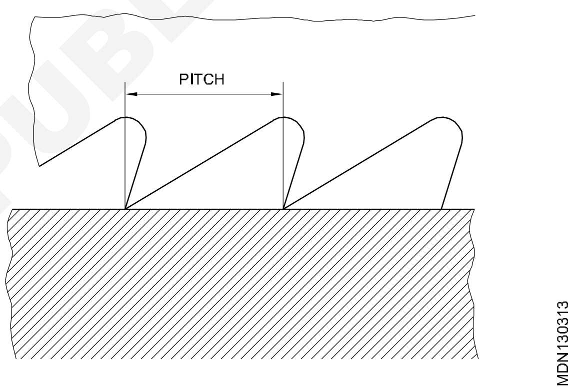
All hard blades: These are hardened to the full width between the pin holes.

Flexible blades: For these types of blades. Only the teeth are hardened. Because of their flexibility, these blades are useful for cutting along curved lines.

Pitch of the blade (Fig 3)

The distance between adjacent teeth is known as the pitch of the blade.

Fig 3



Classification	Pitch
Coarse	1.8 mm
Medium	1.4 mm & 1.0 mm
Fine	0.8 mm

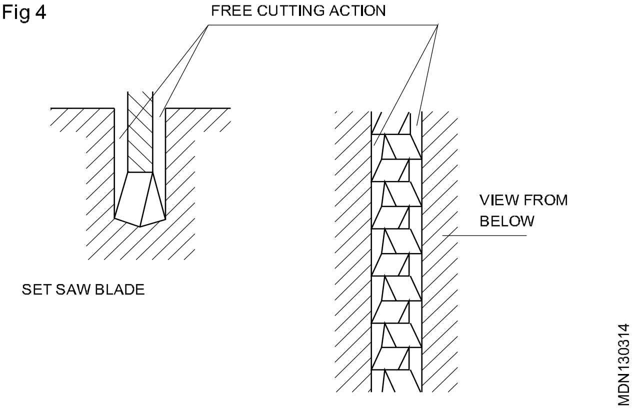
Hacksaw blades are designated according to their length, pitch and type.

To prevent the saw blade binding when penetrating into the material and to allow free movement of the blade, the cut is to be border than the thickness of the saw blade. This is achieved by the setting the saw teeth. There are two types of saw teeth settings.

Staggered set (Fig 4)

Alternate teeth or groups of teeth are staggered. This arrangement helps for free cutting and provides for good chip clearance.

Fig 4



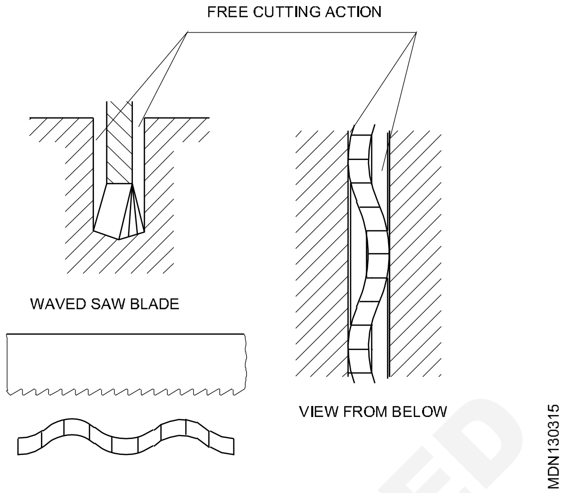
Wave set (Fig 5): In this, the teeth of the blade are arranged in a wave form.

Sets of blades can be classified as follows

Pitch	Type of Set
0.8 mm	Wave -set
1.0 mm	Wave or staggered
Over 1.0 mm	Staggered

For the best results, the blade with the right pitch should be selected and fitted correctly.

Fig 5



Elements of a file

Objective: At the end of this lesson you shall be able to
- **name the parts of a file.**

Methods of Material Cutting

The three methods of metal cutting are abrasion (Fig 1). Fusion (Fig 2) and Incision (Fig 3)

Filing is a method for removing excess material from a work pieces by using a file which acts as a cutting tool. (Fig 4) shows how to hold a file. Files are available many shapes and sizes.

Parts of a file (Fig 5): The parts of a file as can be seen in figure 5, are

Tip or Point: The end opposite to tang.

Face or side: The broad part of the file with teeth cut on its surface.

Edge: The thin part of the file with a single row of parallel teeth.

Heel: The portion of the broad part without teeth.

Shoulder: The curved part of the file separating tang from the body.

Tang: The narrow and thin part of a file which fits into the handle

Fig 4

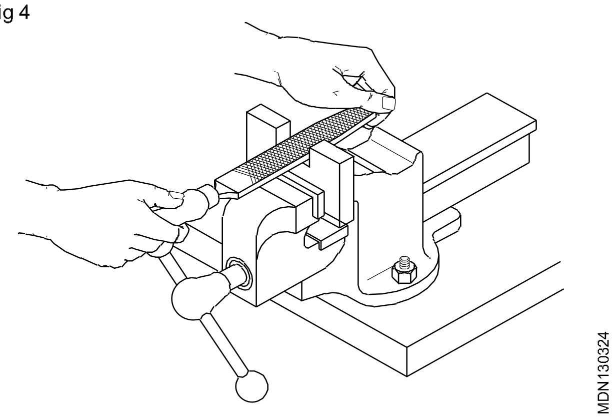


Fig 1

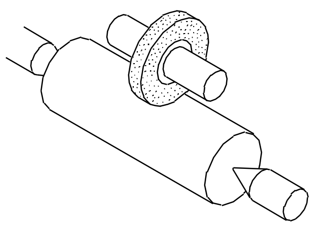


Fig 2

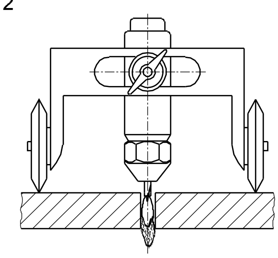
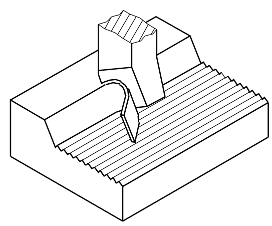


Fig 3



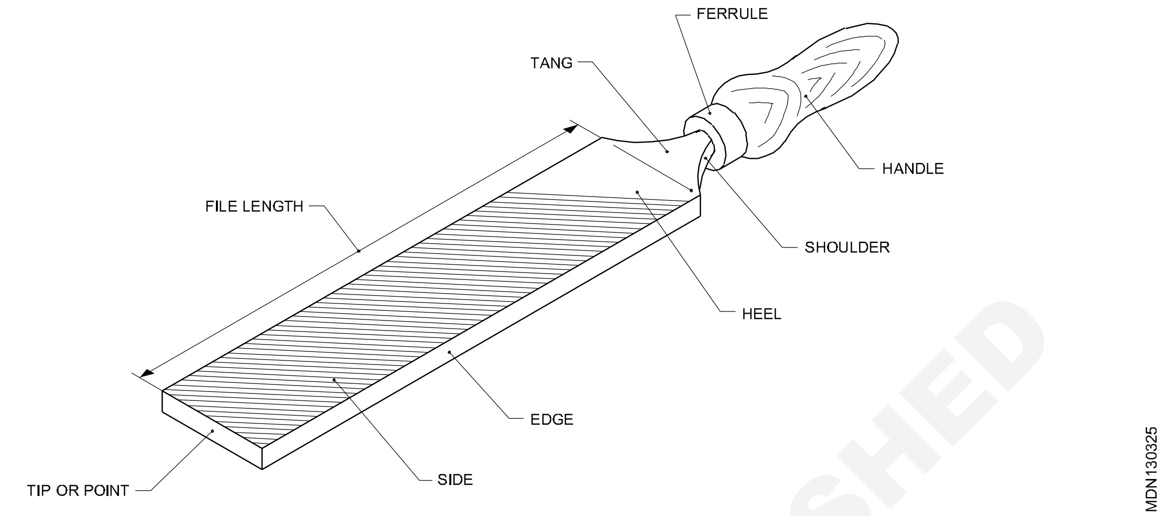
Handle: The part fitted to the tang for holding the file.

Ferrule: A protective metal ring to prevent cracking of the handle.

Materials

Generally files are made of high carbon or high grade cast steel. The body portion is hardened and tempered. The tang is however not hardened.

Fig 5



Cut of files

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

The teeth of a file are formed by cuts made on its face. Files have cuts of different types. Files with different cuts have different uses.

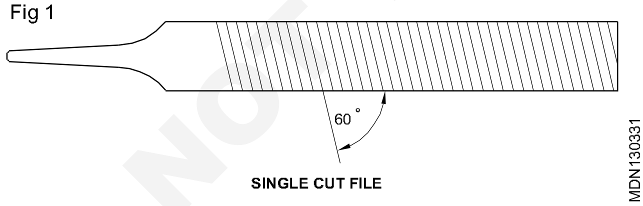
Types of cuts

Basically there are four types.

Single cut. Double cut. Rasp cut and curved cut.

Single cut file (Fig 1): A single cut file has rows of teeth cut in one direction across its face. The teeth are at an angle of 60° to the centre line. It can chips as wide as the cut of the file. Files with this cut are useful for filing soft metals like brass, aluminium, bronze and copper.

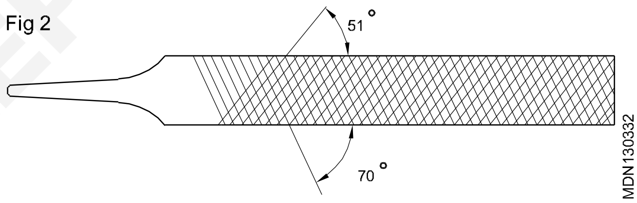
Fig 1



Single cut files do not remove stock as fast as double cut files, but the surface finish obtained is much smoother.

Double cut file (Fig 2): A double cut file has two rows of teeth cut diagonal to each other. The first row of teeth is know as OVERCUT and they are cut at an angle of 70°. The other cut, made diagonal to this, is known as UPCUT and is at an angle of 51°. This removes stock faster then the single cut file.

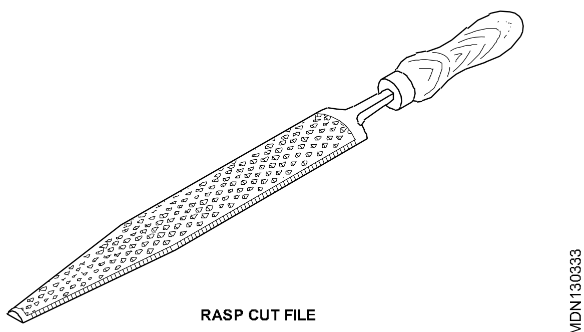
Fig 2



Rasp cut file (Fig 3)

The rasp cut has individual sharp pointed teeth in a line and is useful for filing wood, leather and other soft materials. These files are available only in half round shape.

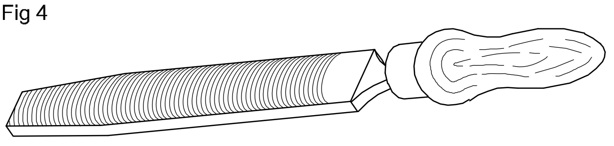
Fig 3



Curved cut file (Fig 4)

These files have deeper cutting action and are useful for filing soft materials like - aluminium, tin, copper and plastic. The curved cut files are available only in a flat shape.

Fig 4



The selection of a file with a particular type of cut is based on the material to be filed. Single cut files are used for filing soft materials. But certain special files, for example, those used for sharpening saws are also of single cut.

File specifications and grades

Objectives : At the end of this lesson you shall be able to
- **state how files are specified**
- **name the different grades of files**
- **state the application of each grade of file.**

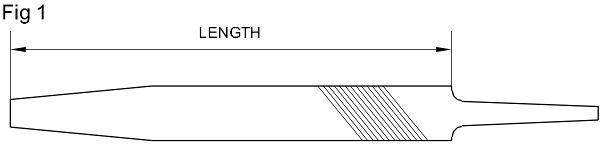
Files are manufactured in different types and grades to meet the various needs.

Files are specified according to their length, grade, cut and shape.

Length of file is the distance from the tip to the heel (Fig 1)

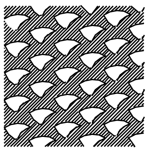
File grades are determined by the spacing of the teeth.

Fig 1



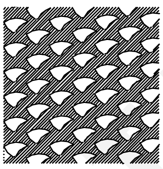
A rough file (Fig 2) is used for removing rapidly a larger quantity of metal. It is mostly used for trimming the rough edges of soft metal castings.

Fig 2



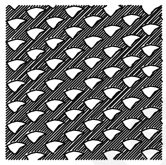
A bastard file (Fig 3) is used in cases where there is a heavy reduction of material.

Fig 3



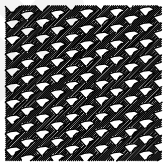
A second cut file (Fig 4) is used to give a good finish on metals. It is excellent to file hard metals. It is useful for bringing the jobs close to the finishing size.

Fig 4



A smooth file (Fig 5) is used to remove small quantity of material and to give a good finish.

Fig 5

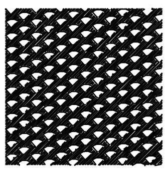


A dead smooth (Fig 6) file is used to bring to accurate size with a high degree of finish.

The most used grades of files are bastard, second cut, smooth and dead smooth. These are the grades recommended by the Bureau of Indian standers. (BIS)

Different sizes of files with the same grade will have varying sizes of teeth. In longer files, the teeth will be coarser.

F Fig 6



File - Applications

Objectives : At the end of this lesson you shall be able to
- **state the features of flat and hand files**
- **state the application of flat and hand files.**

Files are made in different shapes so as to be able to file and finish components to different shapes.

The shape of files is usually specified by their cross section.

The files useful for this exercise are flat files and hand files.

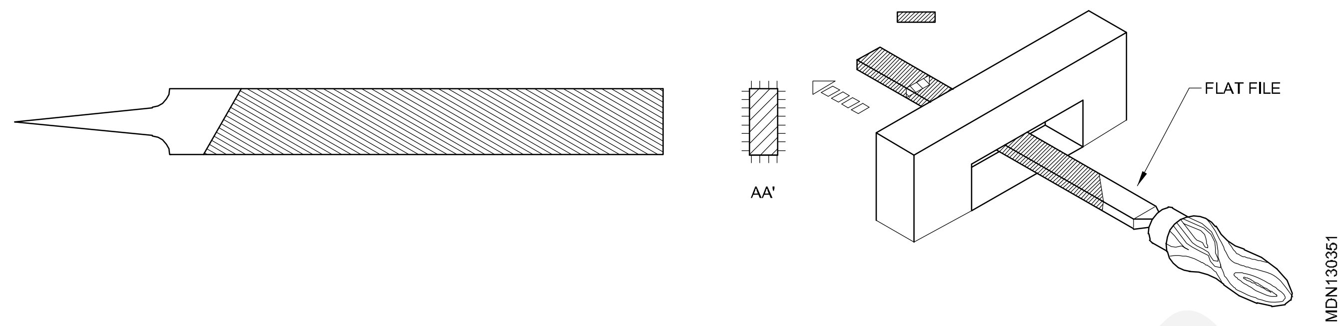
Flat files (Fig 1): These files are of a rectangular cross section. The edges along the width of these files are parallel up to two-thirds of the length, and then they taper towrads the point. The faces are double cut, and the edges single cut. These files are used for general purpose work. They are useful for filling and finishing external and internal surfaces.

Hand files (Fig 1)

These files are similar to the flat files in their cross section. The edges along the width are parallel through the length.

The faces are double cut. One edge is single cut whereas the other is safe edge. Because of the safe edge, they are useful for filling surfaces which are at right angles to surfaces already finished.

Fig 1



Shapes of files

Objectives : At the end of this lesson you shall be able to
- **name the different shapes of files**
- **state the uses of Square, Round, Half Round, Triangular and Knife-edge files.**

For filing and finishing different profiles, files of different shapes are used.

The shape of files is stated by its cross section.

Common files of different shapes

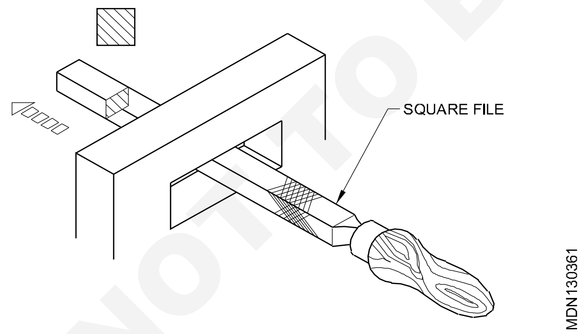
Flat file, Hand file, Square file, Round file

Half found file, Triangular file and Knife-edge file. (Flat and hand files have already been discussed).

Square File

The square file is square in its cross section. It is used for filing square holes, internal square corners, rectangular opening, keyways and spines. (Fig 1)

Fig 1



Round file

A round file is circular in its cross section. It is used for enlarging the circular holes and filing profiles with fillets. (Fig 2)

Half round File

A half round file is in the shape of a segment of a circle. It is used for filing internal curved surfaces (Fig 3)

Triangular file: A triangular file is of a triangular cross section. It is used for filing corners and angles which are more than 60^0. (Fig 4)

Fig 2

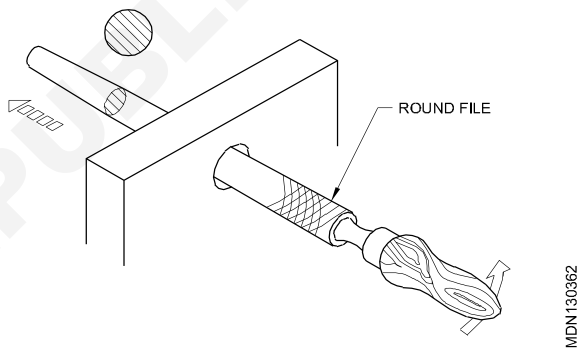


Fig 3

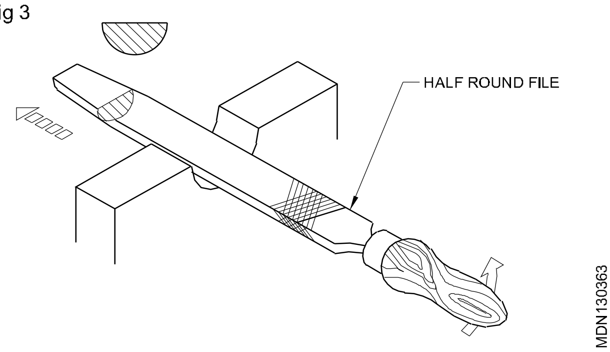
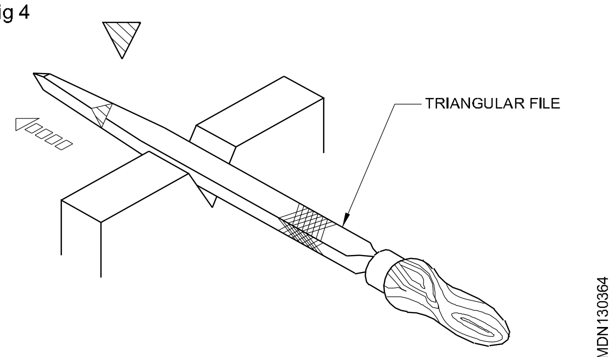


Fig 4



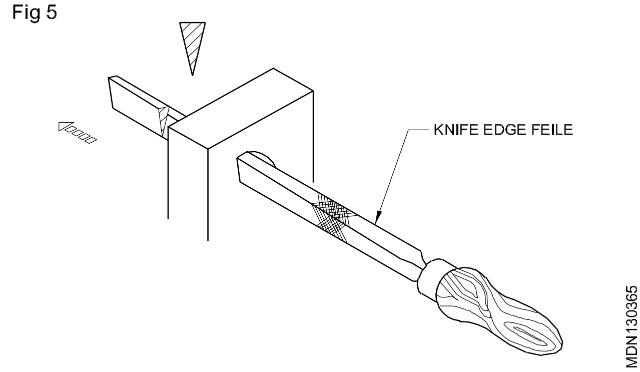
Knife-edge File

A knife-edge file has the cross section of a sharp triangle. It is used for filing narrow grooves and angles above 10^0. (Fig 5)

The above files have one third of their lengths tapered. They are available both in single and double cuts.

Square, round, half-round and triangular-files are available in lengths of 100, 150, 200, 250, 300 and 400 mm. These files are made in bastard, second cut and smooth grades.

Fig 5



Off- hand grinding with bench and pedestal grinders

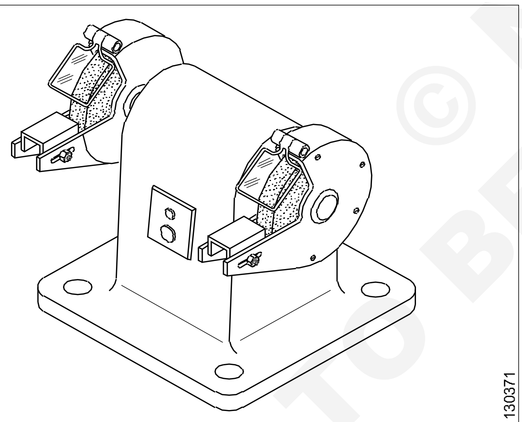
Objectives : At the end of this lesson you shall be able to
- **state the purpose of off-hand grinding**
- **state the features of bench and pedestal grinders.**

Off-hand grinding is the operation of removing material which does not require great accuracy in size or shape. This is carried out by pressing the workpiece by hand against a grinding wheel.

Off-hand grinding is performed for rough grinding of jobs and resharpening of scribers, punches, chisels, twist drills, single point cutting tools etc.

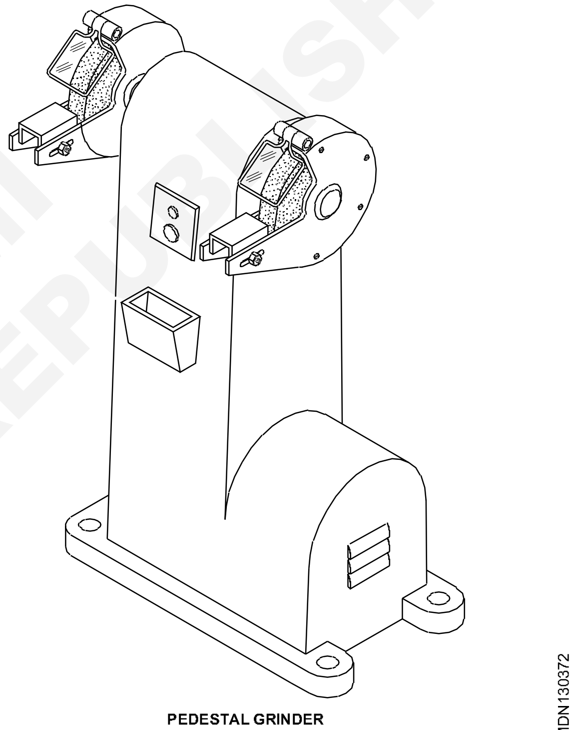
Off-hand grinding is performed with a bench or pedestal grinder (Fig 1 and 2)

Fig 1



BENCH GRINDER

Fig 2



PEDESTAL GRINDER

Bench grinders

Bench grinders are fitted to a bench or table, and are useful for light duty work.

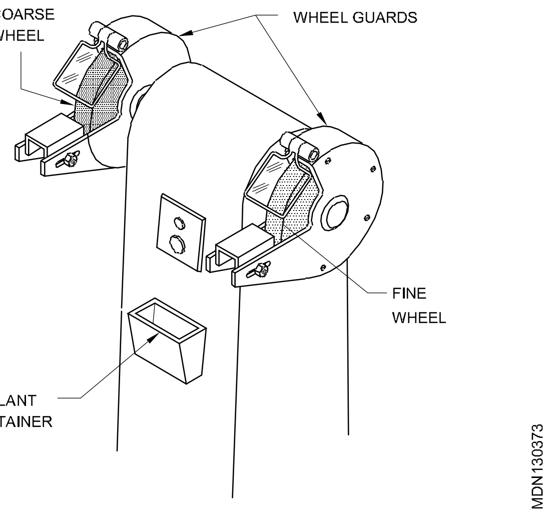
Pedestal grinders

Pedestal grinders are mounted on a base (pedestal), which is fastened to the floor. They are used for heavy duty work.

These grinders consist of an electric motor and two spindles for mounting grinding wheels. On one spindle a coarse-grained wheel is fitted, and on the other, a fine grained wheel. For safety, while working, wheel guards are provided. (Fig 3)

A coolant container is provided for frequent cooling of the work. (Fig 3)

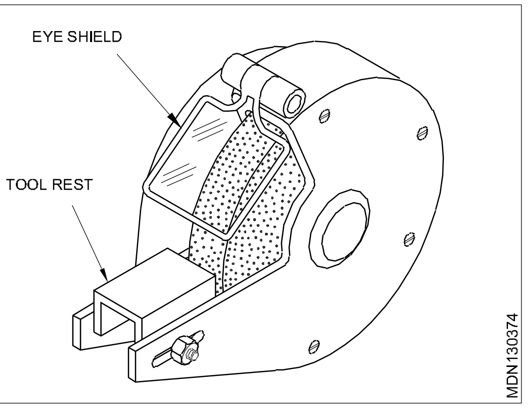
Fig 3



Adjustable work-rests are provided for both wheels to support the work while grinding. These work-rests must be set very close to the wheels. (Fig 4)

Extra eye-shields are also provided for the protection of the eyes. (Fig 4)

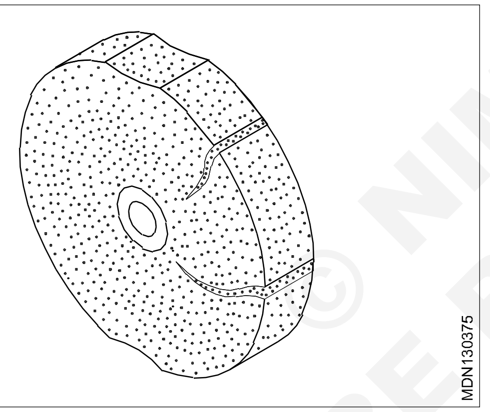
Fig 4



While grinding

Adjust the tool-rest as close to the wheel as possible. The maximum recommended gap is 2 mm. This will help to prevent the work from being caught between the tool-rest and the wheel. (Fig 5)

Fig 5



Small jobs should be held with pliers or other suitable tools. (Fig 5)

Never hold jobs with cotton waste or similar materials.

Use gloves for your hands while grinding heavy jobs.

Do not grind on the side of the grinding wheels. (Fig 6)

Move the work across the full face of the wheel to prevent uneven wearing of the grinding wheel. (Fig 7)

Fig 6

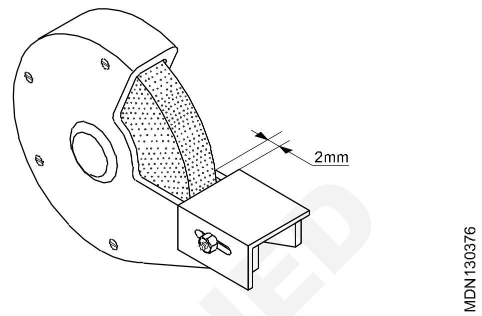
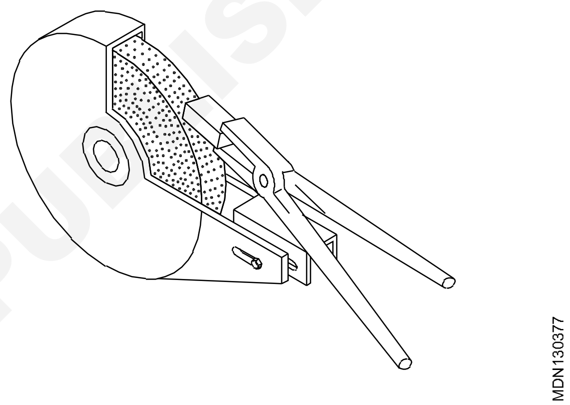


Fig 7



Safe working on off - hand grinders

Objective : At the end of this lesson you shall be able to
- **work safety on an off-hand grinder.**

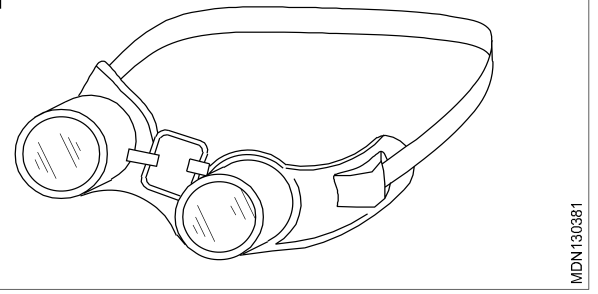
While working on off-hand grinders, it is important to observe the following safety measures.

Before starting

Make sure the grinding wheel guards are in place.

Wear safety goggles while grinding. (Fig 1)

Fig 1

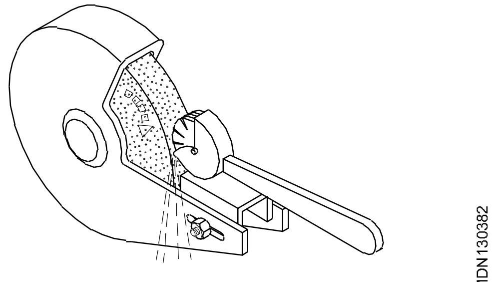


Do not work on grinding wheels which are loaded or glazed. (Fig 2)

If any abnormal sound is noticed, stop the machine. Cracked or improperly balanced wheels are dangerous.

Stand on one side of the machine while starting.

Fig 2



Gasket

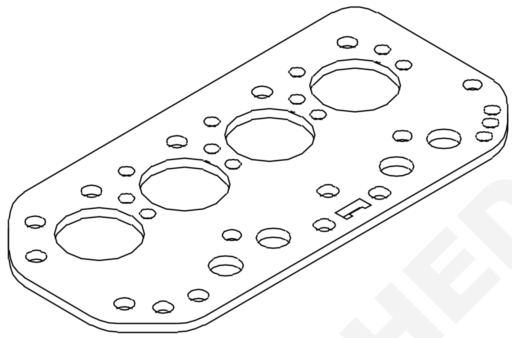
Objectives : At the end of this lesson you shall be able to
- **state the need of gaskets**
- **state the materials of gaskets.**

The gasket (Fig 1) in automotive engines has to combat sealing problems caused by high and low temperatures, expansion and contraction, vibration, pressure or vacuum, corrosion and oxidation, inadequate sealing reduces the service life and efficiency of the components.

The seals which are used between two stationary components are called static seats. The most common static seal is gasket. Gaskets are designed to suit particular needs and are manufactured from different materials like copper, aluminium, cork fibre, asbestos, synthetic rubber, paper and various combinations of these materials. Now a days, semi-liquid is also used as gasket.

Cylinder head gaskets are the most complicated in design and construction because they must withstand extreme pressure, vibration, high temperature and expansion changes. They must seal against compression, oil and coolants. They must resist extrusion, elongation, oxidation and chemicals. The cylinder head gasket consists of a multi-layer of materials with coolant and oil passages.

Fig 1



Oil seal

Objectives : At the end of this lesson you shall be able to
- **state the use of oil seals**
- **explain different types of oil seals**
- **state the material used for oil seals.**

Seals: Seals are sealing parts on static or moving inter faces of machines, devices pipes and tank reservoir. Seals are used for sealing spaces as different pressure against each other, i.e. combustion chamber & oilways etc. Oil seals have flexible lip that rubs against a shaft or housing to prevent leakage of fluid (grease, oil etc.)

All seal are used to retain or separate lubricant on fluid

Types of oil seal

i Flexible lip

ii radial lip

iii rotary shaft seal

Configuration

a single lip b double lip

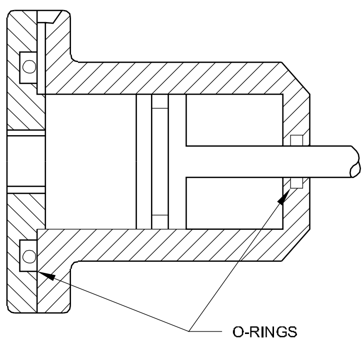
c triple lip d Fan lip

Seals capable of sealing two components which move or rotate insulation to each other are called dynamic seals. The most common dynamic seal is called 'O' rings which are moulded to close tolerances in the cross-sectional areas and to the inner and outer diameters.

Bearing Isolator (Fig 1)

Bearing Isolator are dynamics designed to protect bearing from outside container. The contain potor (rotating) & stater (Stationary) member same bearing Isolator are of labyrinth construction of other use o-rings.

Fig 1



Specifications

Sealing orientation (Fig 2 & 3)

- Rod seals or shaft seals are type of radial seal.
- Radial seal are press fit into a housing bore with the sealing up contacting the shaft.
- Piston seals are radial seal. These seals are fit on a shaft with sealing lip contacting the housing bore. 'O' rings are external lip seals.
- Symmetrical seal works equally as a rod or piston seal.
- An axial seals axially against a housing or machine component.
- Material - Nylon, Rubber, polythene, PTFE etc.

Fig 2

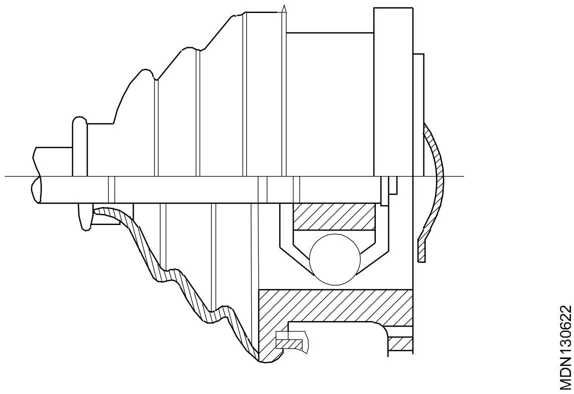
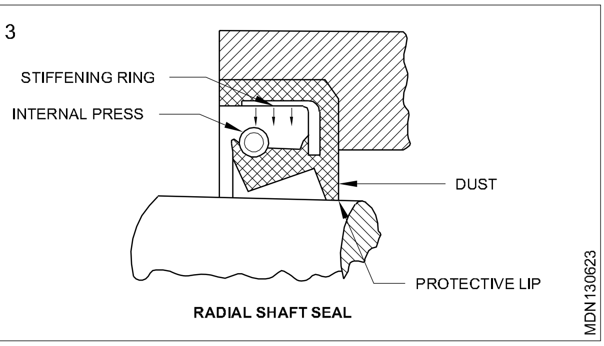


Fig 3



Sealants

Type of sealant: There are three types of sealant used.

1 The Teflon tape

2 Pipe tape

3 Anaerobic resin compound

1 **Teflon tape:** The purpose of this Teflon tape (whir), no sticking tape is the serve as a lubricant when threaded part of pipe a piping system are being assembles.

2 **Pipe tape:** This material relies on a solvent carrier and hardware when the solvent evaporator. The resulting seal adheres to all plastic, metal pipes and effective blocks leak paths.

3 **Anaerobic resin compound:** This sealant is confined within the threads of the metal pipe connection and air in exuded. It maintains the sealing properties even after heat aging, excellent then prelature and solvent remittance.

Key concepts

- Tape does not truly seal, it lubricator.
- Tape can harden and become brittle.
- Anaerobic must be combatable with pipe fitting material.

Sealant selection factors

- Material
- Temperature
- Pressure
- Vibration

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.**

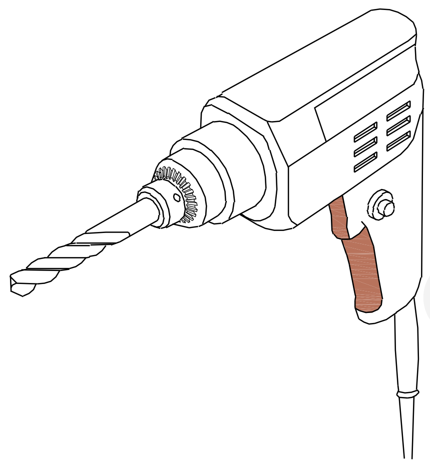
Necessity: Portable hand drills of different types are used for certain jobs which cannot be handled on stationary drilling machines.

Types: There are two types of portable drilling machines, power operated and hand operated.

Power Operated drilling machines

Electric hand drill (light duty) (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.

Fig 1



Electric hand drill (heavy duty) (Fig 2 and 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.

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 2

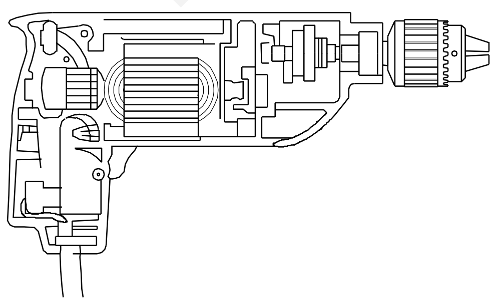


Fig 3

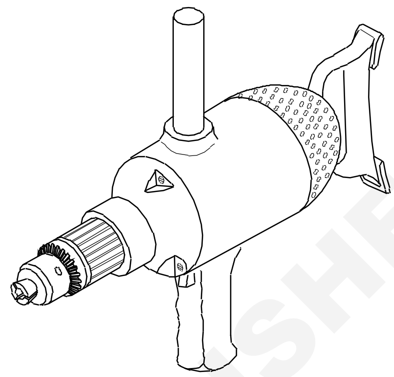
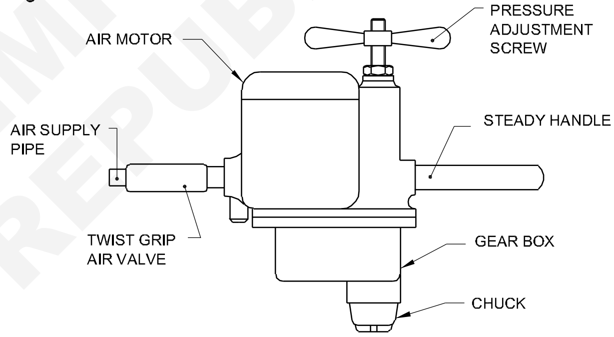


Fig 4



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.

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 5

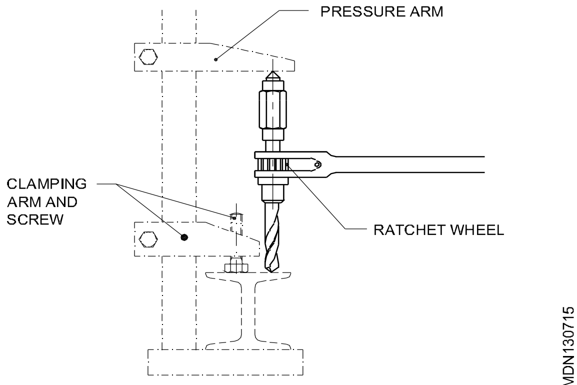


Fig 6

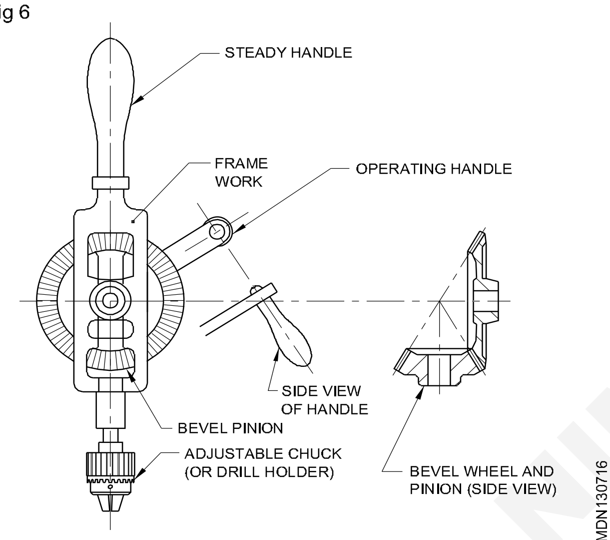
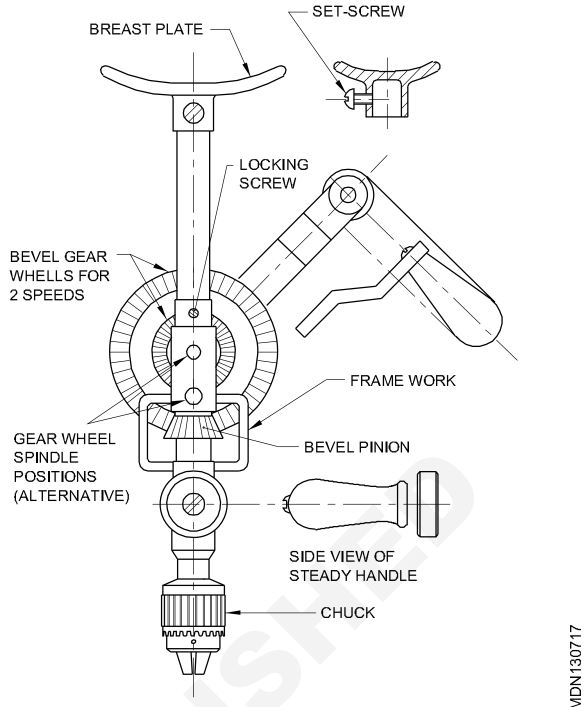


Fig 7



Drilling machines (bench and pillar type)

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**
- **compare the features of the bench type, pillar type and radial drilling machines.**

The principal 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.

Fig 1

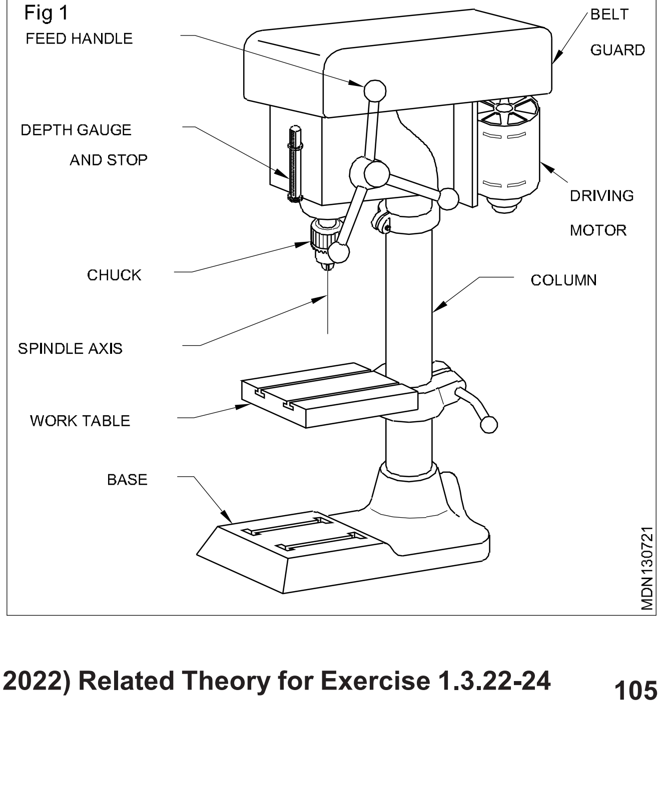
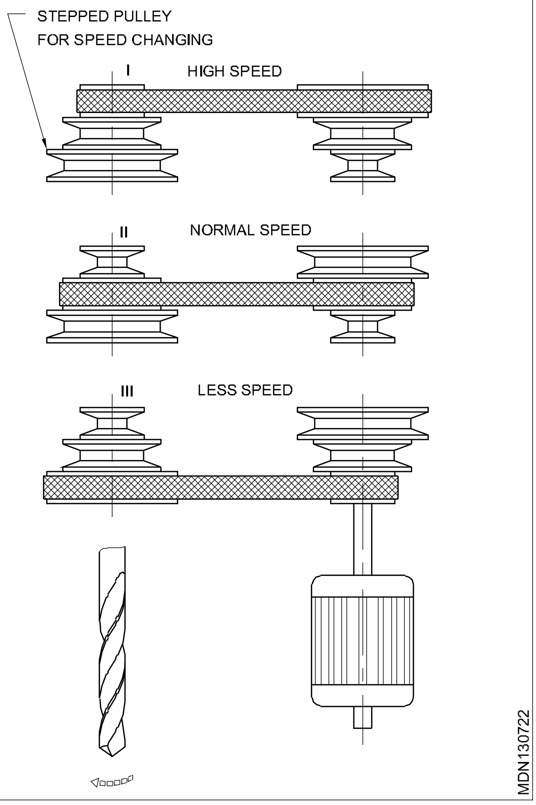


Fig 2

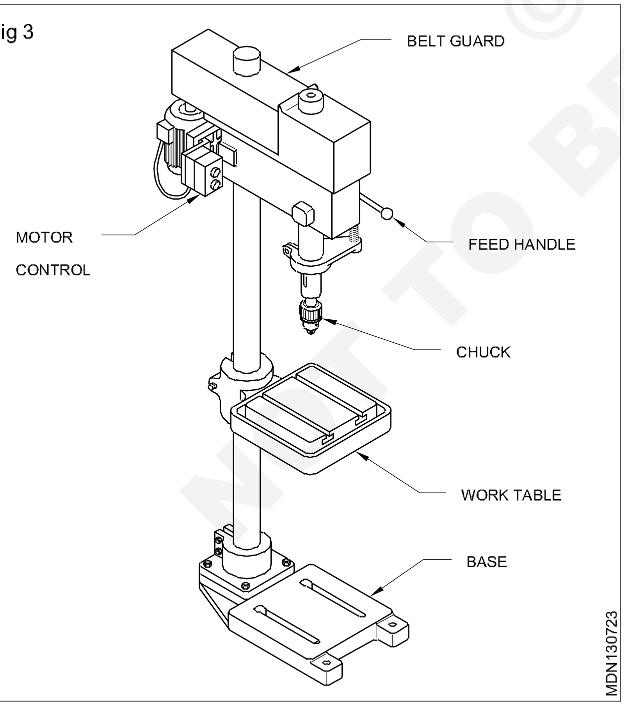


For normal drilling, the work-surface is kept horizontal. If the holes are to be drilled at an angle, the table can be tilted.

Different spindle speeds are achieved by changing the belt position in the stepped pulley. (Fig 2)

The pillar drilling machine (Fig 3)

Fig 3



This is an enlarged version of the sensitive bench drilling machine. These drilling machines are mounded on the floor and driven by more powerful electric motors. They are used for heavy duty work. Pillar drilling machines are available in different sizes.

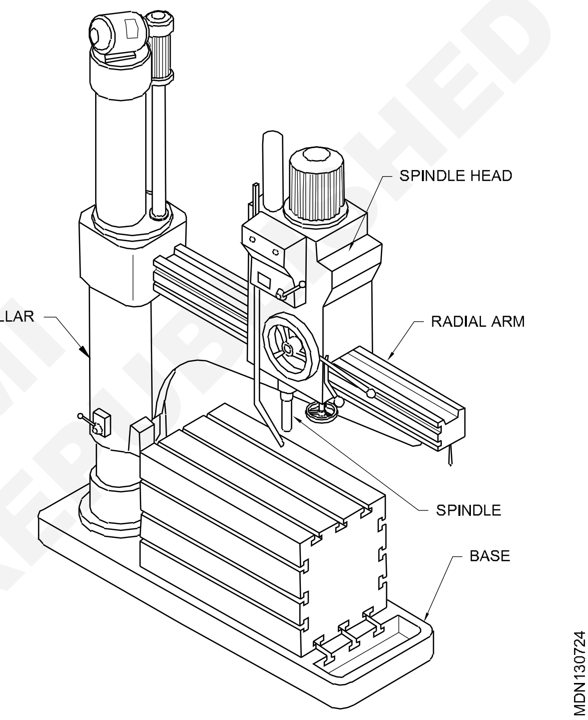
Large machines are provided with a rack and pinion mechanism for moving the table for setting the work.

Radial drilling machines (Fig 4)

These are used to drill;

- large diameter holes
- multiple holes in one setting of the work
- heavy and large workpieces.

Fig 4



Features

The radial drilling machine has a radial arm on which the spindle head is mounted.

The spindle head can be moved along the radial arm and can be locked in any position.

The arm is supported by a pillar (column). It can be rotated about with the pillar as centre. Therefore, the drill spindle can cover the entire working surface of the table. The arm can be lifted or lowered.

The motor mounted on the spindle head rotates the spindle.

The variable-speed gearbox provides a large range of r.p.m.

Cutting speed and RPM

Objectives : At the end of this lesson you shall be able to
- **define cutting speed**
- **state the factors for determining the cutting speed**
- **differentiate between cutting speed and R.P.M**
- **determine R.P.M spindle speed**
- **select R.P.M for drill sizes from tables.**

For a drill to give satisfactory performance, it must operate at the correct cutting speed and feed.

Cutting speed is the speed at which the cutting edge passes over the material while cutting, and is expressed in metres per minute.

Cutting speed is also sometimes stated as surface speed or peripheral speed.

The selection of the recommended cutting speed for drilling depends on the materials to be drilled, and the tool material.

Tool manufacturers usually provide a table of cutting speeds required for different materials.

The recommended cutting speeds for different materials are given in the table. Based on the cutting speed recommended, the R.P.M at which a drill has to be driven, is determined.

Calculate R.P.M

$$V = \frac{n \times d \times \Pi}{1000} \text{ m/min}$$

$$n = \frac{v \times 1000}{d \times \pi} \text{ r.p.m}$$

n = R.P.M

v = cutting speed in m/min

d = diameter of drill in mm

Π = 3.14

Material being drilled for HSS	Cutting speed (m/min)
Aluminium	70 -100
Brass	35-50
Bronze (Phosphor)	20-35
Cast Iron (grey)	25-40
Copper	35-45
LC/MC steel/ Alloy steel	20-30
Thermosetting plastic (low speed due to abrasive properties)	5-8

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 to 5)

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 and it is necessary to determine the clamping method according to the work.

Fig 1

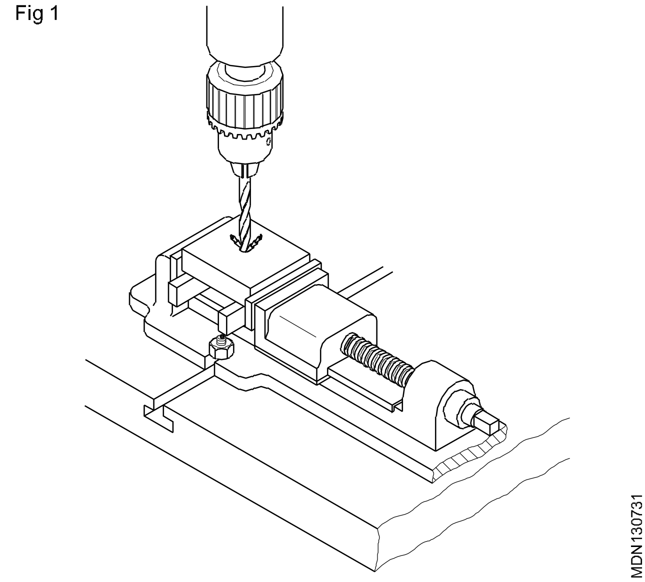


Fig 2

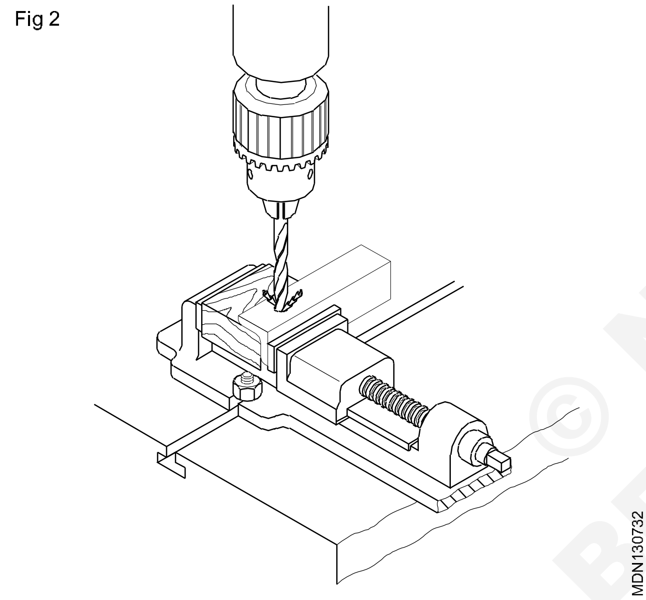


Fig 3

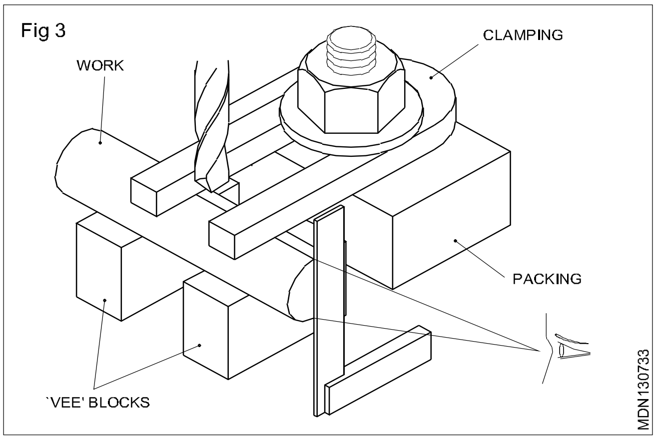


Fig 4

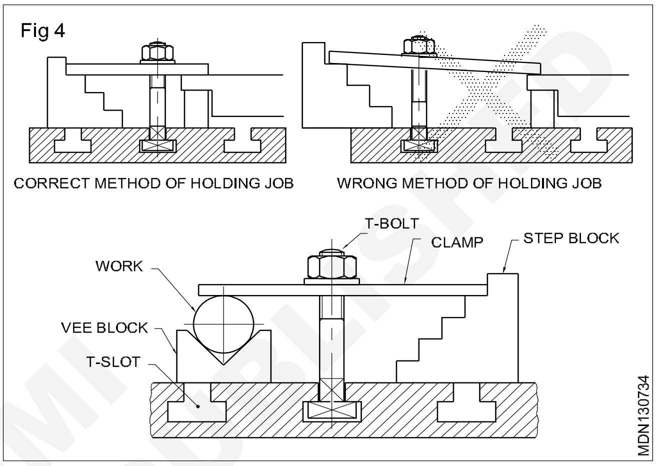
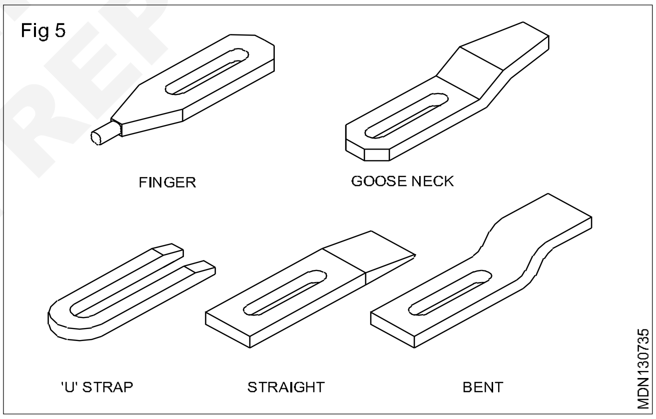


Fig 5



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 of 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.

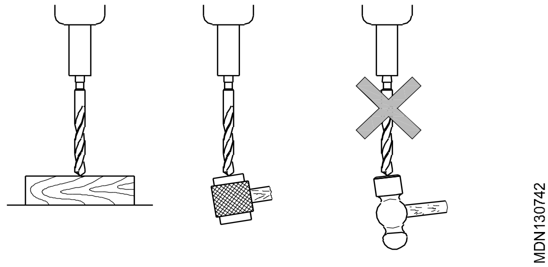
Drills are provided with five different sizes of morse tapers, and are numbered from MT 1 to MT5.

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)

Fig 2



While removing the drill from the sockets sleeves, don't allow it to fall on the table or jobs. (Fig 4)

Fig 3

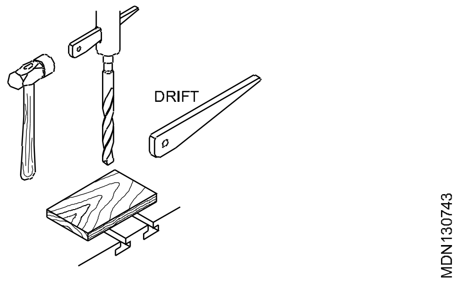


Fig 4

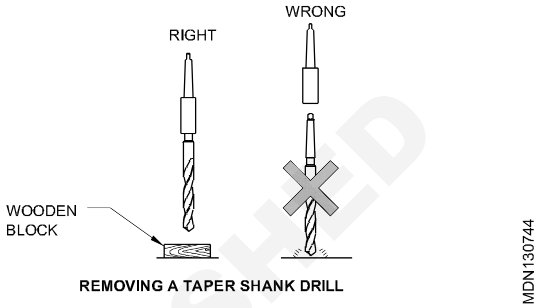
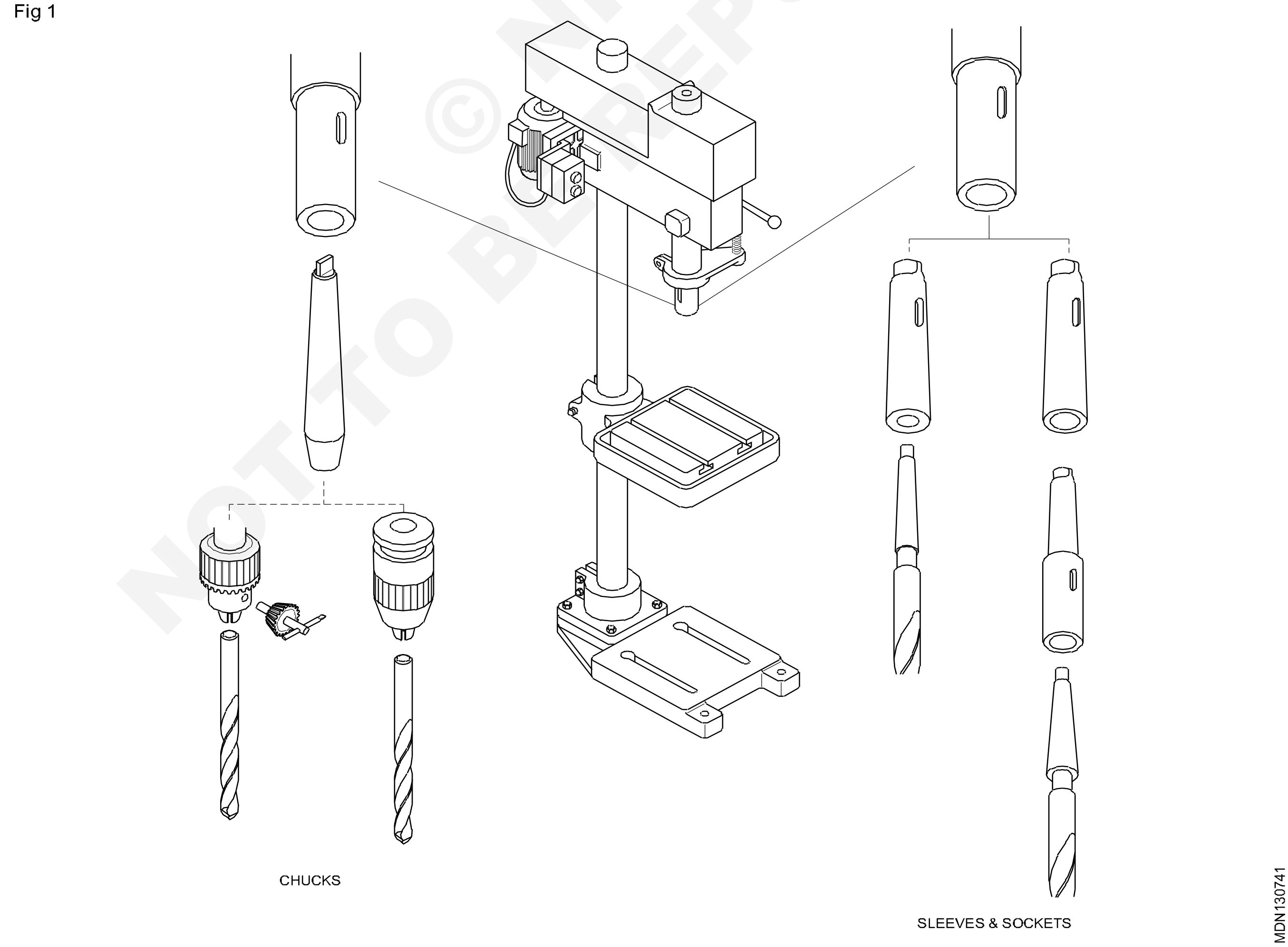


Fig 1

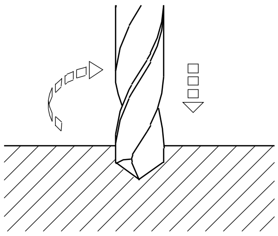


Drill bits

Objectives : At the end of this lesson you shall be able to
- **state the functions of drills**
- **name the parts of a drill**
- **state the functions of each part of a drill.**

Drilling is a process of making holes on workpieces. The drill used as a tool. For drilling the drill is rotated with a downward pressure causing the tool to penetrate into the material (Fig 1)

Fig 1



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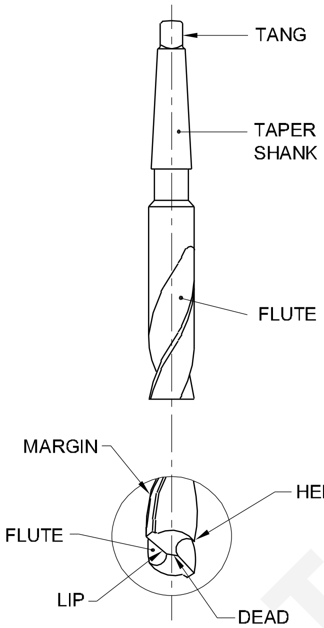
Parts of a Drill: The Various parts of a drill can be identified from Fig 2.

Fig 2



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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.

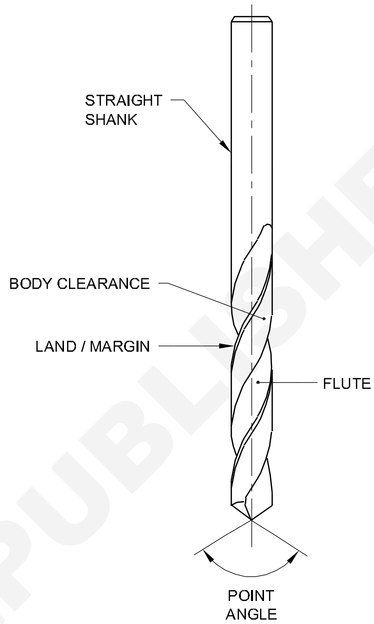
Taper shanks, used for larger diameter drills, and straight shank, used for smaller diameter drills.

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.

Fig 3



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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.

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.

Drill angles

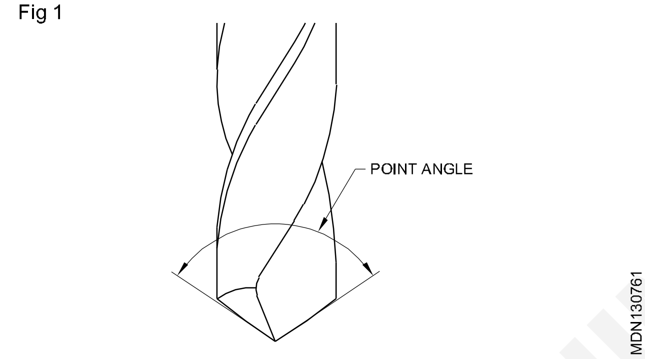
Objectives : At the end of this lesson you shall be able to
- **list the various angles of a twist drill**
- **state the functions of each angle**
- **list the tool types for drill as per ISI**
- **distinguish the features of different types of drills**
- **designate drills as per ISI recommendations.**

Angles: They are different angles for different purposes. They are listed below.

Point Angle, Helix angles, Rake angle, Clearance angle and chisel edge angle.

Point Angle/Cutting Angle: The point angle of a general purpose (standard) drill is 118°.This is the angle between the cutting edges (lips). This angle according to the hardness of the material to be drilled (Fig 1)

Fig 1



Helix Angle (Figs 2 to 4)

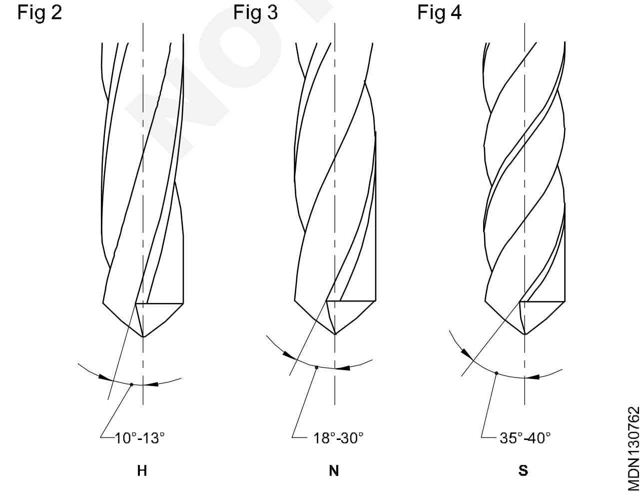
Twist drills are made with different helix angles. The helix angle determines the rake angle at the cutting edge of teh twist drill.

The helix angles vary according to the material being drilled. According to Indian Standards, three types of drills are used for drilling various materials.

- Type N-for normal low carbon steel
- Type H-for hard and tenacious materials
- Type S- for soft and tough materials.

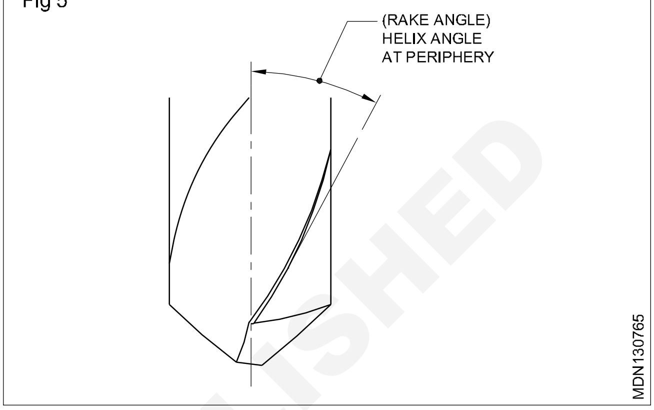
The type N drill is used for general purpose drilling work.

Fig 2 Fig 3 Fig 4



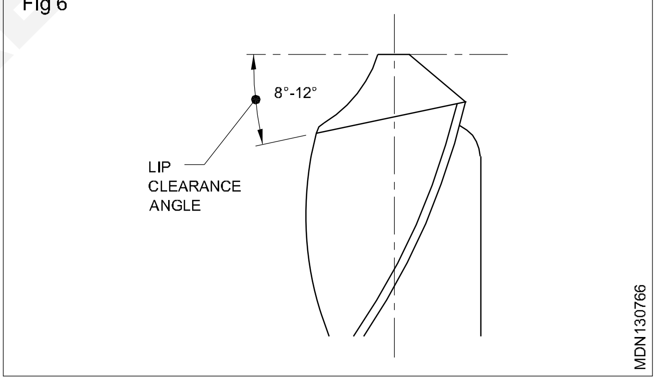
Rake Angle (Fig 5): Rake angle is the angle of flute (helix angle)

Fig 5



Clearance Angle (Fig 6): The clearance angle is to prevent the friction of the tool behind the cutting edge. This will help in the penetration of the cutting edges into the material. If the clearance angle is too much the cutting edges will be weak, and if it is too small the drill will not cut.

Fig 6



Chisel Edge Angle/ Web Angle (Fig 7): This is the angle between the chisel edge and the cutting lip.

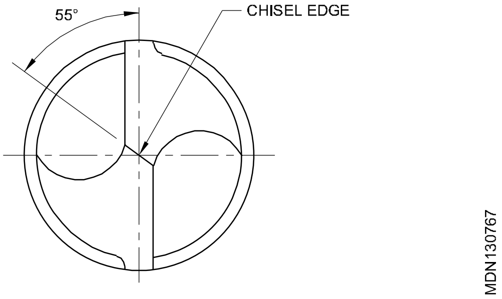
Designation of drills: Twist drills are designated by the
- diameter
- tool type
- material

Diameter of drill IS NO.

Twist drill 9.50 H - IS5101 - HS

Tool Type Material

Fig 7

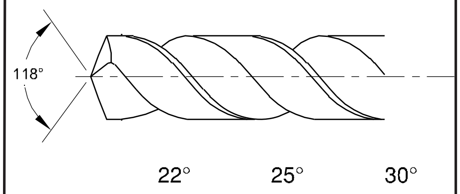
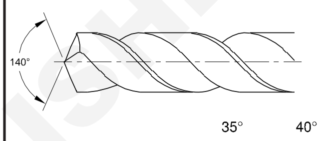
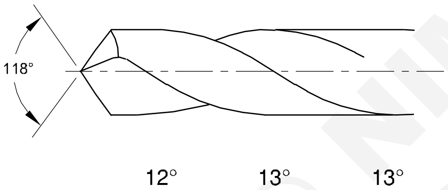
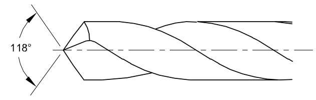
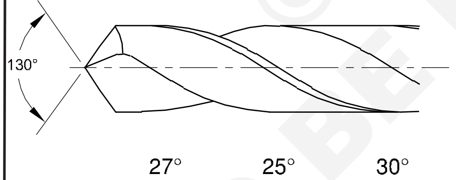
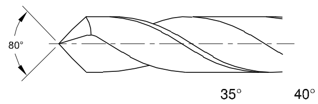
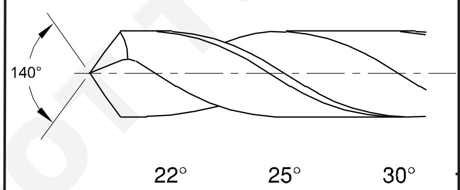
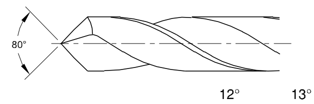
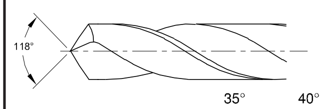


Example

A twist drill of 9.50mm dia of tool type “H’ right hand cutting and made from HSS is designated.

If the tool type is not indicated in the designation, it should be taken as type ‘N’ tool.

Drills for different materials

Recommended drills				
Material to be drilled	Point angle / Helix angle d=3.2-5 5-10		Material to be drilled	Point angle / Helix angle d=3.5 -5
Steel and cast steel up to 70 kgf/mm^2 strength Gray cst iron Malleable cast iron Brass German silver, nickel			Copper (up to 30 mm drill diameter) Al-alloys, forming curly chips celluloid	
Brass, CuZn 40			Austentic steels	
Steel and cast steel 70.... 120 Kgfmm^2			Moulded plastics (with thickness s>d)	
Stainless steel; Copper (drill diameter) more than 30 mm) Al-alloy, forming short - broken chips			Moulded plastics, with thickness s<d Laminated plastics. hard rubber (ebonite) marble, state, coal	
			Zinc alloys	

Hand taps and dies

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.

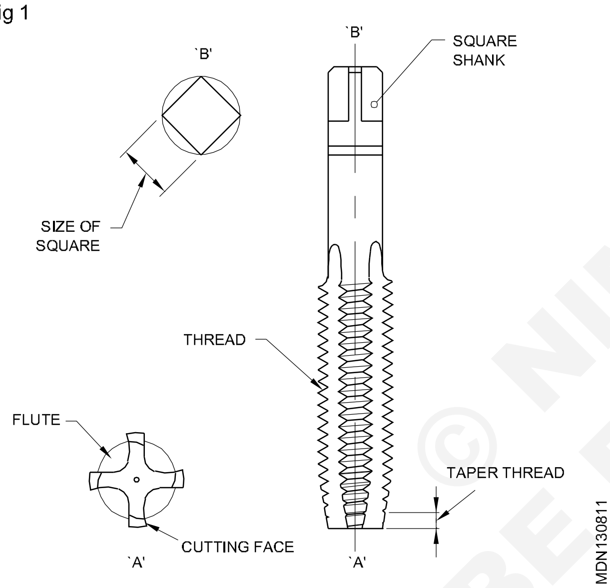
Features (Fig 1)

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.

Fig 1



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

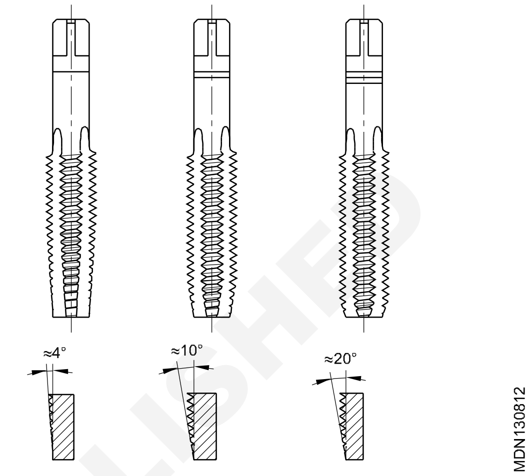
Hand taps for a particular thread are available as a set consisting of three pieces. (Fig 2) These are

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 2)

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.

Double ended adjustable wrench, T-handle tap wrench and solid type tap wrench.

Double ended adjustable tap wrench or bar type tap wrench (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.

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 3

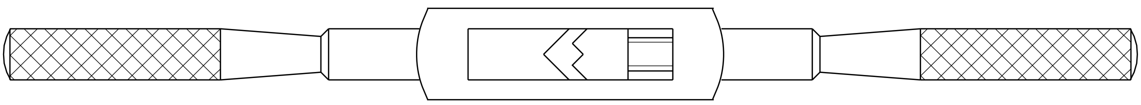
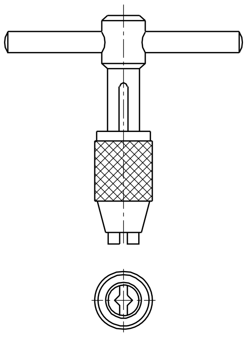


Fig 4

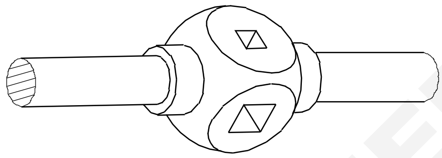


Solid type tap wrench (Fig 5)

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



Tap drill size

Objectives: At the end of this lesson you shall be able to
- **state the tap drill size**
- **choose the tap drill sizes for different threads from tables**
- **calculate the tap drill sizes for ISO metric and ISO inch.**

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

$$\text{Tap Drill size} = \text{Major diameter} - \frac{1}{\text{Number of thread per inch}}$$

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.

TABLE FOR TAP DRILL SIZES - ISO METRIC

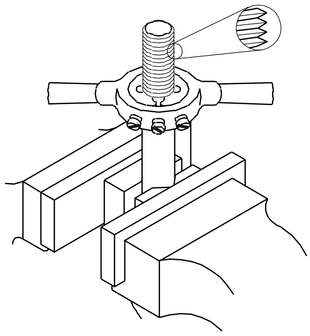
PITCH	0.25	0.3	0.35	0.4	0.45	0.5	0.6	0.7	0.75	0.8	1	1.25	1.5	1.75		2.5	3	3.5	4	4.5	5	5.55
1	0.85																					
1.1	0.95																					
1.2	0.96																					
1.4		1.10																				
1.6			1.25																			
1.8			1.45																			
2				1.60																		
2.2			2.15		1.75																	
2.5			2.65		2.05																	
3			3.15			2.50																
3.5							2.90															
4						3.50		3.30														
4.5						4.00			3.70													
5						4.50				4.20												
5.5						5.00																
6									5.20		5.00											
7									6.20		6.00											
8									7.20		7.00	6.80										
9									8.20		8.00	7.80										
10									9.20		9.00	8.80	8.50									
11									10.20		10.00		9.50									
12											11.00	10.80	10.50	10.20								
14											13.00	12.80	12.50		12.00							
15											14.00		13.50									
16											15.00		14.50		14.00							
17											16.00		15.50									
18											17.00		16.50		16.00	15.50						
20											19.00		18.50		18.00	17.50						
22											21.00		20.50		20.00	19.50						
24											23.00		22.50		22.00		21.00					
25											24.00		23.50		23.00							
26													24.50									
27											26.00		25.50		25.00		24.00					
28											27.00		26.50		26.00							
30											29.00		28.50		28.00		27.00	26.50				
32													30.50		30.00							
33													31.50		31.00		30.00	29.50				
35													33.50									
36													34.50		34.00		33.00		32.00			
38													36.50									
39													37.50		37.00		36.00		35.00			
40													38.50		38.00		37.00					
42													40.50		40.00		39.00		38.00	37.50		
45													43.50		43.00		42.00		41.00	40.50		
48													46.50		46.00		45.00		44.00		43.00	
50													48.50		48.00		47.00					
52													50.50		50.00		49.00		48.00		47.00	
56																						50.50

Die and die stock

Objectives: At the end of this lesson you shall be able to
- **name the different types of dies**
- **state the features of each type of die**
- **state the use 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)

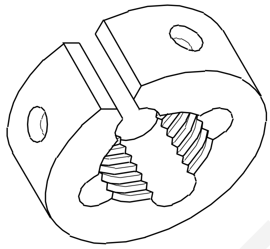
Half Die

Adjustable screw plate die

Circular split die/button die (Fig 2)

This has a slot cut to permit slight variation in size.

Fig 2



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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)

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.

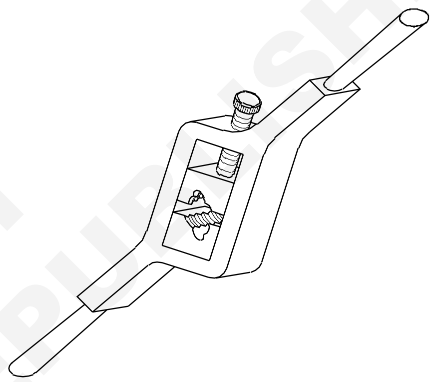
Half Die (Fig 4)

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.

Fig 4



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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.

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. (Fig 5)

Fig 3

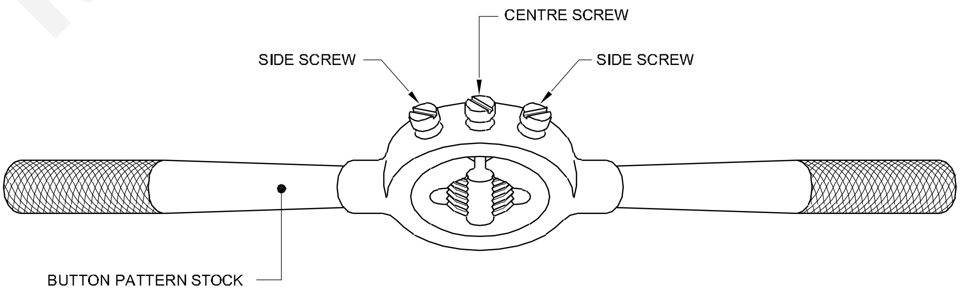

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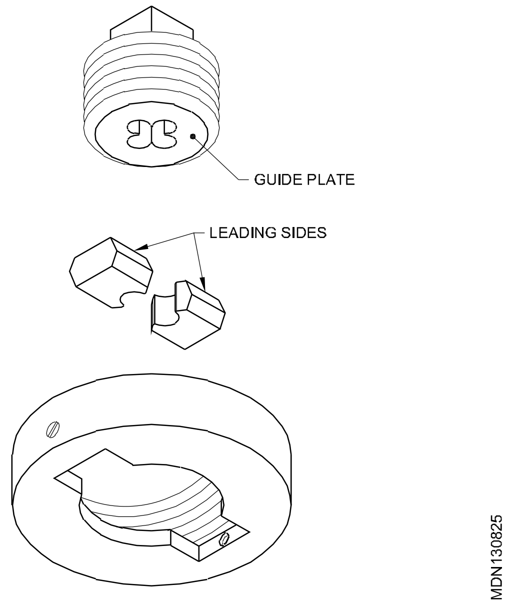
Fig 5



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.

The die nut is turned with a spanner.

The die nuts are available for different standards and sizes of threads.

Die nuts are not to be used for cutting new threads.

Fig 7

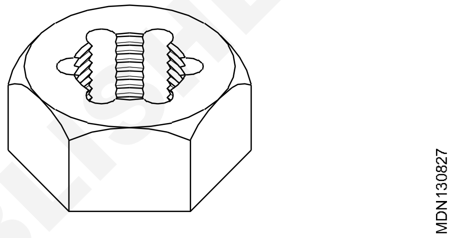
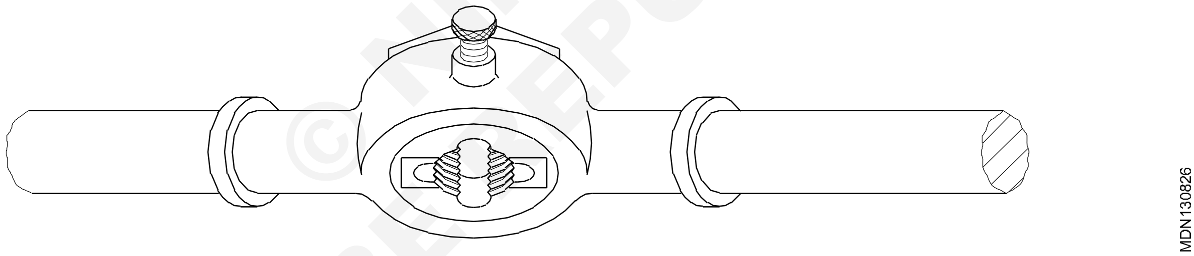


Fig 6



Hand reamers

Objectives : At the end of this lesson you shall be able to
- **state the uses of reamers**
- **state the advantages of reaming**
- **distinguish between hand and machine reamers**
- **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)

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 a hand reamer is done manually for which great skill is needed.

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 a hand reamer are shown in Fig 4

Fig 1

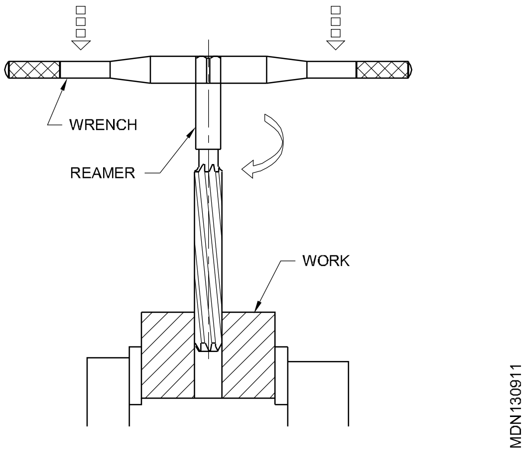
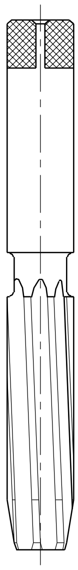
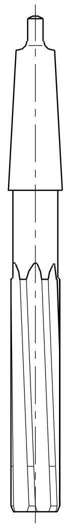


Fig 2



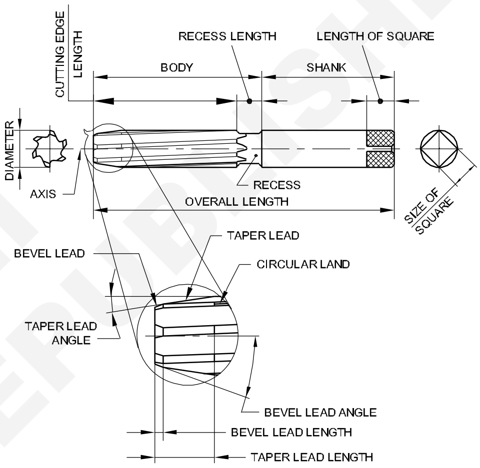
HAND REAMER

Fig 3



MACHINE REAMER

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 practiced 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. (see Table)

TABLE -1

Undersizes for reaming

Diameter of ready reamed hole (mm)	Undersizes of rough bored 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 = Reamed 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

= 9.75mm

Determing 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 - CAUSES 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 ara combination there of.

- 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 charging 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

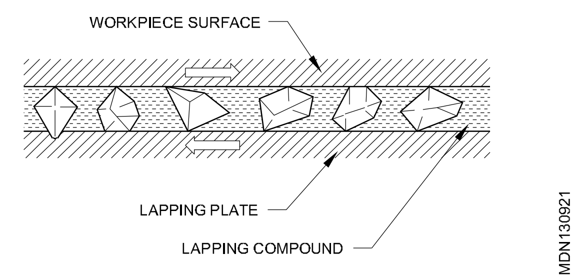
- improves geometrical accuracy
- refines surface finish
- assists in achieving a high degree of dimensional accuracy.
- improves the quality of fit between the mating components.

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)

The lapping compound consists of hard abrasive particles, in suitable 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.

Fig 1

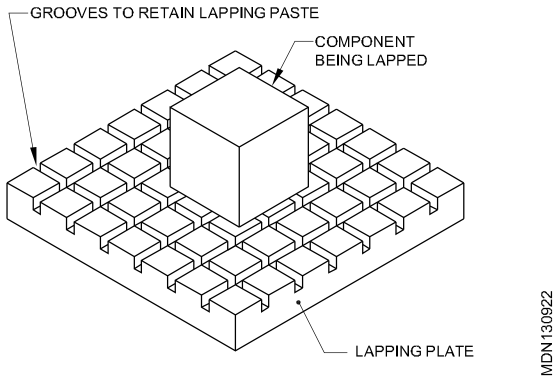


Hand lapping of flat surfaces: Flat surfaces are hand lapped using lapping plates made out of close grained cast iron. (Fig 2) The surface of the plate should be in a true plane for accurate results in lapping.

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.

These grooves are usually about 12mm apart.

Fig 2



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 particles.

This is a process by which the abrasive particles 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 worpiece 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
- **name the different types of lap materials**
- **state the qualities of different 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 arbor. These laps can be expanded when they are worn out. Charging the lap is much quicker.

Lapping abrasives: Abrasives of different types are used for lapping.

The commonly used abrasives are:

- silicon carbide
- aliminium oxide
- boron carbide
- 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.

In addition to the vehicles used in making the lapping compound, solvents like water, kerosene, etc are also used at the time of lapping.

Electricity principles

Objectives: At the end of this lesson you shall be able to
- **describe an atom**
- **describe electricity**
- **describe electron flow**
- **describe conductors**
- **describe insulators**
- **describe semiconductors**
- **describe shielding.**

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. 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.

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.

Atomic Structure

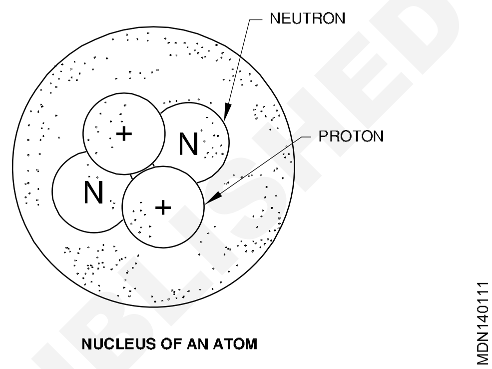
The Nucleus

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.

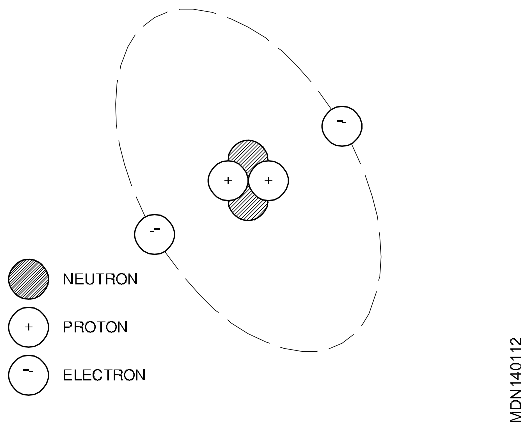
Fig 1



NUCLEUS OF AN ATOM

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 2



Neutron

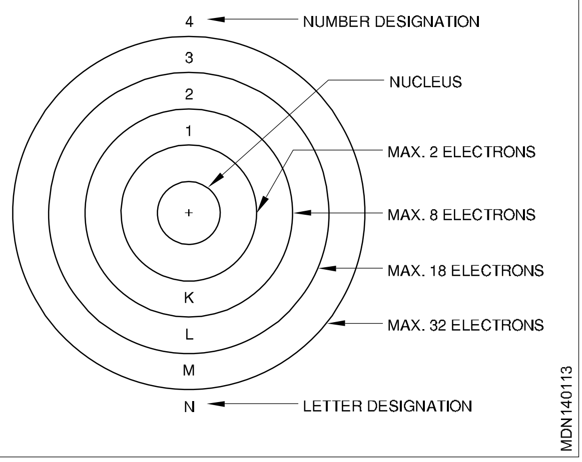
A neutron is actually a particle by itself, and is electrically neutral. Since neutrons are electrically neutral, they are not too important to the electrical nature of atoms.

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 sheel layers are identified by numbers of by letters starting with 'K' nearest the nucleus and continuing alphabetically outwards.

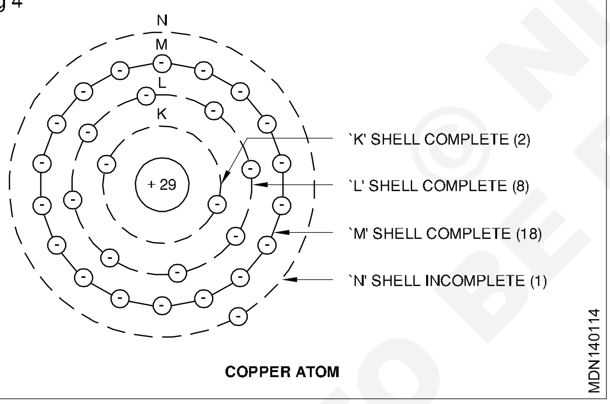
There is a maximum number of electrons that can be contained in each sheel. (Fig 3) illustrates the relationship between the energy shell level and the maximum number of electrons it can contain.

Fig 3



If the total number of electrons for a given atom is known, the placement of electrons in each shell can be easily determined. Each sheel layer, beginning with the first, is filled with the maximum number of electrons in sequence. 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).

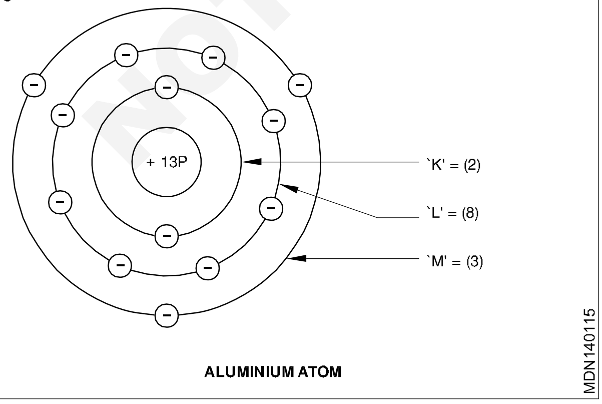
Fig 4



COPPER ATOM

Similarly an aluminium atom which has 13 electrons has 3 shell as shown in (Fig 5).

Fig 5



ALUMINIUM ATOM

Electron distribution

The chemical and electrical behavior 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 semiconductor

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, 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.

Earthing and its importance

Objectives : At the end of this lesson you shall be able to
- **describe the necessity of earthing**
- **describe the reasons for system and equipment earthing**.
- **describe 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.

Earthing the metal frames/ casing of the electrical equipment is done to ensure that the surface of the equipment under faulty conditions does not hold dangerous potential which may lead to shock hazards. However, earthing the electrical equipment needs further consideration as to ensure that the earth electrode resistance is reasonably low to activate the safety devices like earth circuit leakage breaker, fuses and circuit breakers to open the faulty circuit, and thereby, protect men and material.

Earthing of an electrical installation can be brought under the following three categories.

- System earthing
- Equipment earthing
- Special requirement earthing

System earthing

Earthing associated with current - carrying conductors is normally essential to the safety of the system and it is generally known as system earthing.

System earthing is done at generating stations and substations.

Equipment earthing

This is a permanent and continuous bonding together (i.e. connecting together) of all non-current carrying metal parts of the electrical equipment to the system earthing electrode.

'Equipment earthing' is provided to ensure that the exposed metallic parts in the installation do not become dangerous by attaining a high touch potential under conditions of faults. It is also carry the earth fault currents, till clearance by protective devices, without creating a fire hazard.

Special requirements for earthing: 'Static earthing' is provided to prevent building up of static charges, by connections to earth at appropriate locations. Example, operation theatres in hospitals.

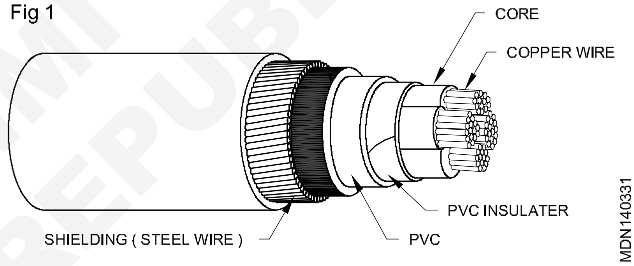
'Clean earth' may be needed for some of the computer data processing equipments. These are to be independent of any other earthing in the building.

Earthing is essentially required for the protection of buildings against lightning.

Reasons for earthing: An electric shock is dangerous only when the current flow through the body exceeds beyond certain milliampere value. In general any current flowing through the body beyond 5 milliamperes is considered as dangerous.

Shielding: Shielding is the (Fig 1) protective device layer over the insulated cable.

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 whether condition like water, oil, grease and heat.

Ohm's Law

Objectives: At the end of the lesson you shall be able to
- **describe an atom**
- **describe electricity**
- **describe electron flow**
- **describe conductors**
- **describe insulators**
- **describe semiconductors.**

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 voltage.

The voltage developed by a source such as a generator is called as 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 passes 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.

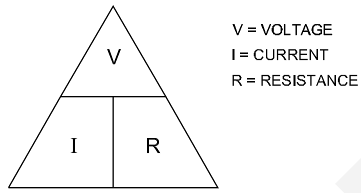
There is a definite relationship between the three electrical quantities of Voltage, Current and Resistance.

Ohm's Law

Ohm's law states that 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)

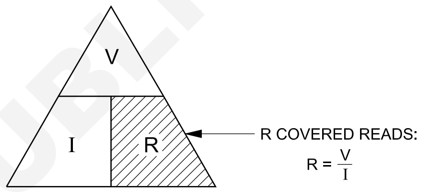
Fig 1



Written as a mathematical expression, Ohm's Law is -

$$\text{Current (I)} = \frac{\text{Voltage (V)}}{\text{Resistance (R)}}$$

Fig 2



$$\text{or } I = \frac{V}{R}$$

Of course, the above equation can be rearranged as:

$$\text{Resistance (R)} = \frac{\text{Voltage (V)}}{\text{Current (I)}}$$

$$\text{or } R = \frac{V}{I}$$ (Refer 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)

Known:

$$I = \frac{V}{R}$$

Solution:

$$I = \frac{1.5\ V}{1000\ ohms} = 0.0015\ amp$$

Answer:

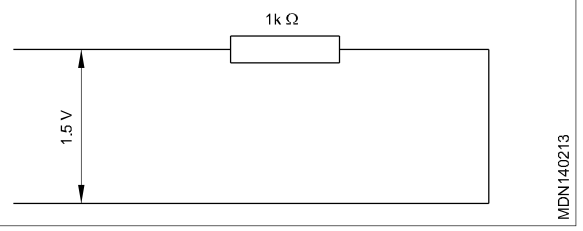
The current in the circuit is 0.0015 A

or

the current in the circuit is 1.5 milliampere (mA).

(1000 milliamps = 1 ampere)

Fig 3



Electrical power (Fig 4)

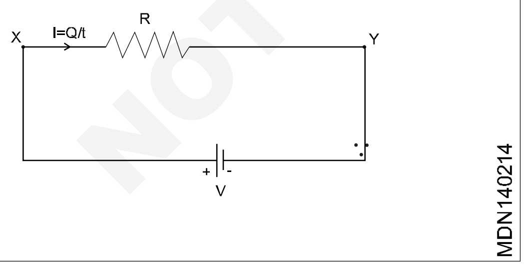
The rate which work is done in an electric circuit is called electrical power.

When voltage is applied to a circuit, it causes current to flow through it or in other words it causes electrons or charge through it, clearly certain amount of work is being done in moving these electrons in the circuit. This work done in moving the electrons in unit time is called as electrical power, From Fig 4.

V	=	P.D. across xy in colts,
I	=	Current in amps.
R	=	resistance between xy in
t	=	time in sec for which current flows.

The total charge flows in t secs is Q = I X T coulombs

Fig 4



As per earlier definition the P.d, $V = \frac{\text{work}}{\text{charge}} = \frac{\text{work}}{Q}$

$\therefore$Work = VQ.

= VIt (Q = IT).

$\therefore$Electrical power $P = \frac{\text{Workdone}}{\text{time}} = \frac{\text{Vit}}{\text{t}}$

W = VI joules/secs. (or)
watts.

Wattmeter is used to measure the electrical power.

Electrical power in watts = Voltage in volts X current in ampere

The digger units of electric power are kilowatts (KW) and Megawatts (MW).

1 KW = 1000 watts(or) 10^3 watts

1 MW = 1000000 watts (or) 10^6 watts

Electrical Energy: (E)

The total work done in an Electric circuit is called as Electrical Energy.

Electrical Energy = Electrical power X time

= VI X t = VIT

i.e. Electrical power multiplied by the time for which the current flows in the circuit is known as Electrical energy. The meter used to measure electrical energy is energy meter. The symbol for electrical energy is E.

The unit of electrical energy will depend upon the units of electric power and time.

a If power is in watts and time is in seconds then the unit of Electrical energy will be watt-sec.

i.e. Electrical energy in watt - secs. = Power in watts Time In secs.

b If power is in watts and time is in hours then the unit of Electrical Energy will be watt-hours.

i.e. Electrical energy in watt - hours = power in watts time in hours

c If Power is in kilowatts (10 watts (or)1000 watts) and time is in hours then the unit of electrical energy will be kilowatt - hour (Kwh).

i.e. Electrical energy in kwh = power in kilowatt time in hours

In practice the electrical energy is measured in kilowatt-hours (KWh). The electricity bills are made on the basis of total electrical energy consumed by the consumer. 1KWh of electrical energy is called as Board of Trade (B.O.T.) Unit or simply 1 unit. i.e. 1KWh = 1Unit.

Thu when we say a consumer has consumed 75 units of electricity means the electrical energy consumed by the consumer is 75 KWh.

In an electrical circuit if 100 watts (or) 1Kw of power is supplied for 1 hour then the electrical energy expended is one kilowatt-hour (1KWH) or 1 electrical unit (Or) 1 unit.

1Kwh = 1 Unit	=	power in watts time in secs
	=	Watts, secs (or) joules.
	=	1000 60 60 joules
	=	36 105 joules (or) watt-sec.
1 calorie	=	4. 186 joules (or)
1 kilo calorie	=	4186 joules.
1kwh = calories	=	860009.557
	=	860000 calories = 860 10^3 calories
	=	860 kilo calories.
∴ 1 kwh	=	860 Kcal.

Identification of AC and DC 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.

(iii) current :

$I = V / R$

$= P / V$

$= \sqrt{P / R}$

(iv) Voltage :

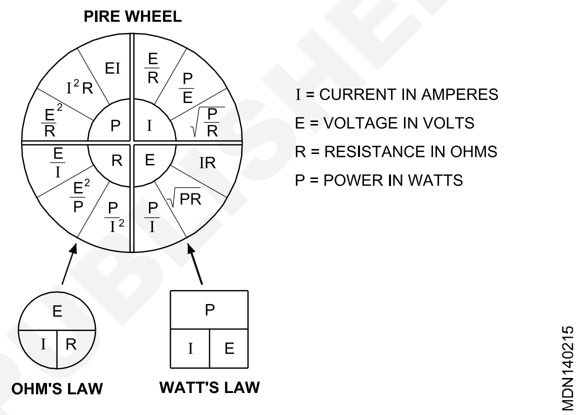
$V = IR$

$= P / I$

$= \sqrt{PR}$

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



Basic types of electrical meters

Objectives: At the end of this lesson you shall be able to
- **describe the connection of an ammeter in the circuit**
- **describe resistance symbols used in wiring diagram**
- **state the use of an ammeter**
- **describe the care to be taken of an ammeter**
- **describe the connection of a voltmeter**
- **describe the use of a voltmeter**
- **describe the care to be taken of voltmeters**
- **describe the connection of an ohmmeter**
- **state the use of an ohmmeter**
- **describe the care to be taken of ohmmeters**
- **describe the maintenance of meters**
- **state the simple electric circuit**
- **state the open electric circuit**
- **state the short electric circuit**
- **state the series circuits & parallel circuits**

There are three basic types of meters used to test the electric circuit and accessories. The following meters are used in Automotives.

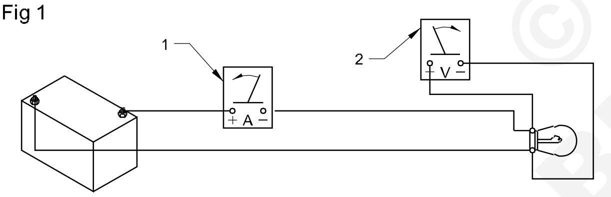
– Ammeter

– Voltmeter

– Ohmmeter

Ammeter (Fig 1)

Fig 1



AMMETER

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

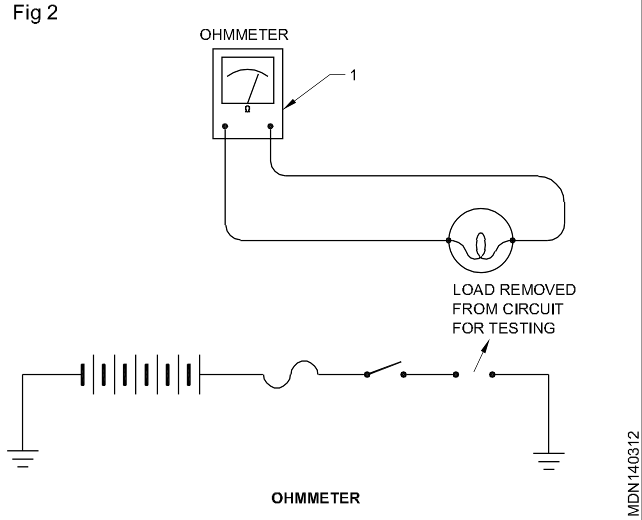
An ohmmeter is used:

– to measure the resistance of any conductor

– to measure the resistance of any load

– to check the continuity of the field coils.

Fig 2



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.

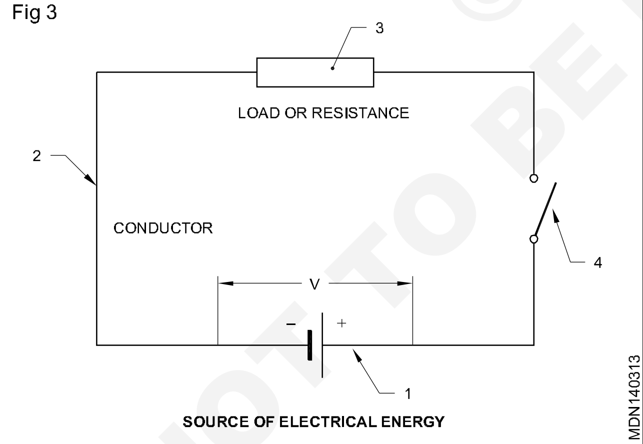
Use the meters within specified loads.

After use, keep the meters in a separate place.

Electrical circuits

Simple electrical circuit (Fig 3)

Fig 3

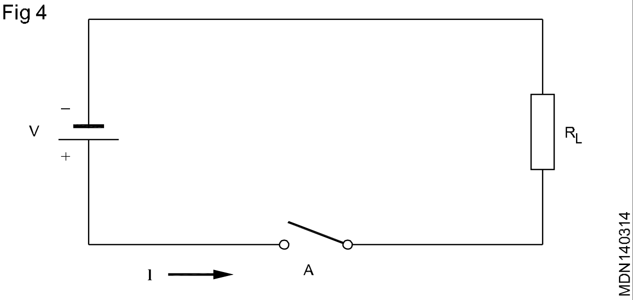


A simple electric circuit is a complete pathway of the current flow from the battery via the switch and load and back to the battery. An electric circuit consists of :

- 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.

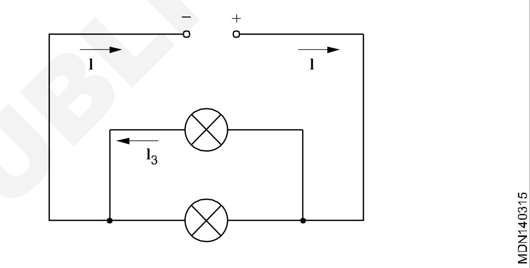
Fig 4



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.

Fig 5



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.

$$\text{Resistance(R)} = \frac{\text{Voltage(V)}}{\text{Current(I)}}$$

$$\text{Current(I)} = \frac{\text{Voltage(V)}}{\text{Resistance (R)}}$$

Voltage = Current (I) x Resistance (R)

Types of resistance

Based on the ohms 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.

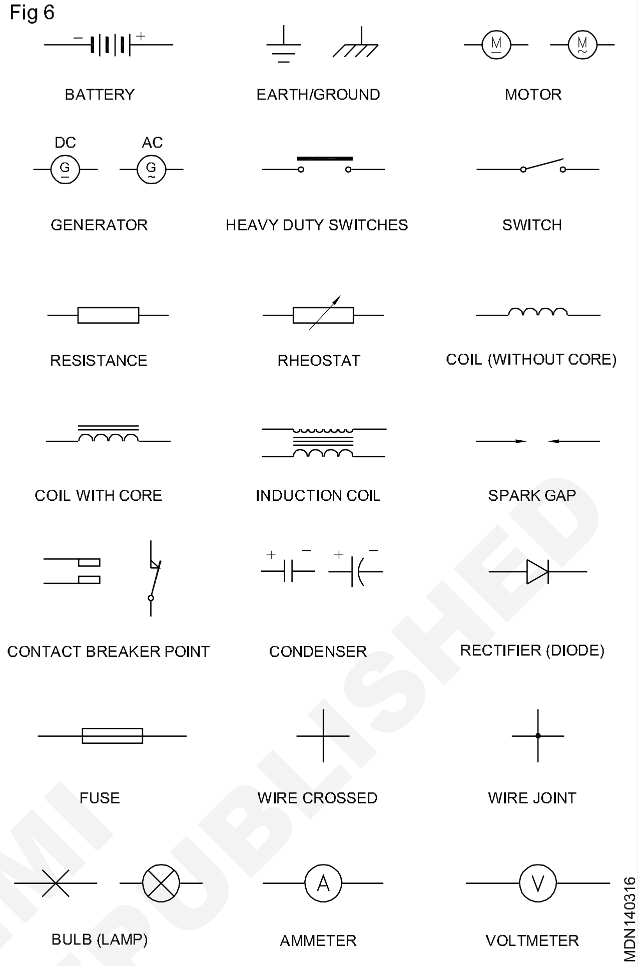
High resistance

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

1 Ordinary multimeters having passive components.

2 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.

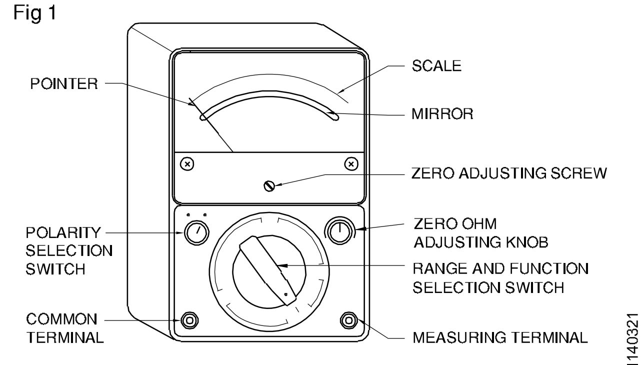
There are several types of multimeters available in the market, manufactured by various manufactures. Each model differs from the others by the extra facilities available. It is a versatile tool for all Automotive. With proper usage and care, it could give service for many years.

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

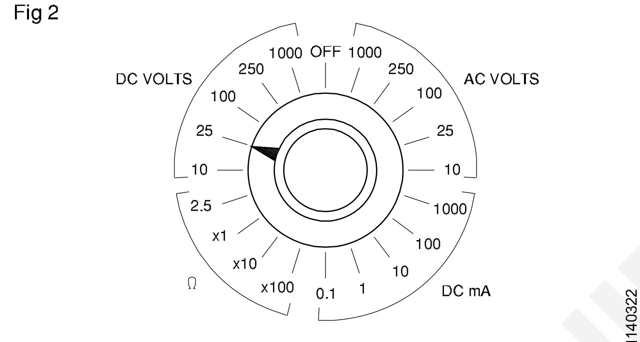


MULTIMETER

Controls

The meter is set to the required current, voltage or resistance range - by means of the range selector switch. in (Fig 2), the switch is set to DC, 25 volts.

Fig 2



FUNCTION AND RANGE SWITCH

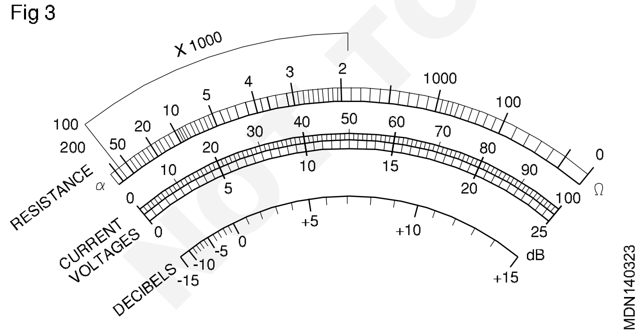
Scale of multimeter

Separate scales are provided for :

- resistance
- voltage and current.

The scale of current and voltage as uniformly graduated (Fig 3)

Fig 3



The scale for resistance measurement is non-linear. That is, the divisions between zero and infinity (α) 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 (α) 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

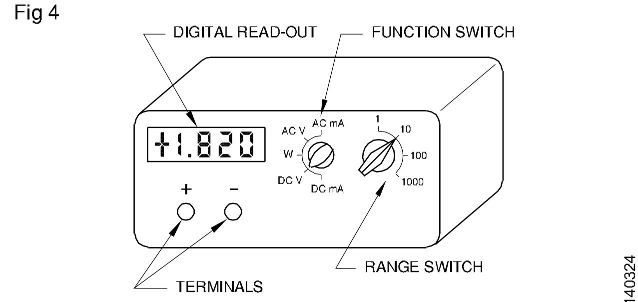
Shunt (parallel) resistors are used to provide multiple ranges so that the meter can measure resistance values from very small to very large values. For each range, a different value of shunt resistance is switched on. The shunt resistance increases for the higher ohm ranges and is always equal to the 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.

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.

Digital multimeter (DMM)

In a digital multimeter the meter movements is replaced by a digital read - out. (Fig 4) 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.

Fig 4



DIGITAL MULTIMETER

Fuse

Objectives: At the end of this lesson you shall be able to
- **state the need of a fuse in the circuit**
- **state the construction of a fuse**
- **list out the types of fuses**
- **describe the working of fuses**
- **describe the circuit with and without a fuse**
- **describe the circuit breakers.**

Introduction

A fuse is a protective device. It is a weakest portion in the electrical circuit.

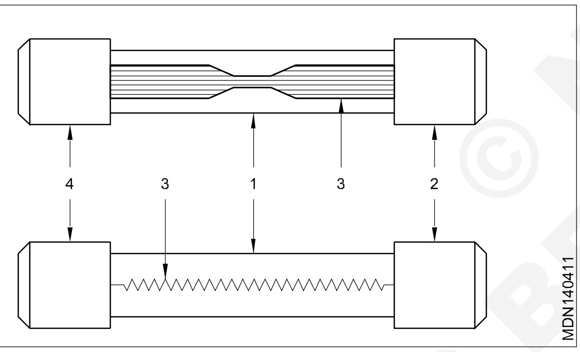
An electric current heats the wire when the current passes through it. The amount of heat depends upon the current and resistance in the wire.

In automobiles, 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 of accessories will be overloaded causing severe damage to them.

Purpose of fuse (Fig 1)

Fig 1



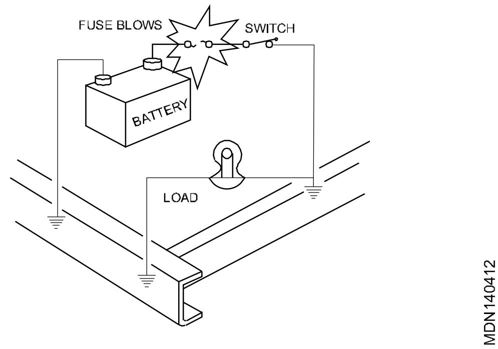
A fuse opens the circuit by blowing out when current (overload) flows in the circuit to prevent severe damage to the accessories.

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.

Fig 2



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 automobiles.

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 (Fig 2).

The glass is foggy white or black the fuse is blown out due to short circuit.

Circuits protected with fuse

- Headlight circuit
- Tail - light circuit
- Number -plate circuit
- Panel lamp circuit
- Interior lamp circuit
- Side indicator circuit
- Horn circuit
- Wiper circuit
- Dashboard / panel instruments circuit
- Heater and air conditioner circuit
- Charging circuit
- Radio / Audio / Video circuit

- Cigarette lighter
- Reverse lamp

Circuits without fuse

- Starting circuit
- Ignition circuit
- Fuel pump circuit
- 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

Fusible link and circuit breakers:

Fusible link (Fig 3)

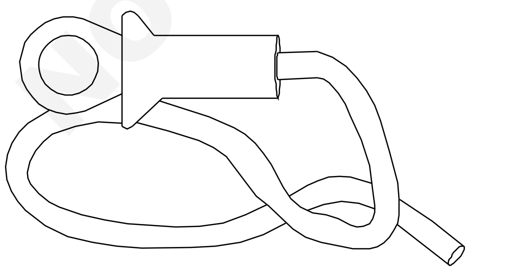
An electrical fusible link is a type of electrical fuse that is constructed simply with a short piece of wire typically four standard wire gauge sizes smaller than the wiring harness that is being protected.

Electrical fusible links are common in high -current automotive applications. The wire in an electrical fusible link is covered with high-temperature fire-resistant insulation to reduce hazards when the wire melts and also encased in special materials that are designed to not catch on fire when exposed to high temperatures.

Fusible links can be found in a variety of places in cars and truck, but they are commonly used in high-amperage applications. Such as starter motors, alternator where load exceeds rated amps.

When this type of fusible link blows, the vehicle will no longer start, but the risks of fire are eliminated.

Fig 3



Circuit Breakers - Automotive

Automotive circuit breakers provide a resettable and reusable alternative over standard fuses for circuit protection, and can altogether replace fuses and fusible links in most applications.

Circuit breakers come in 3 types:

Type 1

This type are auto resettable, and once tripped, will attempt to reset the circuit, as the internal elements of the breaker cool down.

Type 2 (trip and hold)

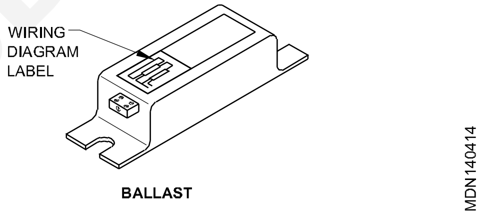
This type are called modified reset, and will remain tripped until the power is removed from the breaker.

Type 3 (circuit breakers)

This type are manual resettable, and require that a button or lever be pushed in order to reset breaker.

Ballast (Choke): The ballast is basically a coil of many turns wound on a laminated iron core (Fig 4). It steps up the supply voltage to start the fluorescent tube conducting. Once the tube is conducting, it regulates the flow of current to the tube cathodes to keep them from burning out.

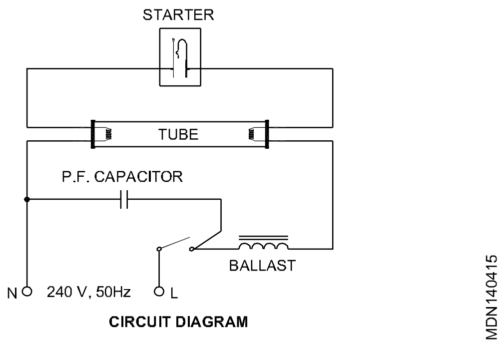
Fig 4



Circuit diagram: The method of connecting the starter, ballast and the tube's electrodes at its either end is shown in Fig 5.

Function of the various parts in a fluorescent light circuit.

Fig 5



Cable colour codes and size

Objectives: At the end of the lesson you shall be able to
- **describe automotive cables**
- **state the needs of colour coding in wiring**
- **state the use of colours in various circuits.**

Description of cables

The cable consists of multi - strand copper conductor covered with good quality PVC insulation.

The current to the various electrical accessories is carried through cables.

The various cables used in wiring are;

- Starting system cable
- General purpose cable
- High tension cable

The specification of the cable refers to the number of stands and diameter of each strand. Eg. 25/012 indicates, the cable consists of 25 strands of 0.012" gauge diameter of each strand.

The size of the cable depends upon the current rating of the accessories connected in that circuit. A thick cable can carry more current and is used in the starting system.

Colour code in cables

In automobiles a number of electric circuits are connnected to the battery which is quite complicated.

The large number of cables are braided into a single harness assembly.

The automotive manufactures use cables of different colours and usually follow the Lucas colour code system. It consists of basic colours (main colours) and combination of colours to identity individual circuits. (Refer of Fig 1).

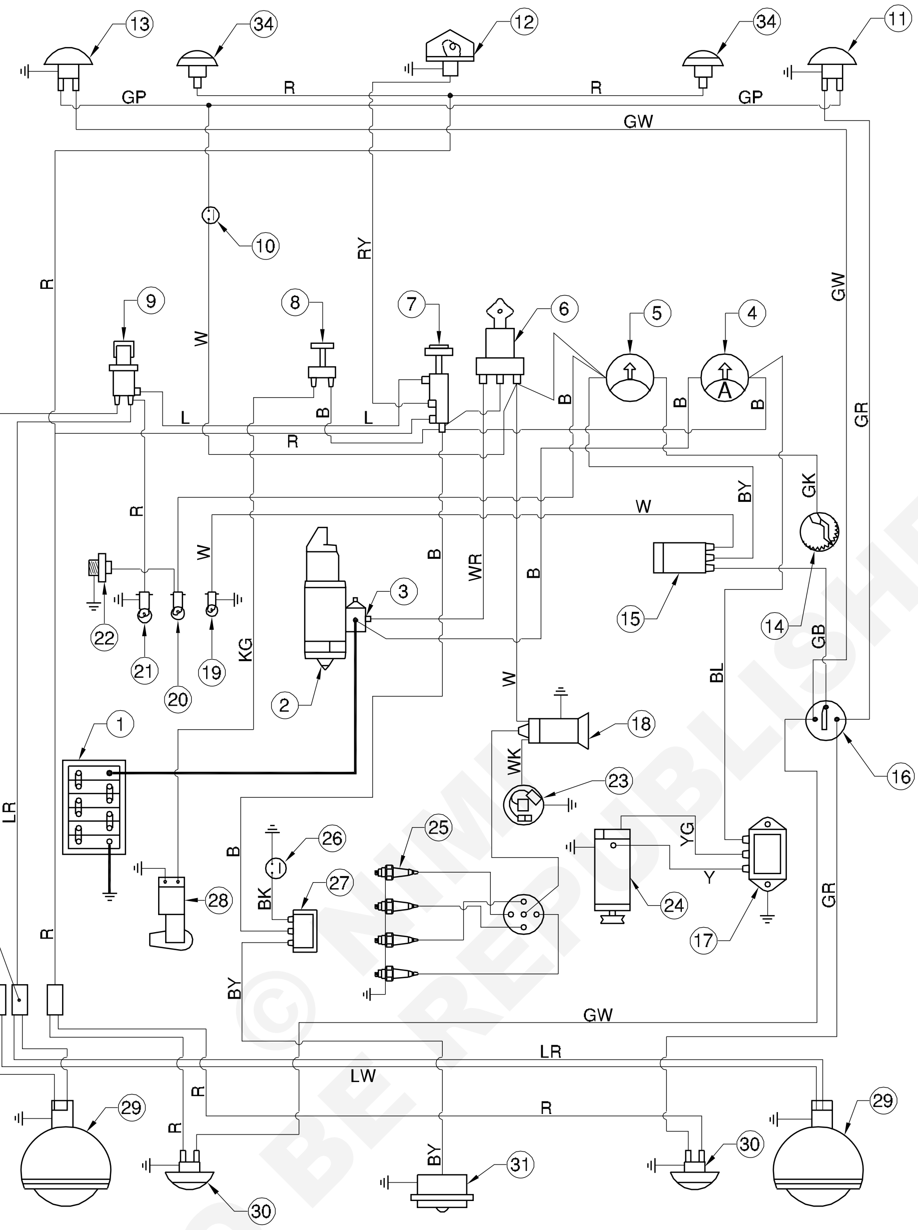
The distinction between wires in a group is done by the use of a coloured bracer on the main colours of the insulator of each wire.

Purpose of colour code

For easy identification of each circuit.

To help to locate the defect easily in a particular circuit and to rectify the same quickly.

Fig 1



NO.	INDEX	NO.	INDEX	COLOUR CODE			
1	BATTERY	18	IGNITION COIL	B	BROWN	GK	GREEN BLACK
2	STARTER MOTOR	19	INDICATOR WARNING LAMP	Y	YELLOW	GP	GREEN PURPLE
3	SOLENOID SWITCH	20	OIL PRESSURE WARNING LAMP	W	WHITE	LR	BLUE RED
4	AMMETER	21	HEAD LIGHT WARNING LAMP	G	GREEN	LW	BLUE WHITE
5	FUEL GUAGE	22	OIL PRESSURE SWITCH	L	BLUE	RG	RED GREEN
6	IGNITION SWITCH	23	DISTRIBUTOR	R	RED	RW	RED WHITE
7	HEADLIGHT SWITCH	24	DYNAMO	K	BLACK	RY	RED YELLOW
8	WIPER SWITCH	25	SPARK PLUG	BL	BROWN BLUE	KG	BLACK GREEN
9	DIM-DIP SWITCH	26	HORN SWITCH	BK	BROWN BLACK		
10	STOP LIGHT SWITCH	27	HORN RELAY	BY	BROWN YELLOW		
11	STOP CUM INDICATOR LAMP	28	WIPER UNIT	BG	BROWN GREEN		
12	NUMBER-PLATE LAMP	29	HEAD LIGHT	YG	YELLOW GREEN		
13	STOP CUM INDICATOR LAMP	30	FRONT PARKING CUM I-LAMP	WR	WHITE RED		
14	FUEL TANK UNIT	31	HORN	WK	WHITE BLACK		
15	FLASHER UNIT	32	DIM SOCKET	GB	GREEN BROWN		
16	INDICATOR SWITCH	33	DIP SOCKET	GW	GREEN WHITE		
17	CONTROL BOX	34	TAIL-LAMP	GR	GREEN RED		

Law of resistances

Objectives: At the end of this lesson you shall be able to
- **state the laws of resistance, compare resistances of different materials**
- **state the formula giving the relationship between the resistance and dimensions of a conductor**
- **state the effect of temperature on resistance and describe the temperature co-efficient of resistance**
- **calculate the resistance of a conductor.**

Scan the QR Code to view the video for this exercise

Laws of resistance (Fig 1): The resistance R offered by a conductor depends on the following factors.

– The resistance of the conductor varies directly with its length.

– The resistance of the conductor is inversely proportional to its cross-sectional area.

– The resistance of the conductor depends on the material with which it is made of.

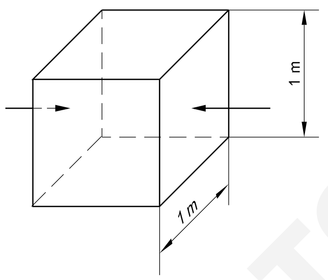
– It also depends on the temperature of the conductor.

Ignoring the last factor for the time being,we can say that

$$R = \frac{PL}{a}$$

where r is a constant depending on the nature of the material of the conductor, and is known as its specific resistance or resistivity.

Fig 1



If the length is one metre and the area, 'a' = 1 m^2, then R = r.

Hence, specific resistance of a material may be defined as `the resistance between the opposite faces of a metre cube of that material'. (sometimes, the unit cube is taken in centimetre cube of that material).

We have $\rho = \frac{aR}{L}$

In the SI system of units

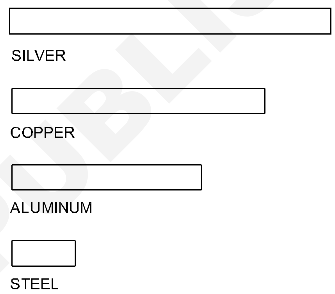
$$\rho = \frac{a\ \text{metre}^2 \times R\ \text{ohm}}{L\ \text{metre}}$$

$$= \frac{aR}{L}\ \text{ohm-metre}$$

Hence the unit of specific resistance is ohm metre (Wm).

Comparison of the resistance of different materials: (Fig 2) gives some relative idea of the more important materials as conductors of electricity. All the conductors have the same cross-sectional area and the same amount of resistance. The silver wire is the longest while that of copper is slightly short and that of aluminium is shorter still. The silver wire is more than 5 times longer than the steel wire.

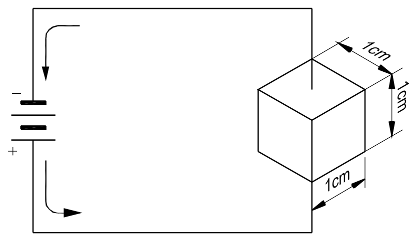
Fig 2



THE CONDUCTANCE OF DIFFERENT MATERIALS

Since different metals have different conductance ratings, they must also have different resistance ratings. The resistance ratings of the different metals can be found by experimenting with a standard piece of each metal in an electric circuit. If you cut a piece of each of the more common metals to a standard size, and then connect the pieces to a battery, one at a time, you would find that different amounts of current would flow. (Fig 3)

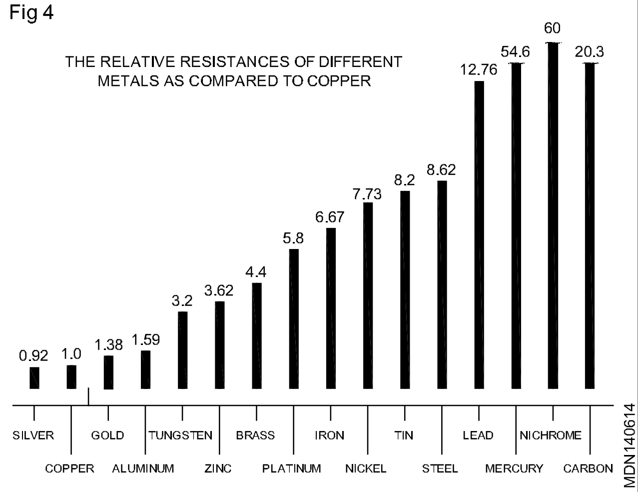
Fig 3



THE MORE RESISTANCE A MATERIAL HAS, THE LESS CURRENT THE MATERIAL WILL CONDUCT. GOOD INSULATORS, SUCH AS GLASS, RUBBER, MICA, POLYSTYRENE, ETC., HAVE CONSIDERABLY MORE THAN A MILLION TIMES THE RESISTANCE OF ANY GOOD CONDUCTOR

The bar graph (Fig 4) shows the resistance of some common metals as compared to copper. Silver is a better conductor than copper because it has less resistance. Nichrome has 60 times more resistance than copper, and copper will conduct 60 times as much current as Nichrome, if they were connected to the same battery, one at a time.

Fig 4



Resistors

These are the most common passive component used in electronic circuits. A resistor is manufacture with a specific value of ohms resistance. The purpose of using a resistor in circuit is either to limit the current to specific value or to provide desired voltage drop (IR) The power rating of resistors may be from O.1.W. to hundred of Watts.

Wire - wound resistors: Wire-wound resistors are manufactured by using resistance wire (nickel - chrome alloy called Nichrome) wrapped around an insulating core, such as cerami porcelain bakelite pressed paper etc (Fig 4). The bare wire used in the unit is generally enclosed in insulating material.

Wire wound resistors are used for high current application. They are available in wattage ratings from one watt to 100 watts or more. The resistance can be less than 1 ohm and go up to several thousand ohms. They are also used where accurate resistance values are required.

One type of Wire-wound resistor is called as fusible resistor enclosed in a porcelain case. The resistance is designed to open the circuit when the current through it exceeds certain limit.

This type of ballast resistor is used in the Automotive vehicle flasher unit. Due to which the indicator lamp flash at the regulation of 70-100 times / min.

Resistors

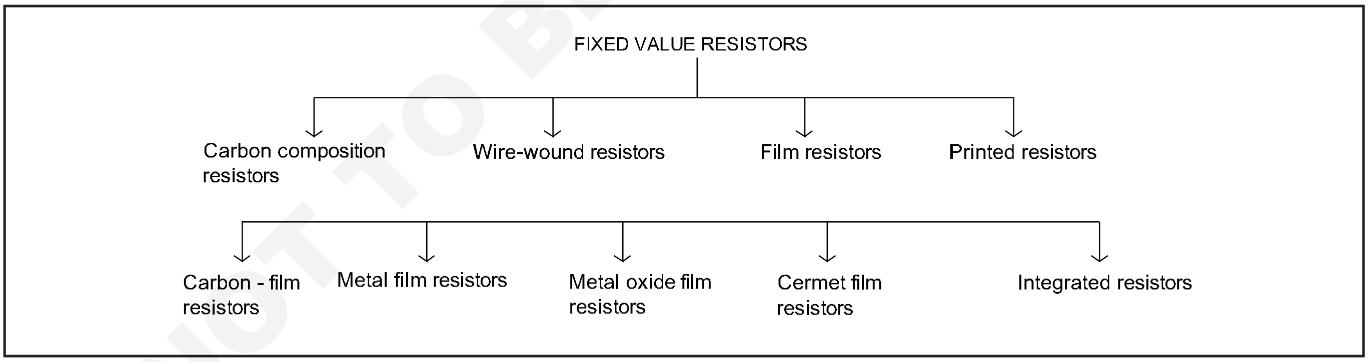
Objectives: At the end of this lesson you shall be able to
- **name the types of resistors**
- **state the meaning of tolerance in resistor**
- **give examples to find the value of a resistor**

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 of making as follows.

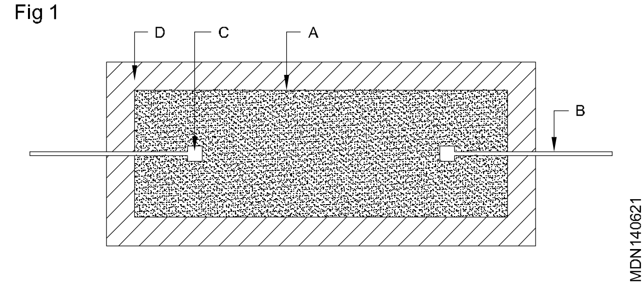


Carbon composition resistors

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 is shown in (Fig 1).

Fig 1

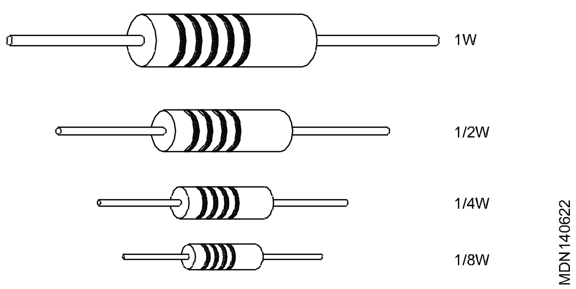


A mixture of finely powdered carbon or graphite(A), filler and binder is made into rods or extruded into desired shapes. Leads(B) made of tinned copper are then attached to the body either by soldering or embedding(C) in the body. A protective layer/tube(D) of phenolic or Bakelite is moulded around the assembly. Finally its resistance value is marked on the body.

Power rating

As already discussed, when current flows through a resistor, heat is generated. The heat generated in a resistor will be proportional to the product of applied voltage (V) across the resistor and the resultant current (I) through the resistor. This product VI is known as *power*. The unit of measurement of power is watts.

Fig 2



The physical size of a resistor should be sufficiently large to dissipate the heat generated. The higher the physical size, the higher is the heat that a resistor can dissipate. This is referred to as the power rating or wattage of resistors. Resistors are manufactured to withstand different power ratings.

(Fig 2) illustrates comparative physical sizes of different wattage resistors. If the product of V and I exceeds the maximum wattage a resistor can dissipate, the resistor gets charred and loses all its property. For instance, if the applied voltage across a 1 watt resistor is 10 volts resulting in 0.5 Amps of current through the resistor, the power dissipated (VI) by the resistor will be 5 watts. But, the maximum power that can be dissipated by the IW resistor is much less. Therefore, the resistor will get overheated and gets charred due to overheat.

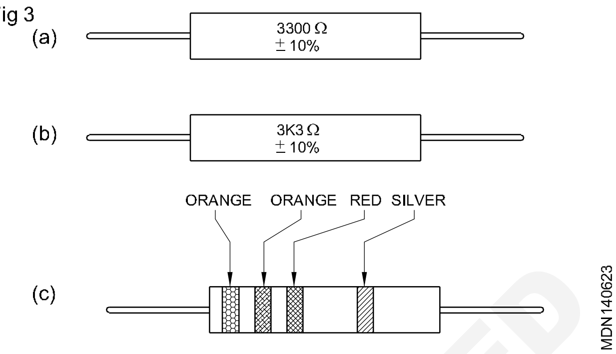
Hence, before using a resistor, in addition to its ohmic value, it is important to choose the correct wattage rating. If in doubt, choose a higher wattage resistor but never on the lower side. The power rating of resistors are generally printed on the body of the resistor.

Resistor values - coding schemes

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. The resistance value of a resistor will generally be printed on the body of the resistor either directly in ohms as shown in (Fig 3a) or using a typographic code as shown in (Fig 3b) or using a colour code as shown in (Fig 3c).

Fig 3



Colour band coding of resistors

Colour band coding as shown in (Fig 3c) 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.

Typographical coding of resistors

In the typographical coding scheme of indicating resistance values, the ohmic value of the resistor is printed on the body of the resistor using an alpha-numeric coding scheme.

> **Some resistance manufacturers use a coding scheme of their own. In such cases it will be necessary to refer to the manufacturer's guide.**

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.

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%

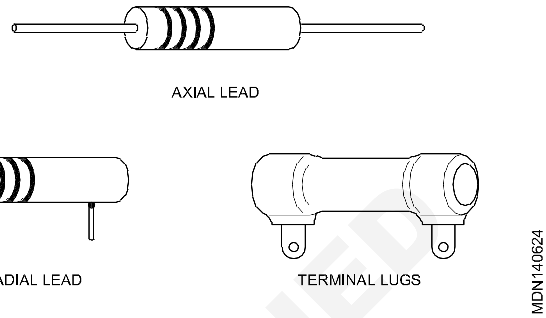
1, 2 and 3: 1st, 2nd and 3rd significant figures;

M : Multiplier ; T : Tolerance ; T_c : Temperature co-efficient

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



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.

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.

Fig 1

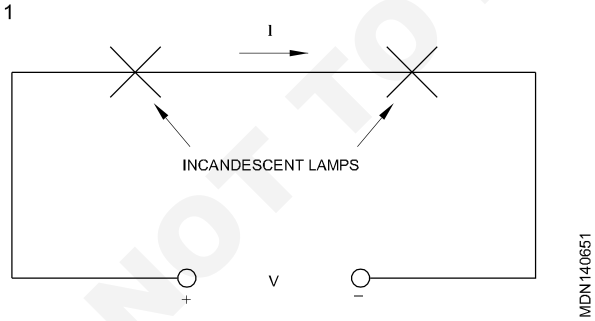
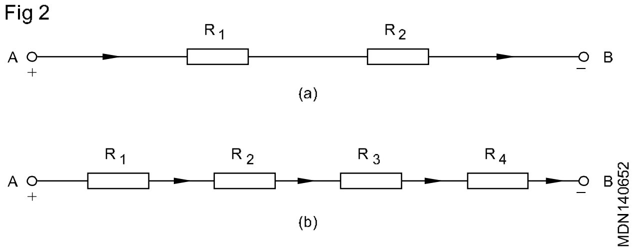


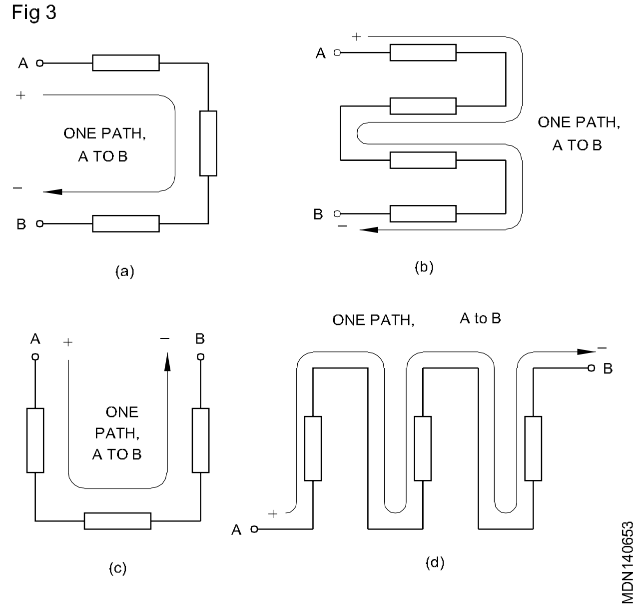
Fig 2



Of course, there can be any number of resistors in a series connection. Such connection provides only one path for the current to flow.

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 3(a), 3(b), 3(c) & 3(d)) shows series resistors drawn in different ways. In all the above circuits we find there is only one path for the current to flow.

Fig 3



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 4(b)). 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)

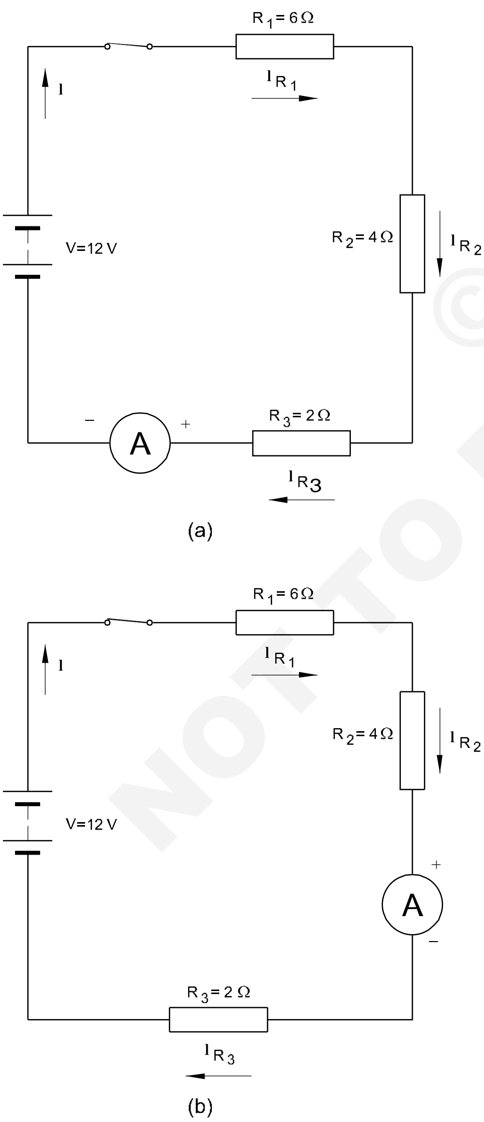
We can conclude that there is only one path for the current to flow in a series circuit. Hence, the current is the same throughout the circuit.

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.

Fig 4



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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.

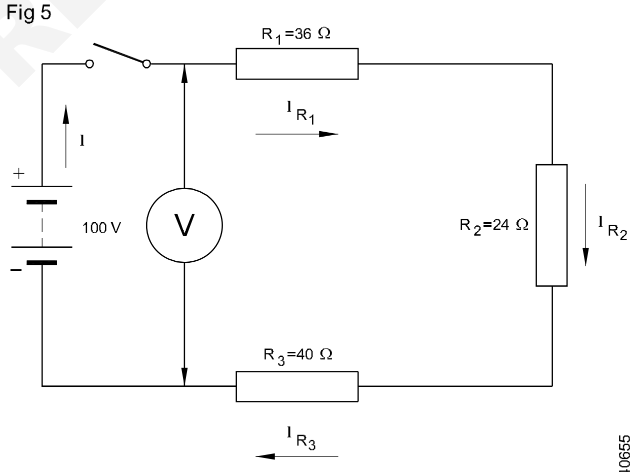
As the source voltage divides/drops across the series resistance depending upon the value of the resistances

$V = V_{R1} + V_{R2} + V_{R3} + ...$

the total voltage of a series circuit must be measured across the voltage source, as shown in (Fig 5).

Voltages across the series resistors could be measured using one voltmeter at different positions as illustrated in (Fig 6).

Fig 5



MEASURIING THE TOTAL VOLTAGE OF SERIES CIRCUIT

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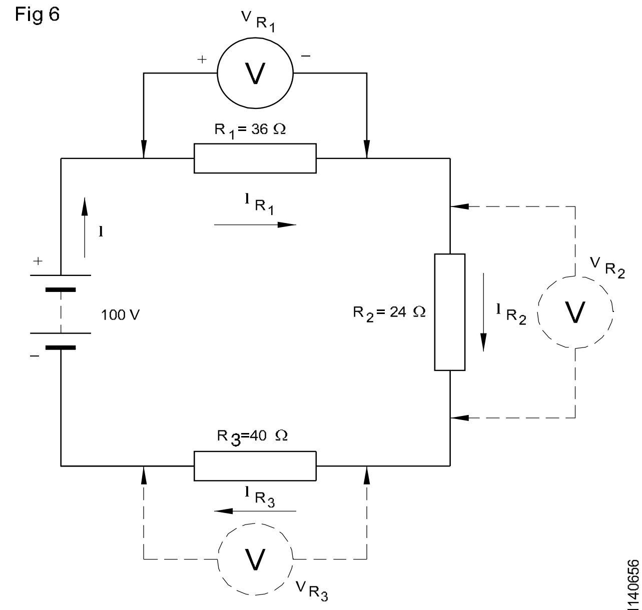
When Ohm's law is applied to the complete circuit having an applied voltage V, and total resistance R, we have the current in the circuit as

$I = V/R$

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

Fig 6



VOLTAGE DROP IN A SERIES CIRCUIT

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)

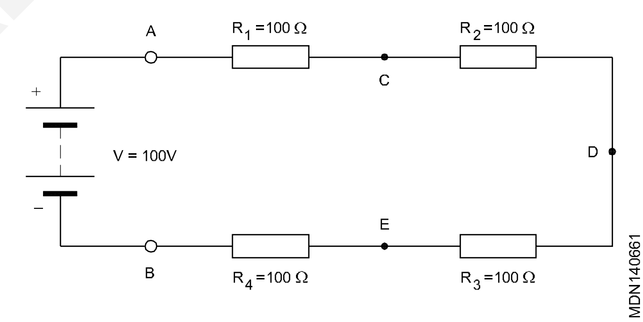
The voltage lost by resistance in a circuit is called the Voltage drop or IR drop.

Example 1

The resistances and applied voltage are known. (Fig 1)

What are the voltage drops across the resistors

Fig 1



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.

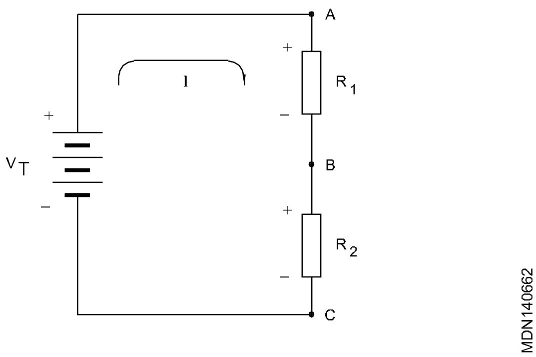
The sum of the voltage drops in a circuit must be equal to the applied voltage.

$V_{Total} = V_{R1} + V_{R2} + V_{R3} + V_{R4}$.

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.

Fig 2



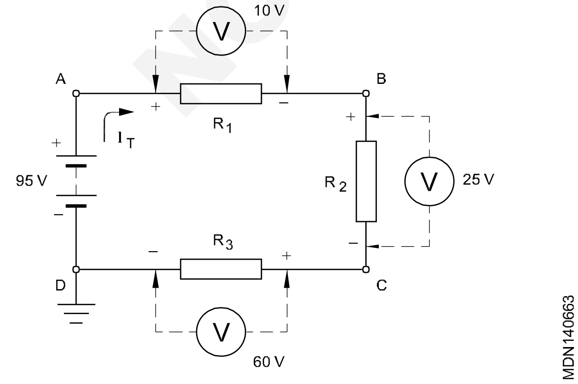
Therefore, the terminal of R_1 connected to point A has a more positive potential than point B. We say that the voltage across R_1 is such that point A is more positive than point B. Similarly the voltage of point B is more positive than point C. Another way to look at polarity between any two points 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.

Fig 3



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.

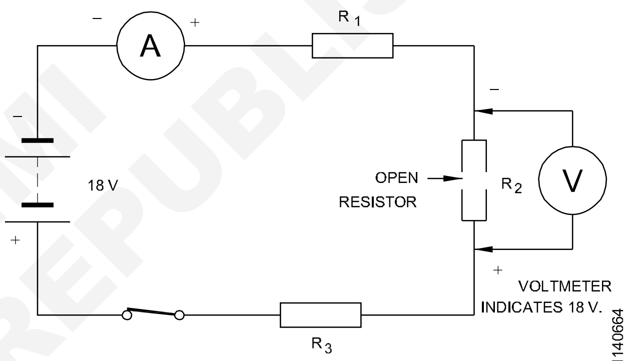
There is a voltage drop of 10 V across R_1; so voltage at B is

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).

Fig 4



OPEN CIRCUIT DUE TO OPEN RESISTOR R_2

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

$= 18\text{ V} - V_{R1} - V_{R2} - V_{R3}$

$= 18\text{ V} - 0\text{ V} - 0\text{ V} - 0\text{ V} = 18\text{ V}.$

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.

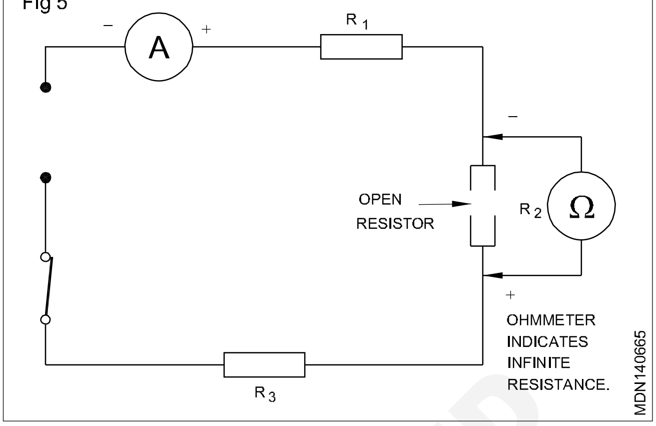
Alternatively, the open circuit may be found using an ohmmeter. With the voltage removed, the ohmmeter will show no continuity (infinite resistance), when connected across the broken wire or open resistor. (Fig 5)

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.

Fig 5



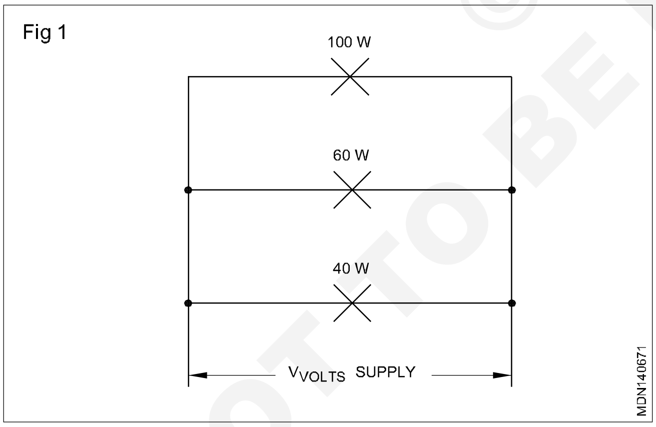
DC parallel circuit

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.

Fig 2

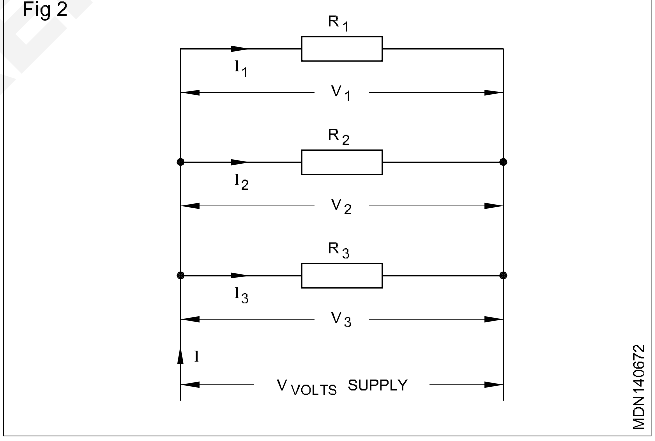
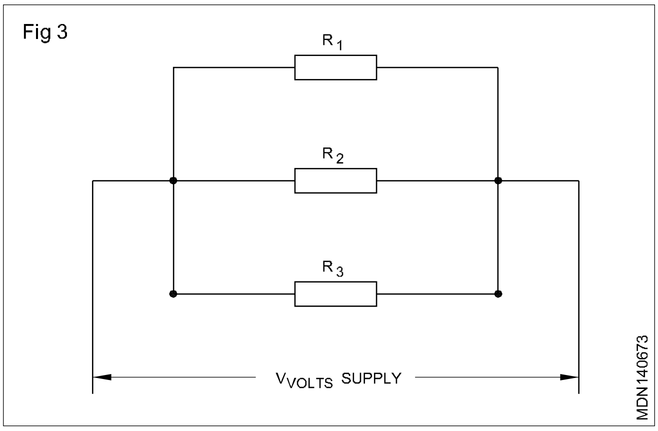


Fig 3



Current in resistor $R_1 = I_1 = \quad = \quad .$

Current in resistor $R_2 = I_2 = \quad = \quad .$

Current in resistor $R_3 = I_3 = \quad =$

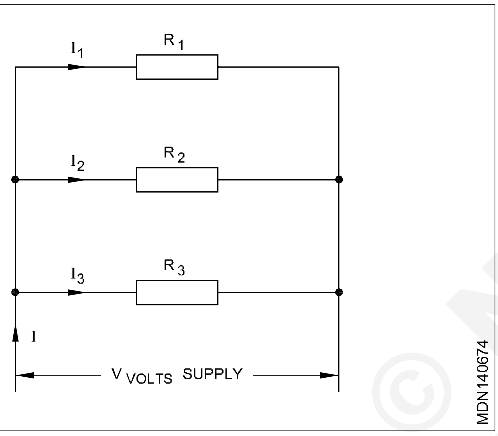
as $V_1 = V_2 = V_3$.

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)

Fig 4



In a parallel circuit, individual branch resistances offer opposition to the current flow though the voltage across the branches will be same.

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.

$$R = \frac{r}{N}$$

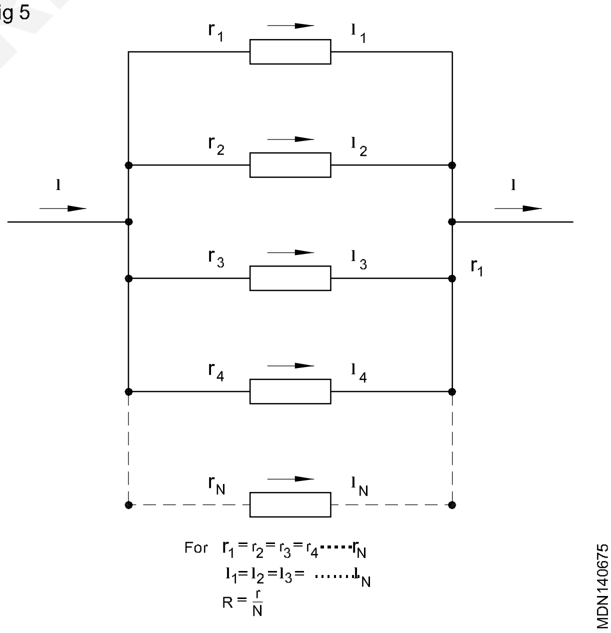
Applications of parallel circuits

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



Battery

Objectives: At the end of the lesson you shall be able to
- **state the classification of cells**
- **describe the primary cells**
- **describe the secondary cells**
- **describe the construction of a lead acid battery**
- **describe the chemical action during discharging**
- **describe the chemical action during charging**
- **describe the maintenance of a battery**
- **describe the testing of a battery.**

Scan the QR Code to view the video for this exercise

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.

- Voltanic 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. 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.

Fig 1

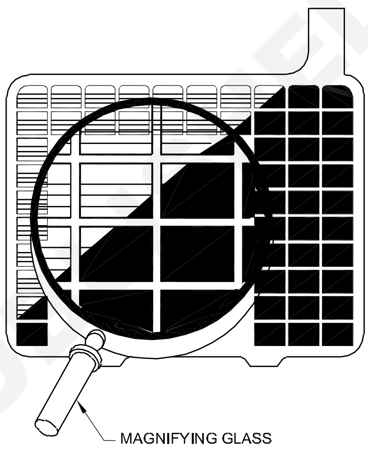
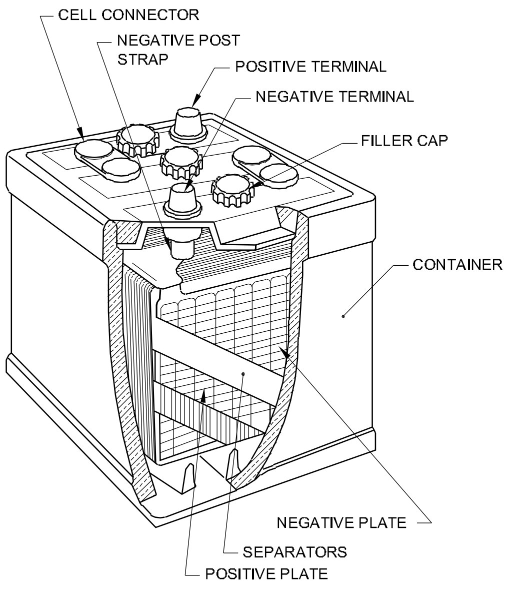


Fig 2



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 alternatively, and in between the plates, seperators 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 From battery cells..

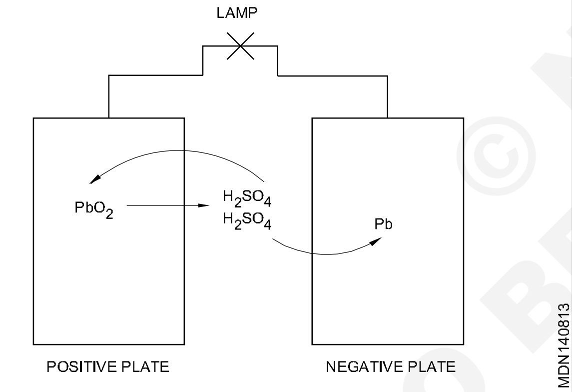
Chemical Reactions

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)

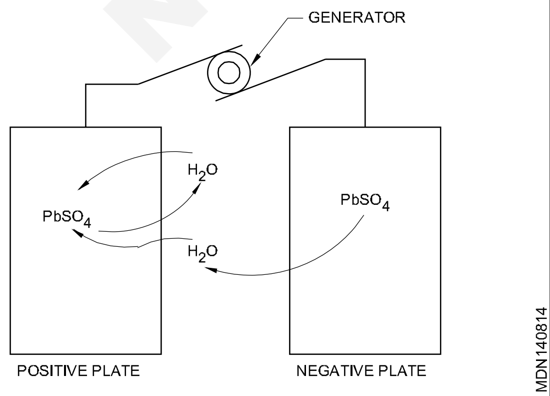
Fig 3



Charging (Fig 4)

When the battery is charged (Fig 4) 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).

Fig 4



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.

$$PbSO_4 + 2H_2O + PbSO_4 \rightleftharpoons PbO_2 + 2H_2SO4 + Pb$$

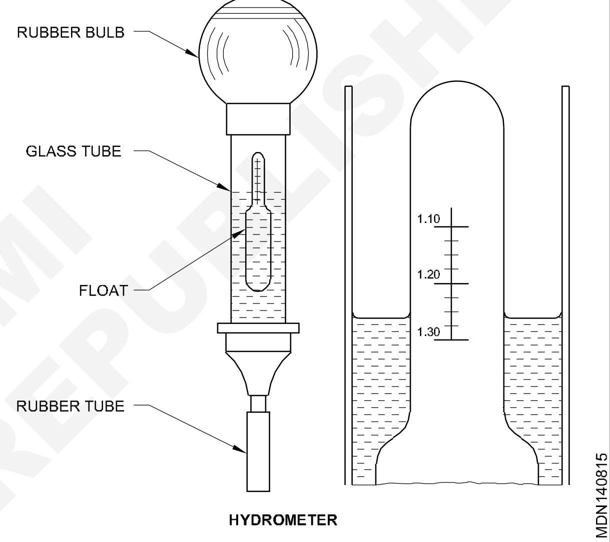
(+ve) (water) (-ve) (+ve) (Electrolyte) (-ve)

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.

Fig 5



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

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.

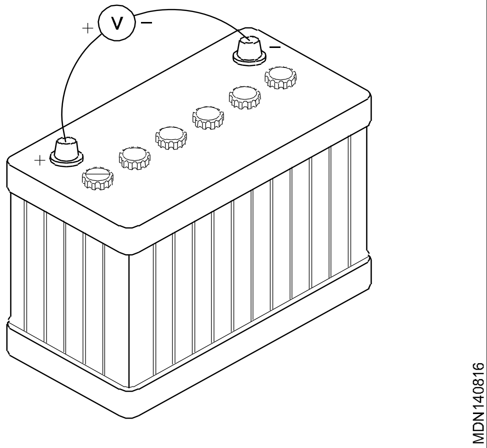
While charging do not overcharge the battery.

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 (Fig 6) : With the help of a voltmeter the voltage of battery is tested. This will commonly vary from 12-13V.

Fig 6



Battery selection: 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 1000A 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.

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 importants 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	1300CC Diesel vehicles
60 Amps 12V	2.5 Ltrs LCV
80 Amps 12V	4 Ltrs medium
120 Amps 12V	6 Ltrs Diesel HCV
180 Amps 12V	6 Ltrs 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.

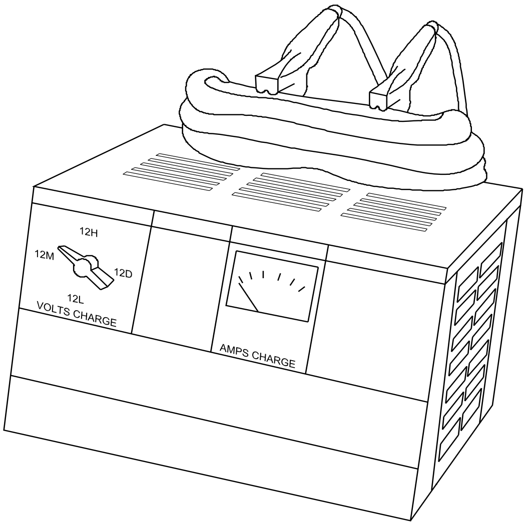
Battery is fully charged when over a two hour period at a low charging rate in amperes all cells are gassing freely and no change in specific gravity occurs. For the most satisfactory charging, the lower charging rates in amperes are recommended.

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 110^0F (43^0C), the charging rate should be decreased.

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.

Fig 7



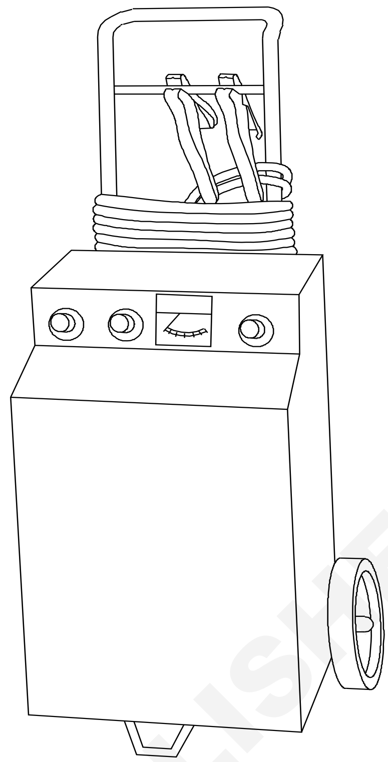
A TYPICAL SLOW CHARGER

MDN140817

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 125^0F (65^0C), 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.

Fig 8



A TYPICAL FAST CHARGER

MDN140818

Features of sealed maintenance free battery

- No need for checking electrolyte level and tapping throughout 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 conventional 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.
- It indicates the battery current charging rate through inbuilt indicator.

Electricity effects

Objectives: At the end of this lesson you shall be able to
- **state the electro chemical process**
- **state the effect of an electric currents.**
- **state the thermo couple**
- **state the thermo electric energy**
- **state the piezo electric energy.**
- **state the photo voltaic 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.

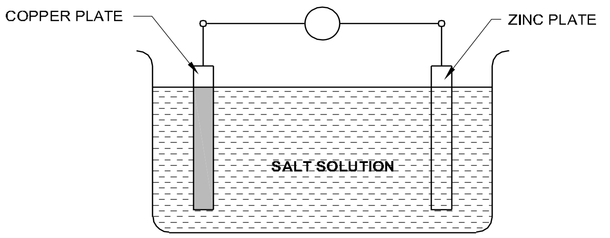
Copper and Zinc in salt solution is one combination.

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.

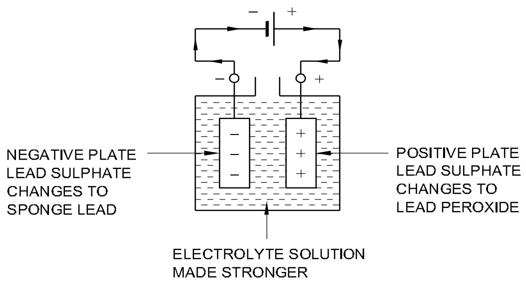
Dynamic electricity (Fig 2): The current is produced by A/C or D/C generators, by conversion of mechanical energy into electrical energy. The generation of electric current is based on the fact when a conductor is moved in a magnetic field an E.M.F is set up in the conductor. When a large number of conductors are moved in a powerful magnetic field, high voltages and current are produced. This is the Principle of Dynamo.

Fig 1



ELECTRICITY GENERATION BY DISSOLVING IN ELECTROLYTES

Fig 2



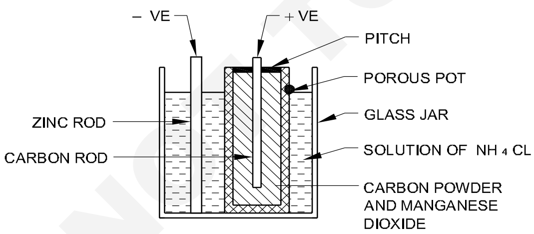
DURING CHARGING PROCESS

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.

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



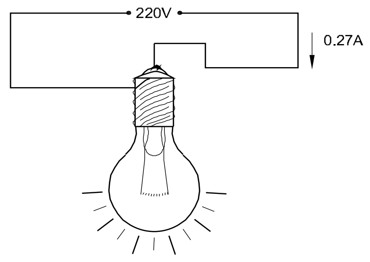
LECLANCHE CELL

Heating effect (Fig 4): When a current is applied to a bulb filament (fine wire) it becomes white hot and thus produces light.

Magnetic effect (Fig 5)

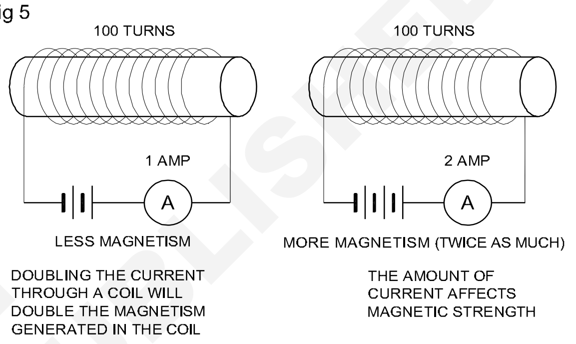
- If a soft iron bar is placed in a coil of wire and a current is passed through the wire, the iron bar becomes magnetised. If the current is withdrawn the bar with retain some magnetism depending on the materials.
- If a bar magnetic is moved in a coil of wire, to and fro then Current flow is occurred in the coil of wire. This can be find 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 4



HEATING EFFECT

Fig 5



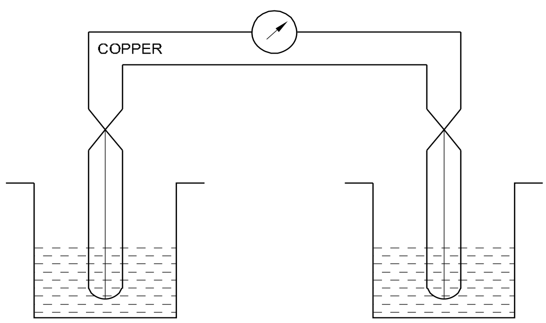
Shock effect: If the current flow through Human body, it may give a severe stock or cause even death of the individuals so one must be careful in dealing with electrical current during work.

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 seebake.

Fig 6



Thermo electric energy: Thermo electric energy is the electrical energy produced by waste heat of an IC engine using seeback effect. Thermo electric generation 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 convertring them to an electrical charge.

Application: It is 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 1 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.

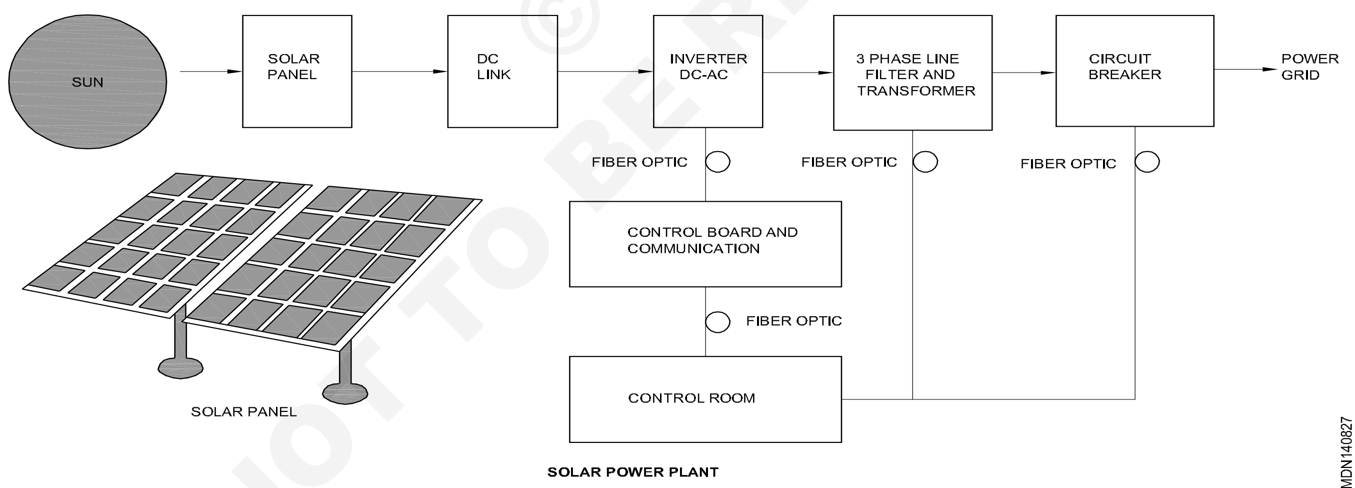
Solar panels installation may be ground, rooftop or wall mounted. The solar panels mount may be fixed a solar tracker to follow the sun across the sky.

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 quantiles 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 (Fig 7) : 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.

Fig 7



Electromagnetic induction, self-induced emf - inductors

Objective: At the end of this lesson you shall be able to
- **state the principle and law of electromagnetic induction.**

Faraday's Law of Electromagnetic induction are also applicable for conductors carrying alternating current.

Faraday's First Law states that whenever the magnetic flux is linked with a circuit changes, an emf is always induced in that circuit.

The second Law states that the magnitude of the induced emf is equal to the rate of change of flux linkage.

According to the first law, induced emf can be produced either by moving the conductor in a stationary magnetic field or by changing magnetic flux over a stationary conductor. When conductor moves and produces emf, the emf is called as dynamically induced emf. (Ex. generators)

When changing flux produces emf the emf is called as statically induced emf as explained below. (Ex. Transformer)

Tracing auto electrical components in circuit - Solenoid & relay

Objectives: At the end of the lesson you shall be able to
- **define a relay**
- **classify relays according to the operating force and function**
- **describe the function of current sensing relay & voltage sensing relay**
- **state the function of solenoid.**

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.

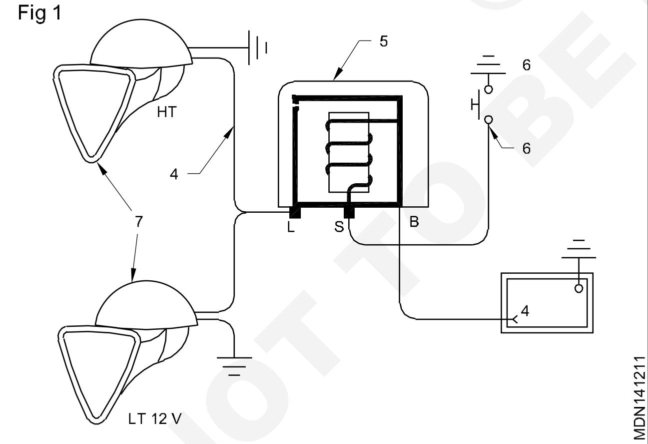
The relays are sensitive to conditions of voltage, current, temperature, frequency or some combination of these conditions.

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.

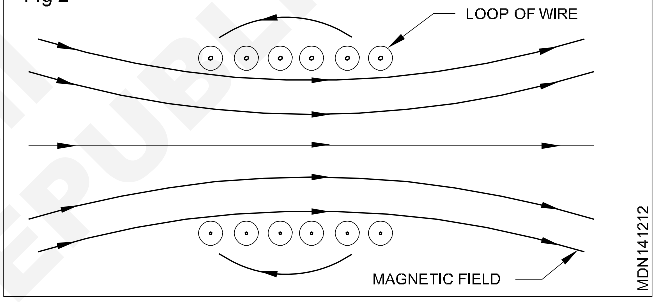
Current sensing relay : A current sensing relay functions whenever the current the coil reaches an uppe limit. The difference between the current specified for pick up (must operate) and non - pick up (must non operate) is usually closely controlled. The difference in current may also be closely controlled 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 metallic core, which produces a uniform magnetic field in a volume of space. (Fig 2)

Fig 2



Application

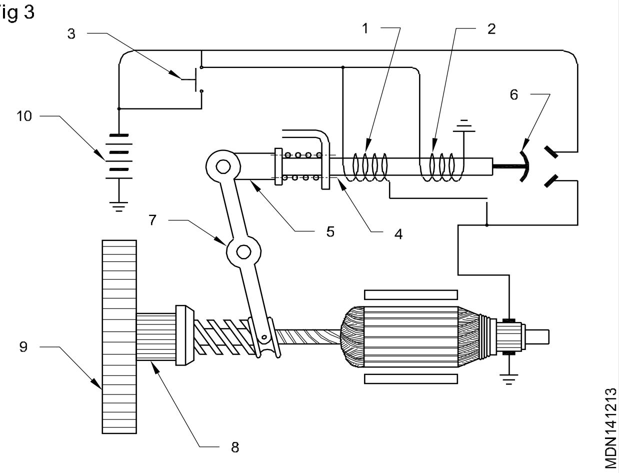
Need for solenoid switch: The solenoid switch is a strong electromagnetic switch. It is used to operate the over running clutch drive pinion to engage with the fly wheel ring gear. It also acts as a relay to close the contacts between the battery and the staring motor.

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.

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 (3) is turned, current flows from the battery to the solenoid windings (1) and (2). This energises the windings which pull the plunger (5). The plunger (5) operates are 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 starting motor.

Fig 3

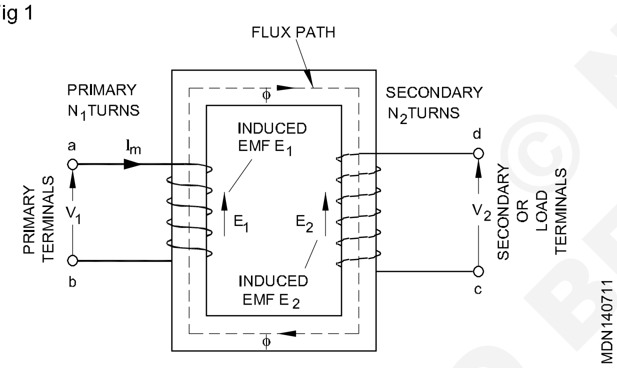


Primary and secondary winding, transformers, stator and rotor coil

Objectives : At the end of this lesson you shall be able to
- **define the primary and secondary of a transformer**
- **state the constructional features of a power transformer and the function of each part**
- **state the reasons for laminated silicon steel being used as core material.**

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 circuits 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 and battery charger.

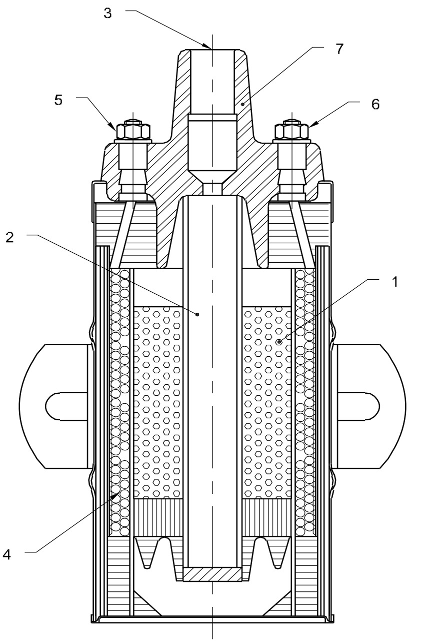
Ignition coil (Fig 2)

It is used to step up low voltage to high voltage to generate sparks. It consists of two windings, one 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.

Rotor: Rotor is the moving part of a rotary electric motor, electric generator alternated which rotates because the wire and magnetic field of the motor are arranged so that them to develop about the rotor axis.

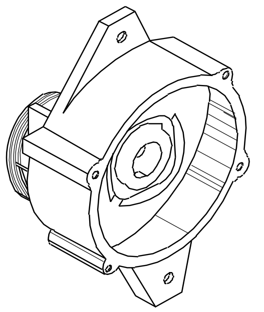
Fig 2



Description of parts of an alternator

Drive end frame (Fig 3): The drive end frame supports a pre - lubricated sealed sliprimgs in which the drive end of rotor shaft rotates.

Fig 3



DRIVE END FRAME

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 stationary part which is held between two end covers. (Fig 5)

Fig 4

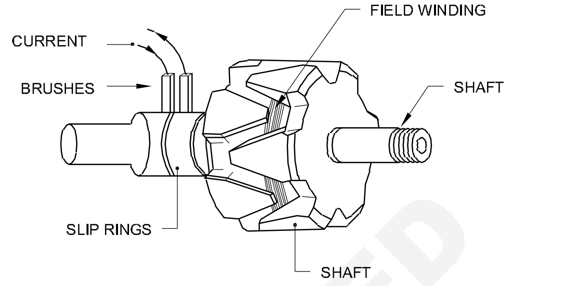
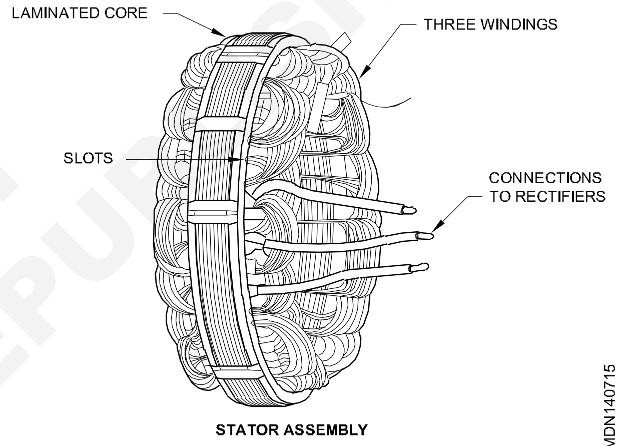


Fig 5



STATOR ASSEMBLY

Diodes

Objectives: At the end of the 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.**

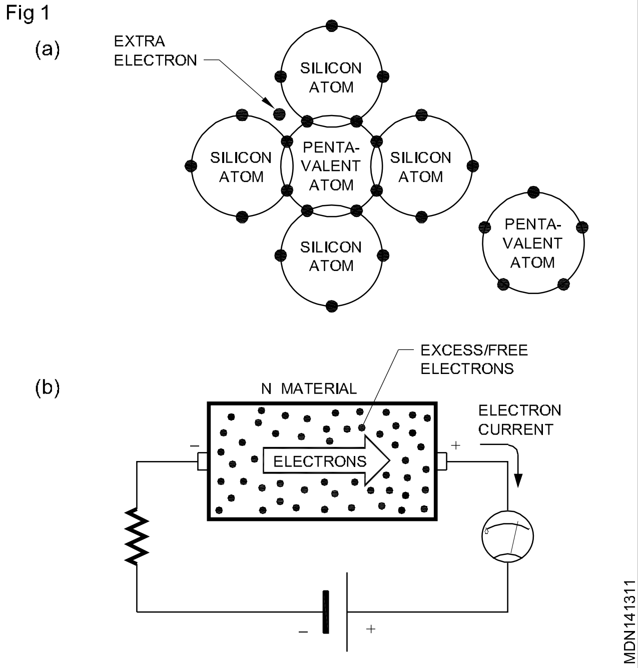
Semiconductors

Semiconductors 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.

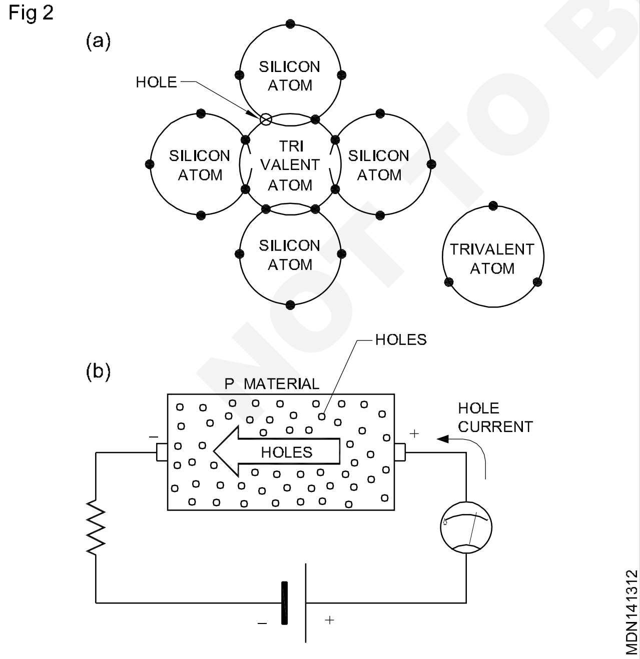
Fig 1



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.

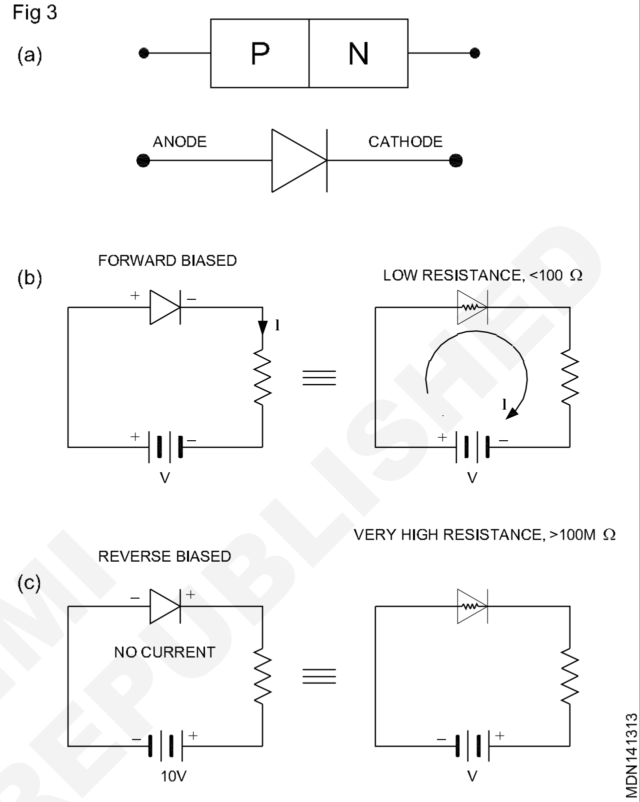
Fig 2



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.

Fig 3



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 the names given to the leads of a transistor**
- **state the functions of the three sections of a transistor**
- **state the uses of putting sleeves to transistor leads**
- **describe the two tests to be conducted on a transistor before using it.**

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.

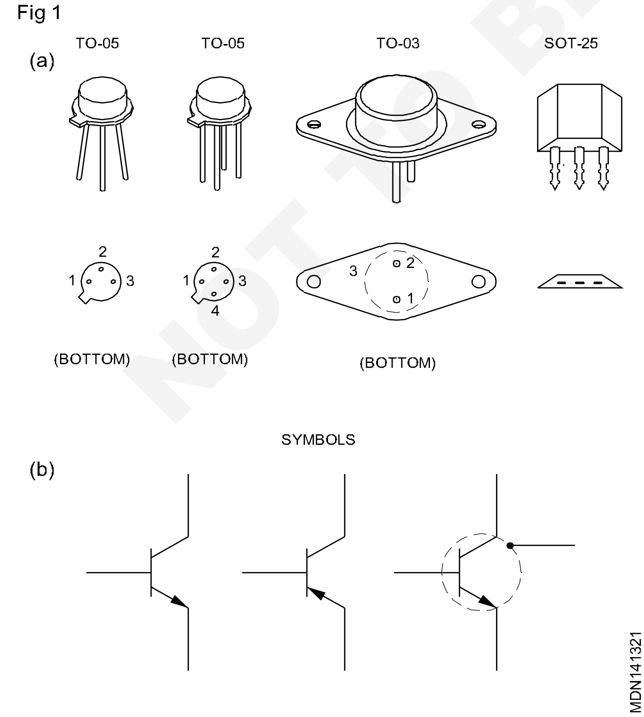


Fig 1

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.

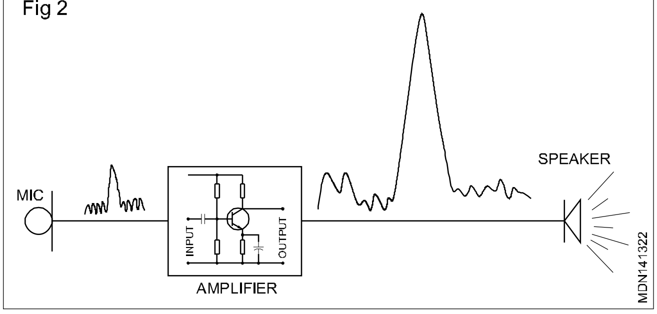


Fig 2

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.

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.

Fig 3

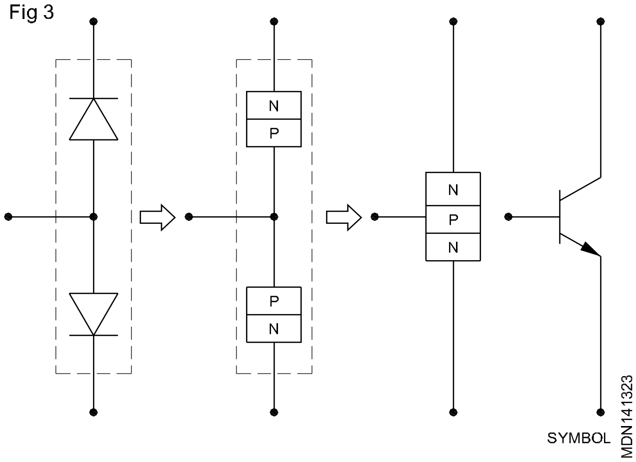
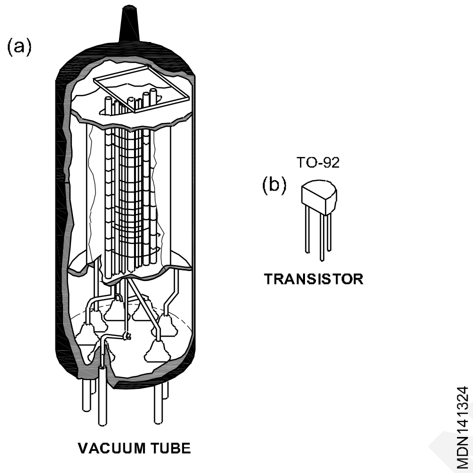


Fig 4



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 absolute 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 (see Fig 4b)
- 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.

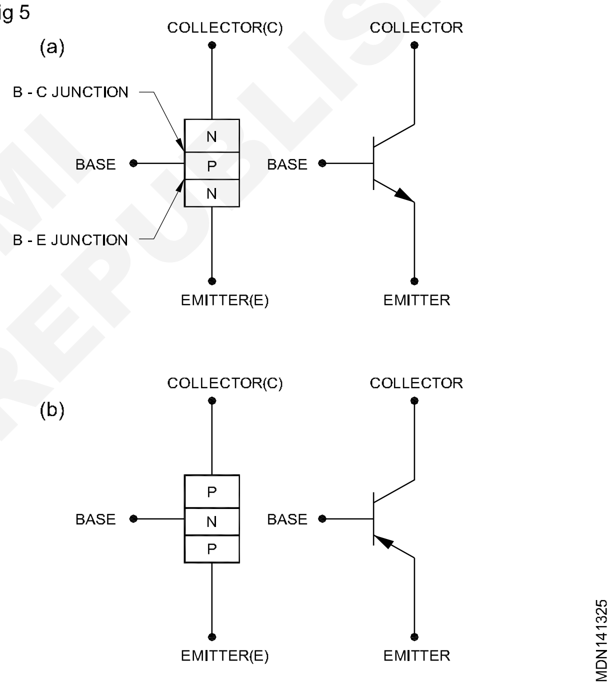
2 Based on the way the P and N junctions are organized as shown in Fig 5

- 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.

Fig 5



3 Based on the power handling capacity of transistors as shown in Table below (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.

Low power transistors (less than 2 watts)	Medium power transistors (2 to 10 watts)	High power transistors (more than 10 watts)

Fig 6

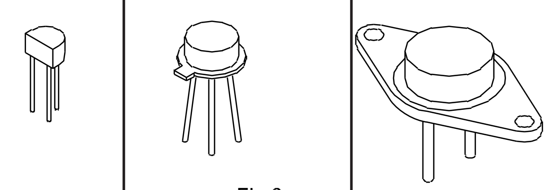


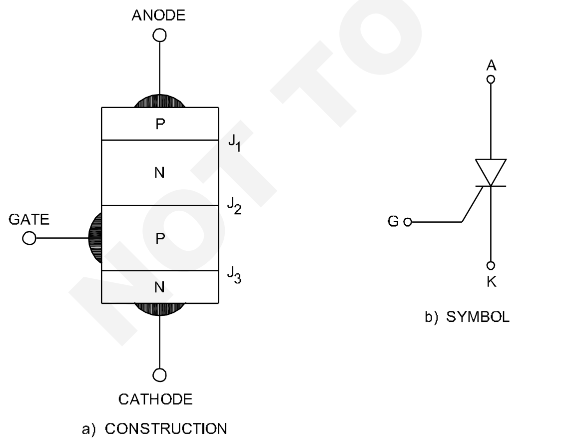
Fig 6

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.

Fig 7



SILICON CONTROLLED RECTIFIER

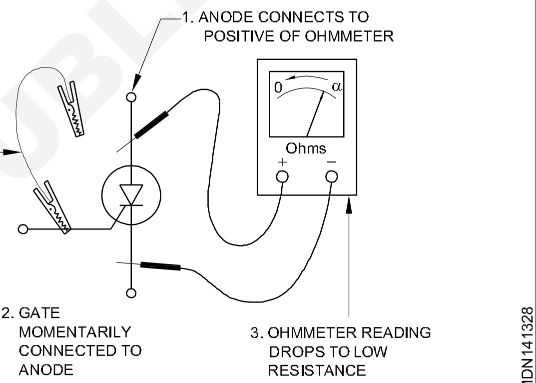
In the on-state, the current is limited by the external impedance. If the anode-to cathode voltage is now reduced, since the original depletion layer and the reverse-biased junction J_2 no longer exist due to the free movement of the carriers, the device will continue to stay on.

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.

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.

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 40 Ohm.

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, i.e. 30 to 40 Ohm.

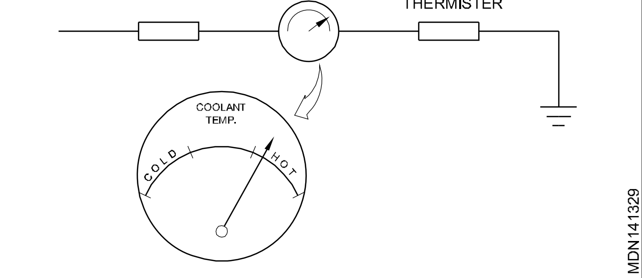
Thermistor: It is also semiconductor device used in most vehicles today. They are named because they are actually a temperature sensitive resistor. It is made of powdered nickel, cobalt, copper, iron and manganese which has been fused together at a higher temperature. The electrical resistance of a thermistor 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



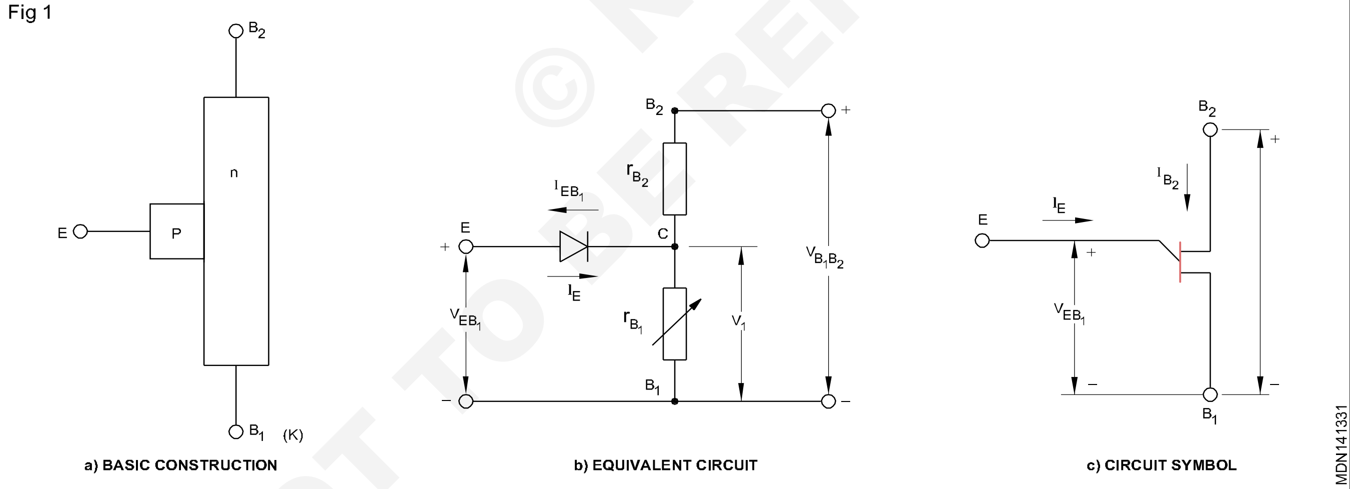
Uni-junction transistor (UJT)

Objectives: At the end of this lesson you shall be able to
- **explain the construction, equivalent circuit and symbol of an UJT**
- **state the application of UJT.**

The Uni-junction transistor (UJT): The uni-junction transistor consists of a bar of lightly doped n-type silicon with small piece of heavily doped P-type material joined to one side at 60% of height from the base as shown in Fig 1a. The end terminals are named as base 1(B_1) or Cathode (K) and base 2(B_2) or anode (A) and the P-type material as emitter (E). The highly doped n-type material has a high resistance and can be represented by two resistor r_{B1} and r_{B2}. The sum of r_{B1} and r_{B2} is designated as R_{BB} (Refer Fig 1b). The emitter (P-type) form a PN junction with the n-type silicon bar and this junction is represented by a diode in the equivalent circuit (Fig 1b). The circuit symbol is shown in Fig 1c.

Application of UJTs: UJTs are employed in a wide variety of circuits involving electronic switching and voltage or current sensing applications.

Fig 1



Field effect transistors

Objectives : At the end of this lesson you shall be able to
- **explain the difference between bi-polar transistors and field effect transistors**
- **write the basic construction and symbol used.**
- **explain the theory of operation of FETs**
- **explain a typical FET a.c voltage amplifiers.**

Field Effect Transistor (FET)

The main difference between a Bi-polar transistor and a FET is that,

Bi-polar transistor is a current controlled device.

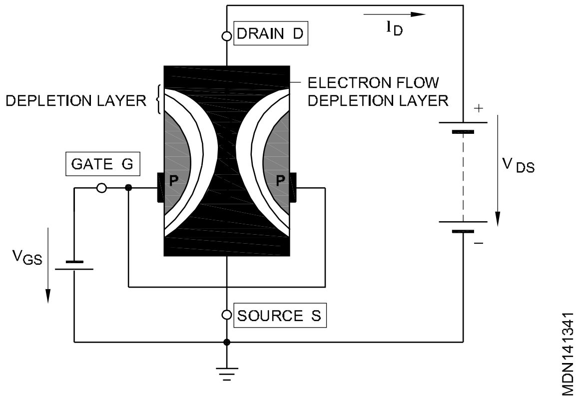
In simple terms it means that the main current in a bi-polar transistor is controlled by the base current.

FET is a voltage controlled device.

This means that the voltage at the gate controls the main current.

In addition to the above, in a bi-polar transistor, the main current always flows through N-doped and P-doped semiconductor materials. Where as in a FET the main current flows either only through the N-doped semiconductor or only through the P-doped semiconductor as shown in Fig 1.

Fig 1



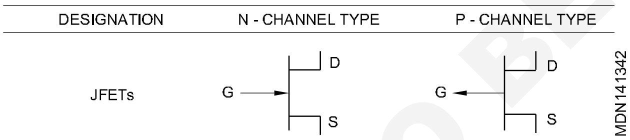
If the main current flow is only through the N-doped material, then such a FET is reffered as a P-channel or P type FET. The current through the P-doped material in the P-type FET is only by Holes.

Unlike in bipolar transistors in which the main current is both by electrons and holes. In contrast in FETs depending on the type(P or N type) the main current in either by electrons and holes and never both for this reason FETs are also known as Unipolar transistors or unipolar device.

Junctin Field Effect Transistor (JFET)

It is a three terminal device and looks similar to a bi-polar transistor. The standard circuit symbols of N-channel and P-channel type FETs are shown in Fig 2.

Fig 2

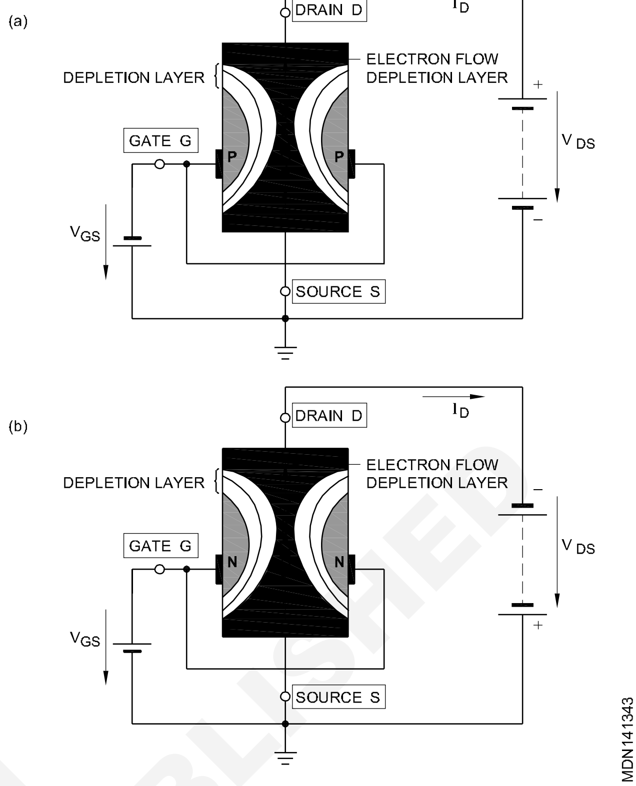


Construction: As shown in Fig 3a, a N-channel JFET has a narrow bar of n-type. To this, two p-type junctions are diffused on opposite sides of its middle part fig 3a.These diffused junctions form two PN diodes or gates. The N-type semiconductor area between these junctions/gates is called the channel. The diffused P regions on opposite sides of the channel are integrally connected and a single lead is brought out which is called gate lead or terminal.

Direct electrical connections are made at the two ends of the bar. One of which is called source terminal S and the other terminal, D is called drain-D.

A P-channel FET very similar to the N-channel FET in construction except that it uses P-type bar and two N-type junctions as shown in Fig 3b.

Fig 3



FET notation listed below are essential and worth memorizing.

1 Source terminal: It is the terminal through which majority carriers enter the bar (N or P bar depending upon the type of FET).

2 Drain terminal: It is the terminal through which majority carriers come out of the bar.

3 Gate terminal: These are two internally connected heavily doped regions which form two P-N junctions.

4 Channel: It is the space between the two gates through which majority carriers pass from source to drain when FET is working (on).

Working of FET

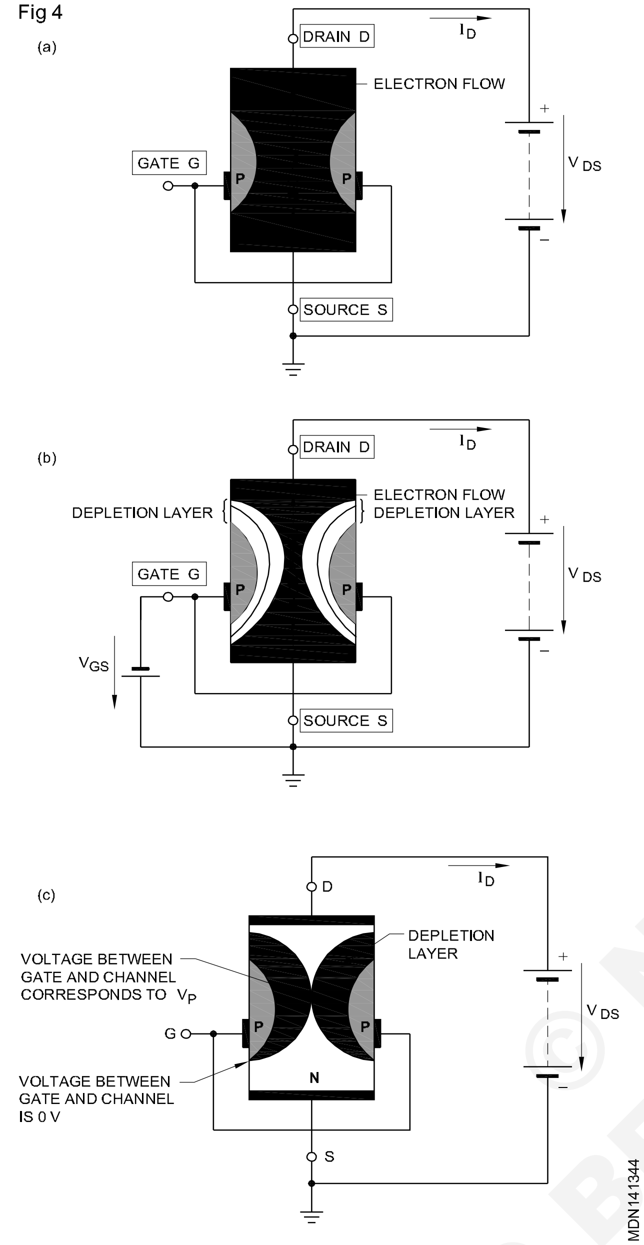
Similar to Bipolar transistors, the working point of adjustment and stabilization are also required for FETs.

Biasing a JFET: The biasing arrangement of JFET is shown in Fig 4. In which the gates are always reverse biased. Therefore the gate current Ig is practically zero.

The current source terminal is always connected to that end of the supply which provides the necessary charge carriers. For instance, in a N-channel JFET source terminal S is connected to the negative of the d.c power supply. And, the positive of the d.c power supply is connected to the drain terminal of the JFET.

Where as in a P channel JFET, Source is connected to the positive end of the power supply and the drain is connected to the negative end of the for the drain to get the holes from the P-channel Where the holes are the charge carriers.

Fig 4



Where as in a N channel JFET, the drain is made positive with respect to source by voltage Vds as shown Fig 4a.When gate to source voltage Vgs is zero, there is no control voltage and maximum electron current flows from source(S)-through the channel-to the drain (D).This electron current from source to drain is referred to as Drain current,Id.

When gate is reverse biased with a negative voltage as shown in Fig 4b,the static field established at the gate causes depletion region to occur in the channel as shown in Fig 4b.

This depletion region decreases the width of the channel causing the drain current to decrease.

If Vgs is made more and more negative, the channel width decreases further resulting in further decreases in drain current. When the negative gate voltage is sufficiently high, the depletion regions meet and block the channel cutting off the flow of drain current as shown in Fig 4c.This voltage at which this effect occurs is referred to as the pinch off voltage, Vp.

Thus, by varying the reverse bias voltage between gate and source (-Vgs),the drain current can be varied between maximum current (with –Vgs=0) and zero current (with –Vgs=pinch off voltage).So,JFET can be reffered as a voltage controlled devices.

P channel JFET operates in the same way as explained above except that bias voltages are reversed and the majority carrier of channel are holes.

Metal Oxide Field Effect Transistor (MOSFET)

Objectives: At the end of the lesson you shall be able to
- **state the MOSFET's operation principle and its types**
- **list the special type of MOSFET**
- **explain the features of MOSFET.**

In MOSFETs, control is via an insulating layer instead of a junction (as in JFETS). This insulating layer is generally made of silicon dioxide, from which the very name MOSFET is derived(Metal Oxide Semiconductor). Some times the MOSFETs are also referred to as Insulated-gate FET, for which the abbreviation used are IFET or IGFET.

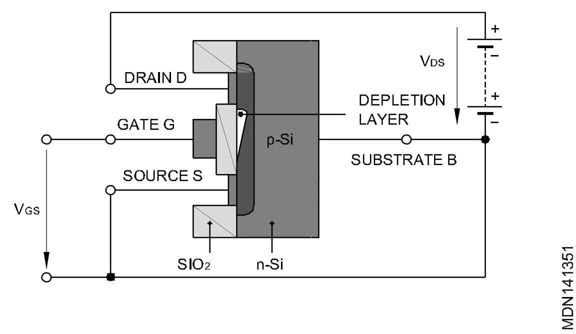
Type of MOSFET

Depletion-type MOSFET

Construction and mode of operation

Fig 1 shows the construction of a depletion MOSFET of the n-channel type.

Fig 1



Here, two highly doped n-zones are diffused into p-doped silicon plate, which is referred to as the substrate, and are provided with junction-free drain and source connections. Between the two zones there is a thin weakly n-doped channel, which produces an electrical connection between the source and drain without an external field-action.

This channel is covered by an insulting layer of silicon dioxide (SIO_2), to which a metal electrode is applied as the gate connection.

If a voltage U_{DS} is applied between source and drain, at U_{GS} =)V an electron current flows from the source electrode via the n-channel to the drain electrode. If, however, a negative voltage is applied to control electrode G, the electrons present in the n-channel are forced out of the vicinity of the gate electrode, so that a zone depleted of charge carriers is produced there.

This causes a constriction of the n-channel and consequently also a reduction of its conductivity. If the gate voltage becomes more negative, the conductivity of the channel is reduced, as is consequently also the drain current I. Another peculiarity of depletion type MOSFET s is that they can also be controlled with a positive gate-voltage. charge carries are then drawn out of the P-doped substrate into then-channel and its conductivity is increased even further, compared with the conductivity at U_{GS}- OV

Designations and circuit symbols

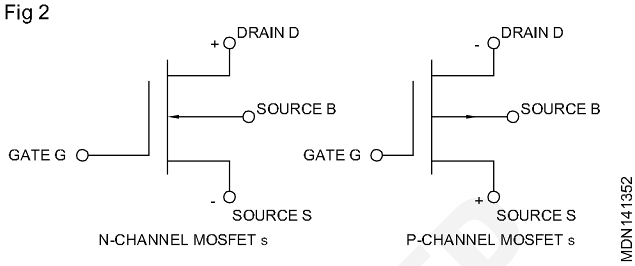
The same designations are used for the connections of MOSFETs as they are for JFETs, i,e. source, drain and gate. MOSFETs, however, have another electrode, which is referred to as the substrate connection. Together, which is referred to as the substrate connection.

Together with the semiconductor material of the channel, this substrate forms a P-N junction, which can be used as a second control- electrode. It is then led out of the casing. Like the other electrodes is connected directly to the additional control possibility.

Fig 2 Shows the circuit symbols for depletion- type n-channel MOSFETs and p-channel MOSFETs. For the n-channel type, the arrow points towards the line representing the channel, in the case of the P-Channel type, on the other hand, it points away from the line representing the channel. The continuous line representing the channel indicates that it is depletion-type MOSFET.

N- Channel MOSFETs are operated with a positive drain-source Voltage. They have a considerably greater practical significance than p-channel MOSFETs, which require a negative drain-source voltage for their operation.

Fig 2

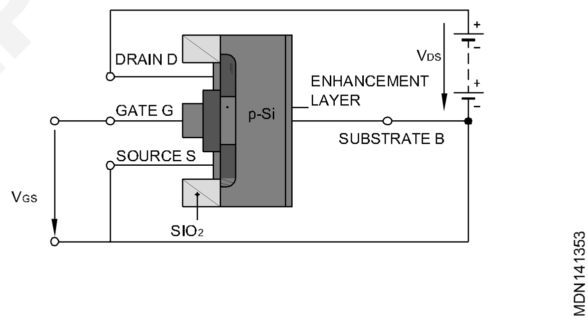


Enhancement-type MOSFET

Construction and mode of operation

Enhancement-type MOSFETs have a similar technological construction to the depletion types. Without the external action of a field. However no conducting channel exists between the drain connection and the source connection, so that at U_{GS}=)V, no drain current can flow (Fig 3). Shows the construction of an enhancement-type n-channel MOSFET.

Fig 3

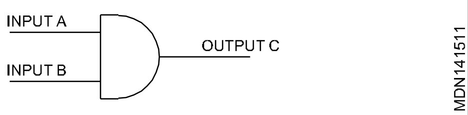


Basic logic gates

Objective: At the end of this lesson you shall be able to
- **describe the AND, OR, NOT & NAND gate and their applications with simple digital circuits.**

Logic circuits (Fig 1): Digital ICs are made up of many different elements. Most important of these are transistors. This transistor circuits are called logic circuits or digital circuits and are made up of combinations of different types of so-called gates. These gates have the special ability to logically process two or more signals. Thus they are also called logic gates.

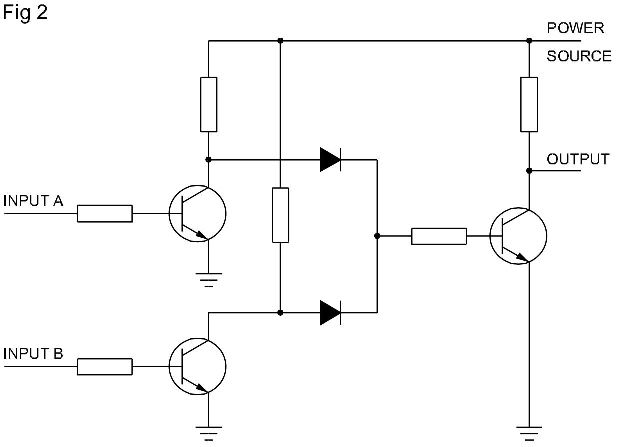
Fig 1



The "AND" Gate: Logic circuits are usually indicated by a special symbol. Such a circuit, however is actually composed of semiconductor elements as shown in (Fig 2).

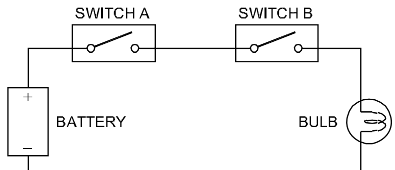
To make an AND gate easily understand, a simple mechanical circuit without the use of semiconductors is shown in (Fig 3). In this circuit the switches A and B are equivalent to (C). The light bulb lights only if both switches A and B are closed. If either switch is open, the bulb will (or it both are open), not come on.

Fig 2



SEMICONDUCTOR CIRCUIT THAT CORRESPONDS TO AN "AND" GATE

Fig 3



SIMPLE MECHANICAL CIRCUIT THAT CORRESPONDS TO AN "AND" GATE

Similarly, in an actual AND gate, there will be an "on" signal (often represented as the number 1) at the output terminal (C) only if there is a voltage at both input terminals (A and B). If either A or B is zero (off) or if both are zero, C will also be zero. These combination can be shown in a truth table.

AND - gate truth table

Inputs		Output
A	**B**	**C**
0	0	0
0	1	0
1	0	0
1	1	1

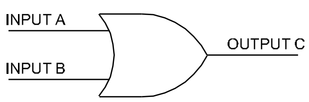
The "OR" Gate (Fig 4 to 6)

Fig 4 shown the symbol for an "OR" gate, its corresponding semiconductor circuit, and an equivalent mechanical circuit.

If there is voltage at either input terminal (or if there is a voltage at both inputs) there will be voltage at the output terminal "OR" gate truth table is given.

The symbol for a "NOT" gate is shown in (Fig 7). A corresponding semiconductor circuit and an equivalent mechanical circuit are as shown in (Fig 8).

Fig 4



THE "OR" GATE

Fig 5

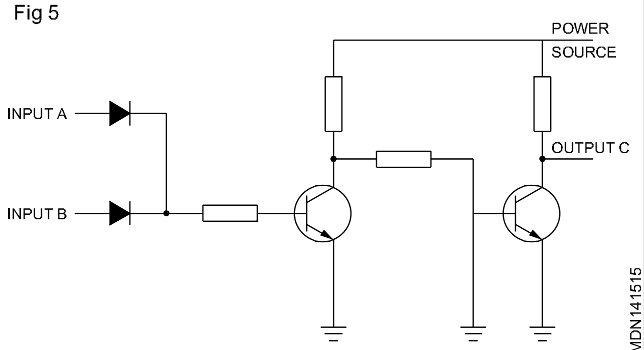


Fig 6

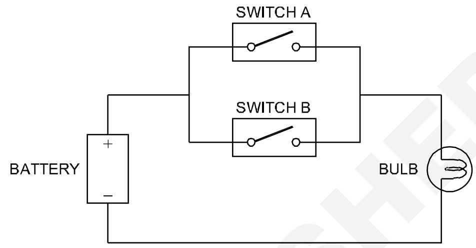
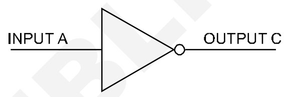
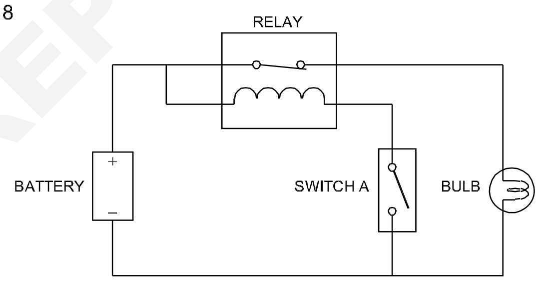


Fig 7



"NOT" GATE

Fig 8



SIMPLE MECHANICAL CIRCUIT THAT CORRESPONDS TO "NOT" GATE

In the mechanical NOT circuit, the light bulb does not go on if switch A is closed. When switch A is opened the relay closes and the bulb is turned on.

As can be seen in the truth table, the "NOT" gate inverts the signal so that the output is always the opposite of the input. For this reason it is called as "inverter". (Fig 9)

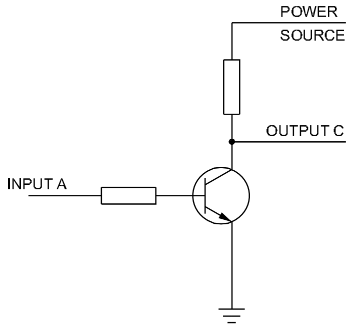
"NAND" is a combination of "AND" gate and a "NOT" gate as shown in (Fig 10).

A zero will appear at the output terminal (C) only if there is a voltage at both input terminals (A and B). If there is a zero at either A or B, an "on" signal (number 1) will appear at C.

This can be observed in Truth Table as shown.

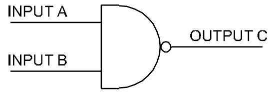
A "NOR" gate is a combination of an "OR" gate and a NOT gate (Fig 11). For this reason, an "on" signal will appear at the output terminal only if there is an "off" signal (zero) at both input terminals. If there is an "on" signal at either A or B, terminal C will zero as shown in the truth table.

Fig 9



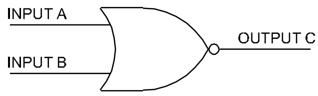
SEMICONDUCTOR CIRCUIT THAT CORRESPONDS TO "NOT" GATE

Fig 10



"NAND" GATE

Fig 11



"NOR" GATE

Introduction to hydraulics and pneumatics

Scan the QR Code to view the video for this exercise

Objectives: At the end of this lesson you shall be able to
- **define the term of fluid power**
- **explain the working principle of pneumatic systems and advantages and disadvantages**
- **explain the working principle of hydraulic systems and advantages and disadvantages.**

Fluid power systems

Fluid power is the driving force in most industrial and mobile applications. A bulldozer or excavator used for moving soil where a new project is being built, and a brake used in a car or truck are some examples of where fluid power is used. Fluid power involves the use of a fluid medium, such as air or oil, in a controlled manner, to get some useful work. Two specialized areas cover the scope of the definition of the term 'fluid power'. They are: (1) Pneumatics and (2) Hydraulics. Transmission and control of power by means of air is called pneumatics and transmission and control of power by means of liquid is called hydraulics.

Pneumatic systems

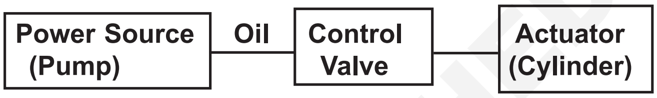
In a pneumatic system, energy in the form of compressed air is transmitted to an actuator, where work is to be done. The basic elements of the system are power source, control valves and actuators, as shown in Figure, Air compressor is used as the power source to increase the pressure of the related air medium to the required level. However, the process of pressure development in the system is quite slow. The slow response of the air compressor in developing sufficient pressure necessitates storage of compressed air in a receiver tank. The energy that is stored in the receiver tank can be transmitted, in a controlled manner, to an actuator to perform some useful work.

Pneumatic systems

An important advantage of pneumatic systems is that they can produce linear motion quite easily. They can also produce high-speed operation. Speed control can also be achieved easily by using simple flow control valves. However, pneumatic systems are not suitable for providing uniform motion. Operating pressures in pneumatics are generally much lower than that used in hydraulics. Therefore, pneumatic systems are ideal for applications that involve small magnitude of linear forces.

Hydraulic systems

In a hydraulic system, energy in the form of pressurized liquid (oil) is transmitted to an actuator, where work is to be done. The basic elements of the system are power source, control valves and actuators, as shown in Figure. In the hydraulic power transmission, a pump is used as the power source to create flow and subsequently raise the pressure of an enclosed incompressible oil medium to the required level almost instantaneously. The hydraulic energy can, then, be transmitted through the pressurised oil medium, in a controlled manner, to an actuator to perform some useful work.



Hydraulic systems

A major advantage of hydraulic systems is that they can easily generate linear motion through the basic actuator, cylinder. Operating pressures in hydraulics are generally much higher than that used in pneumatics. Therefore, high-pressure hydraulic systems are capable of generating large magnitude of forces economically to drive heavy loads. Speed control of an actuator can also be achieved easily by regulating the flow rate of oil to the actuator. Precise control of speed even at low values is another advantage of hydraulic systems.

Extensive use of hydraulics is due to the following facts;

- Oil is practically incompressible
- Oil can transmit high forces rapidly and accurately
- Simple step-less control of speed, force or torque
- Have simple over load protection
- Simple, compact and highly reliable

Hydraulic systems are used in the following subsystems in modern Automotives and related maintenance equipment

- Fuel injection system
- Lubrication system
- Brake system
- Steering system
- Shock absorbers
- Adoptive suspension system
- Automatic transmission system
- Clutch actuating mechanism
- Jack
- Hoist
- Bearing puller etc.

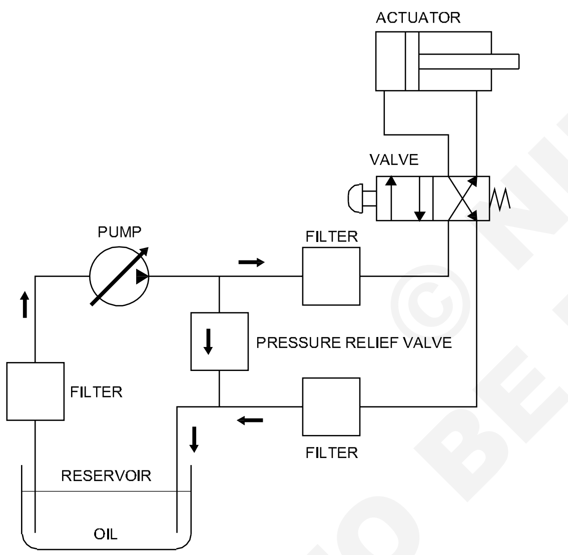
Hydraulics

Objectives: At the end of this lesson you shall be able to:
- **describe the hydraulic system**
- **understand the components of a hydraulic power pack**
- **explain the working of a hydraulic pump.**

Hydraulic System: The 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.

Fig 1

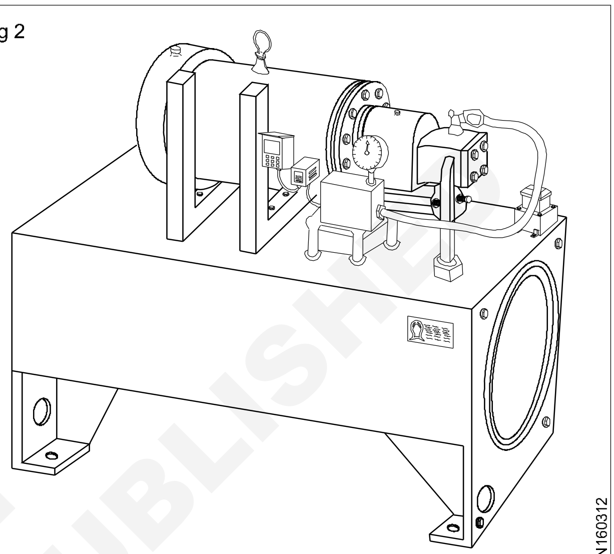


REPRESENTATIONS OF A TYPICAL HYDRAULIC SYSTEM

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.

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.

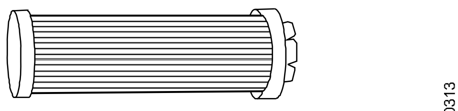
Fig 2



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.

Fig 3



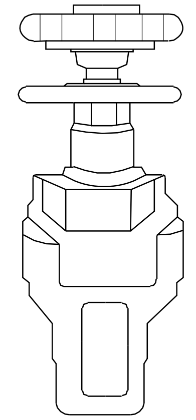
HYDRAULIC FILTER ELEMENT

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.

External gear pump: Fig 5 illustrates the operation of an external gear pump with the help of its schematic diagrams in three critical positions. It is 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.

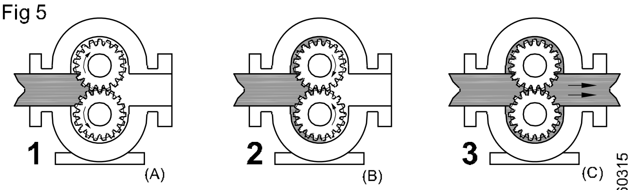
Fig 4



PRESSURE RELIEF VALVE

MDN160314

Fig 5



SCHEMATIC DIAGRAMS ILLUSTRATING THE OPERATION OF AN EXTERNAL GEAR PUMP

MDN160315

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).

The oil then travels around the periphery of the rotating gears as two streams (Fig 5b). Since the pump has a positive internal seal against leakage, the oil is positively ejected out of its delivery port (Fig 5c). 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.

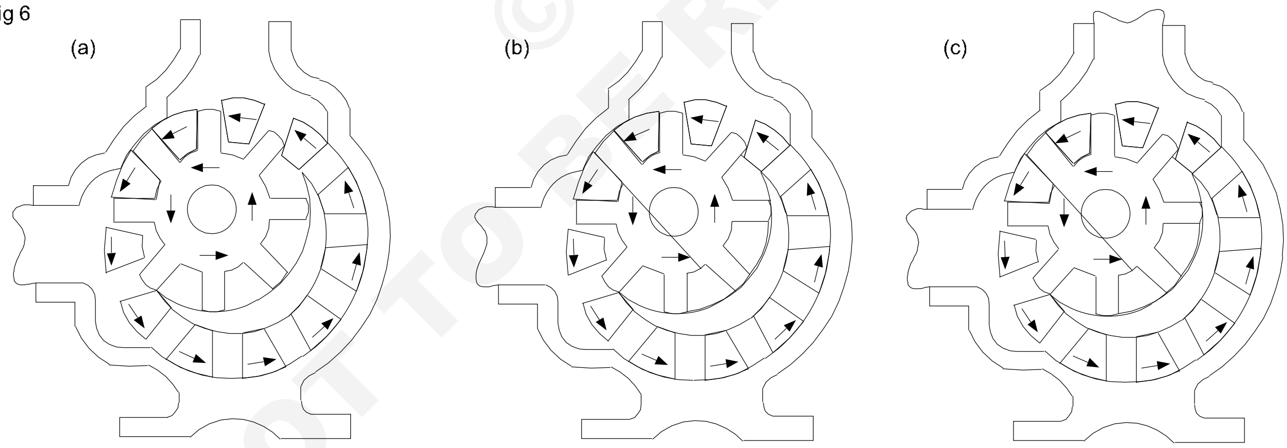
Internal Gear Pump (Fig 6): Illustrates the operation of an internal gear pump with the help of its schematic diagrams in three critical positions. This pump consists of an outer rotor gear, an inner spur gear, and a crescent-shaped spacer, all enclosed in a housing.

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 6a).

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 6b & 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

MDN160316

Hydraulic actuators and valves

Objectives: At the end of this lesson you shall be able to
- **explain the 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, as used in hydraulic system, converts hydraulic power into a controllable linear force and/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.

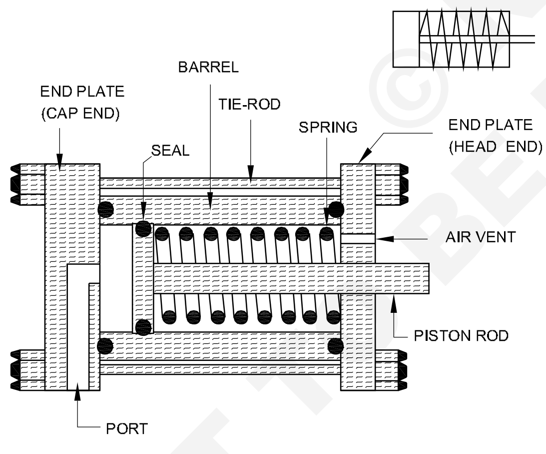
Application of a hydraulic pressure through the port moves the piston-and-rod assembly in one direction to provide the working stroke. The piston-and-rod assembly moves in the opposite direction, either by a spring force or by gravity, or even by exerting an external force. In a cylinder with a spring-assisted retraction, the spring is designed not to carry any load, but, to retract the piston-and-rod assembly with sufficient speed.

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.

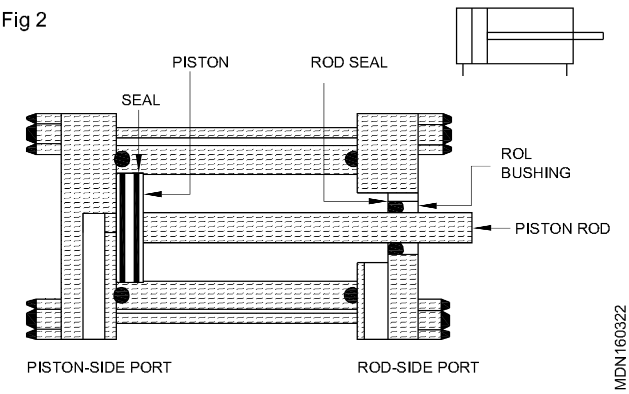
Fig 1



Cross-sectional view of a double-acting cylinder. (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.

Fig 2

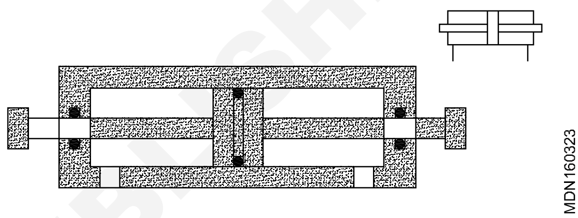


Double rod-end hydraulic cylinders

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.

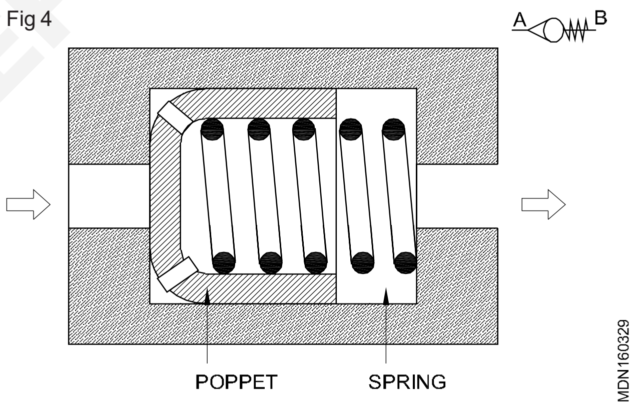
A double rod-end hydraulic cylinder. (Fig 3)

Fig 3



Two positions of the circuit for the control of a double-acting hydraulic cylinder (Fig 4).

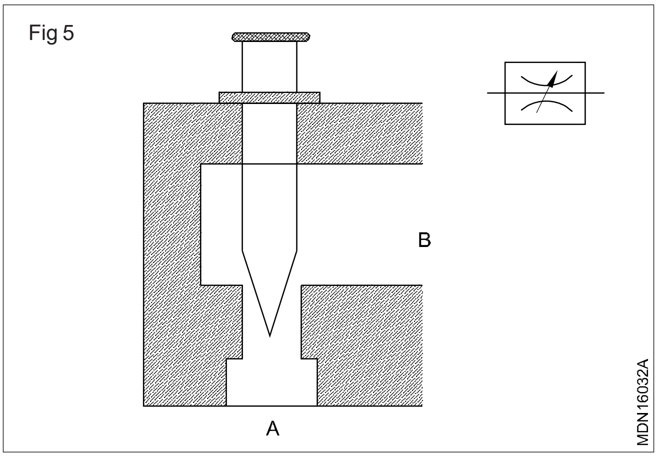
Fig 4



(Fig 4) Cross-sectional views of a check valve.

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 5.



(Fig 5) A cross-sectional view of an adjustable type throttle 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.

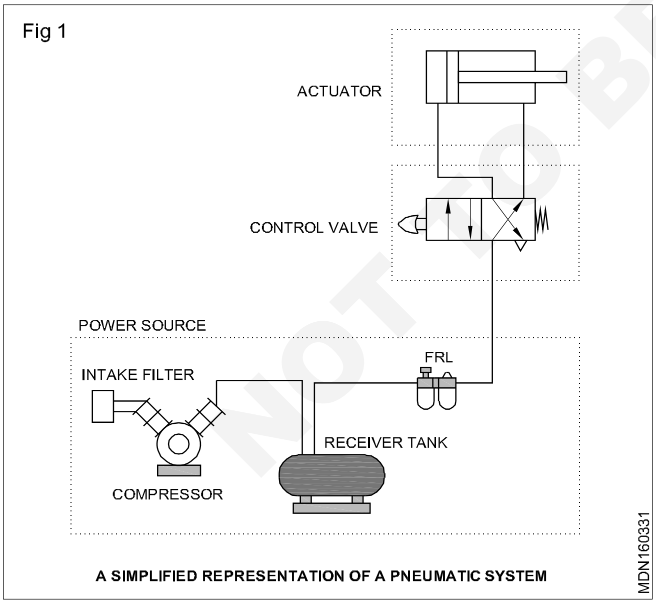
Flow control (throttle) valve: A throttle valve is a device with a restriction that offers a resistance to the system oil flowing through it. The throttle valve regulates the flow rate of the system oil. According to the type of restriction, throttle valves are of two types. They are (1) Fixed type and (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.

Pneumatic system

Objectives: At the end of this session you shall be able to
- **explain 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 compressor: 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,

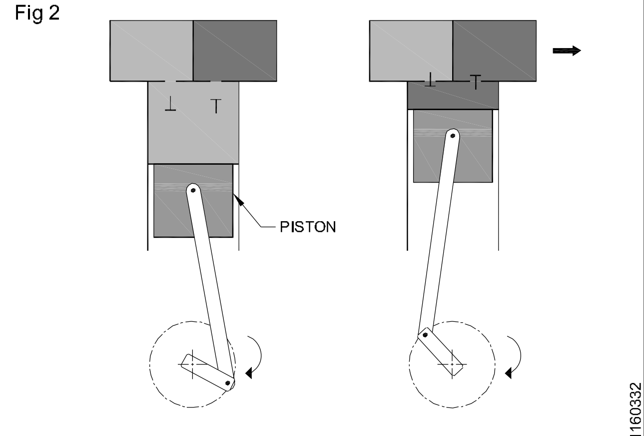
$$P_1V_1 = P_2V_2 \text{ (Temperature constant)}$$

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.

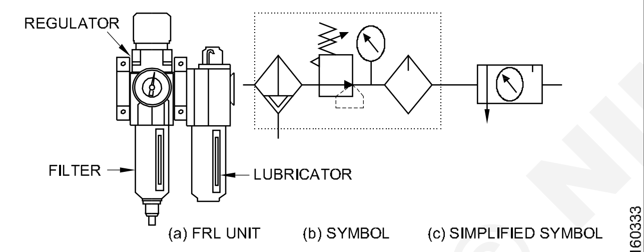
FRL or air service unit: Compressed air, which is dry and clean, is the most important requirement for the satisfactory operation of any pneumatic system. As we are aware, compressed air in a pneumatic system is liable to be contaminated to a high degree. It is essential to remove fine dirt particles, 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 2



RECIPROCATING COMPRESSOR

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.

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.

spool is held in the centre position by the spring, it is said to be "spring-centred". Symbols for methods of valve actuation are presented.

Scan the QR Code to view the video for this exercise

Classification of vehicles

Objective: At the end of this lesson you shall be able to
- **classify the vehicles.**

Classification of vehicles

Based on central motor vehicle act

- Motor cycle
- Invalid carriage
- Three wheelers
- Light motor vehicle
- Medium passenger motor vehicle
- Medium goods vehicle
- Heavy passenger motor 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)
- Front engine front wheel drive (Alto, Ertiga, santro, Tiago etc) (Fig 4)
- Four wheel/ All wheel drive (jeep, Scorpio, Gypsy etc) (Fig 3)

Fig 1

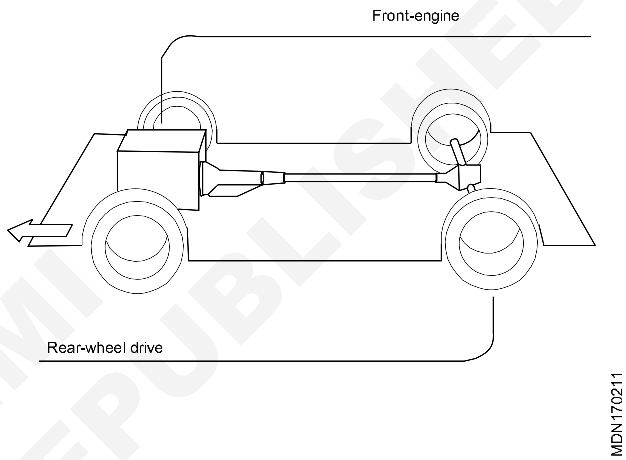


Fig 2

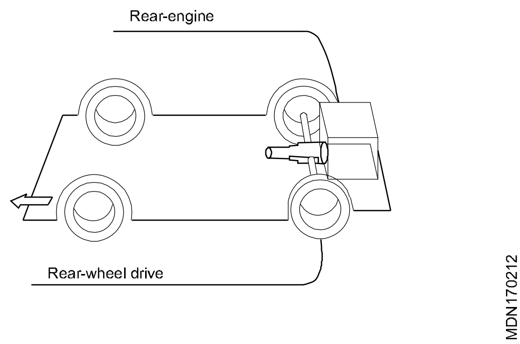


Fig 3

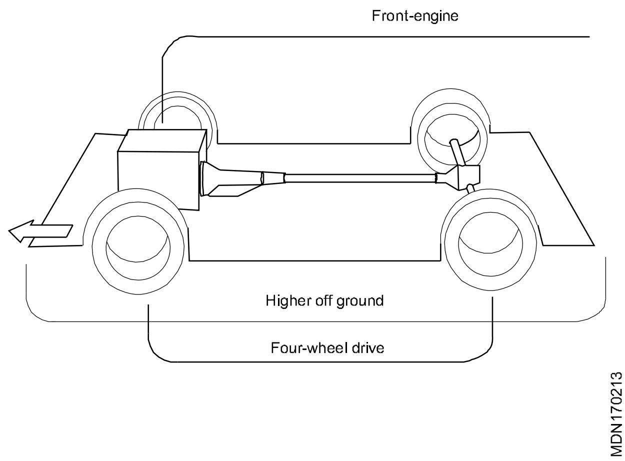
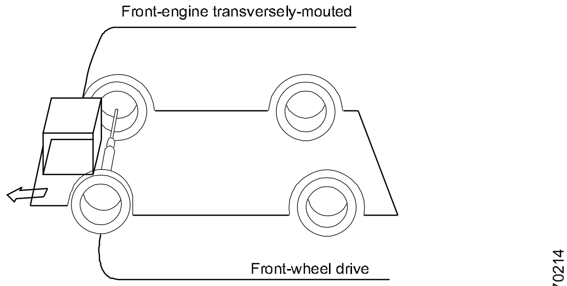


Fig 4



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

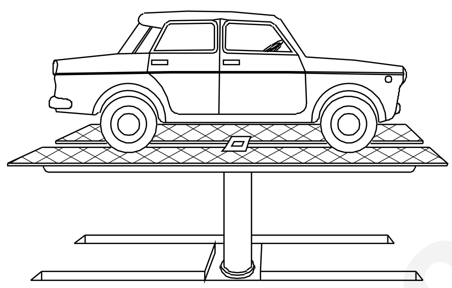
Objectives: At the end of this lesson you shall be able to
- **state the function of vehicle hoists**
- **state the function of engine hoists**
- **sate the function of jacks**
- **state the function of axle stand.**

The modern automobile 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 (Fig1): It is facilitate the servicing and reaper 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

MDN170411

Two post hoist (Fig 2): It is operated 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.

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.

Fig 2

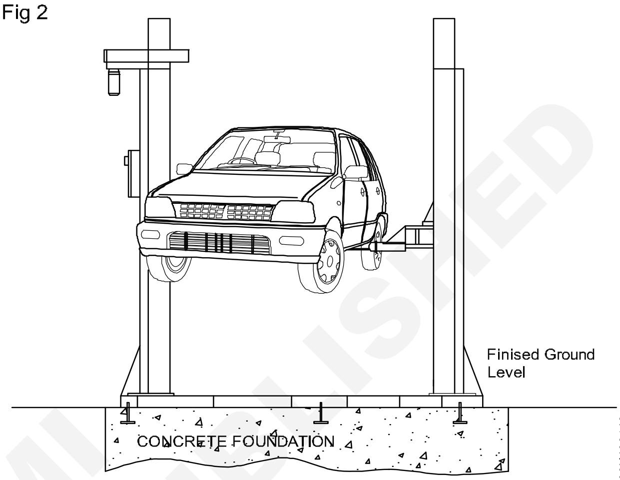


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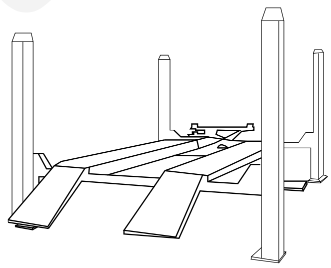
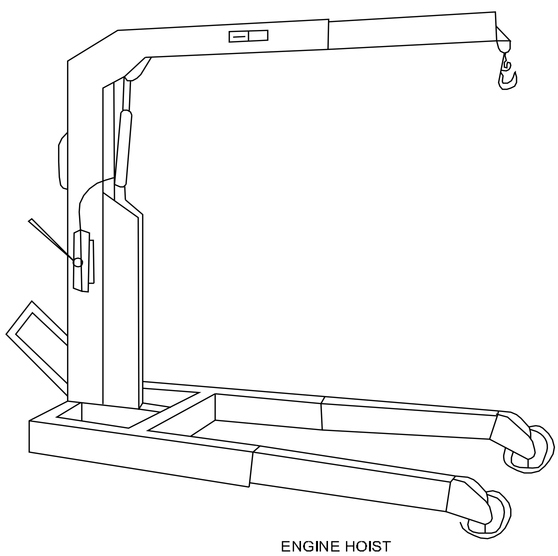
Fig 3



FOUR POST HOIST

MDN170413

Fig 4



ENGINE HOIST

MDN170414

Jacks: Jacks 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.

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 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.

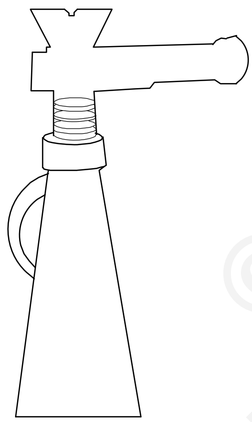
Types of jacks

- 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) .

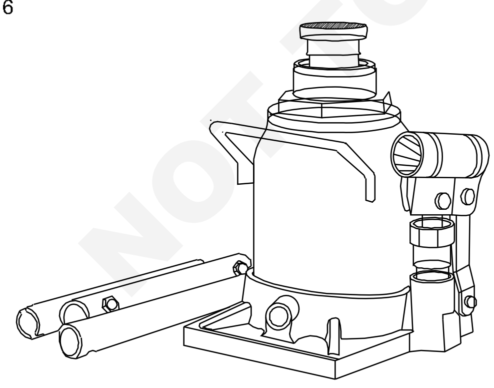
Fig 5



MANUAL TYPE LIFITING JACK

MVN163615

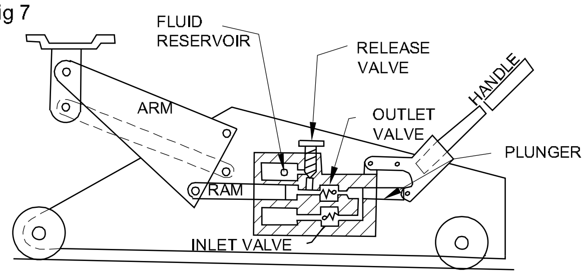
Fig 6



HEAVY DUTY BOTTEL TYPE LIFITING JACK

MDN170416

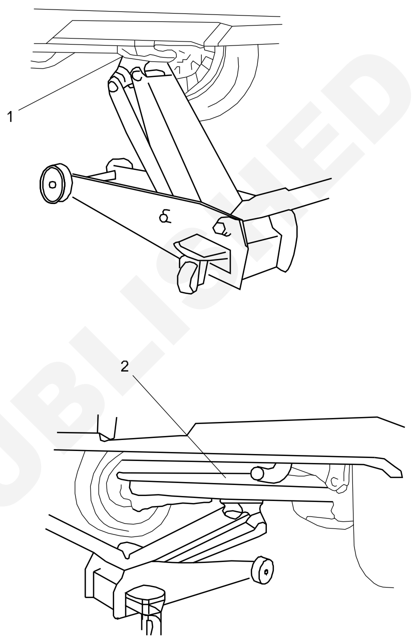
Fig 7



TROLLEY TYPE JACK

MDN170417

Fig 8



FLOOR JACK

MDN170418

Caution: Never apply jack against suspension parts (i.e., stabilizer, etc.) front bumper or vehicle floor, Otherwise it may get deformed.

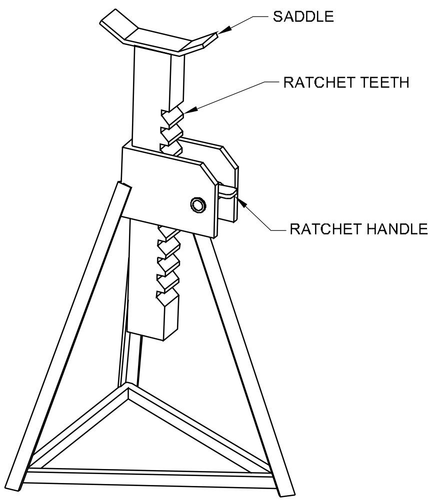
Warning: If the vehicle to be jacked up only at the front or rear end, be sure to block the wheels on ground in order to ensure safety.

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.

Axle stand (Fig 9): It is always enjure the safety before starting the work under the lifted vehicle, Jack report 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's sake.

Fig 9



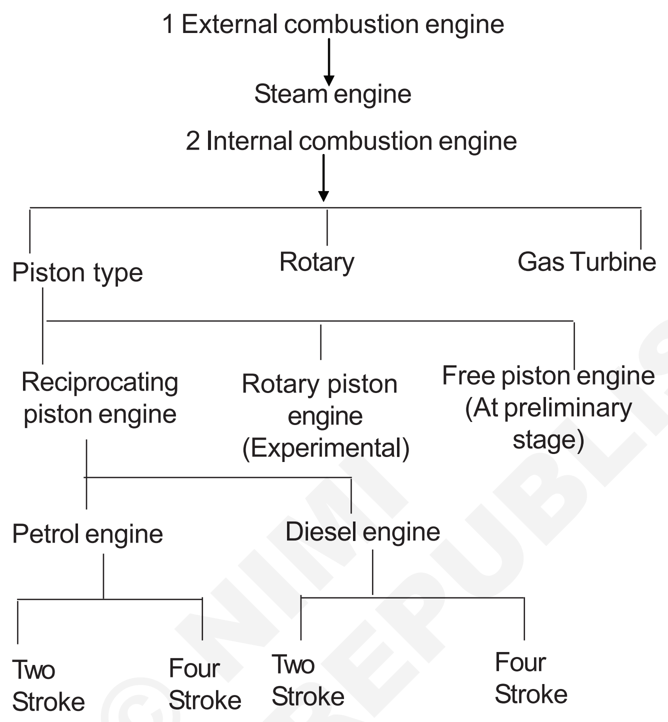
TYPICAL ADJUSTABLE JACK STAND

Internal and external combustion engine

Scan the QR Code to view the video for this exercise

Objective : At the end of this lesson you shall be able to
• **explain the types of heat engine.**

Types of heat engines



Classification of I.C Engine

Objective: At the end of this lesson you shall be able to
• **state the classification of engine.**

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

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.

V 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.

Fig 1

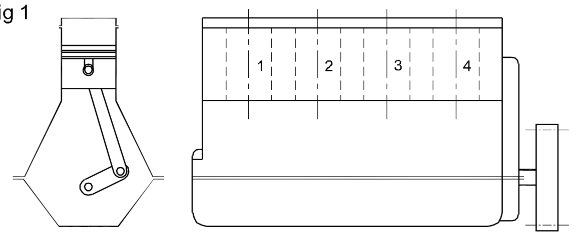


Fig 2

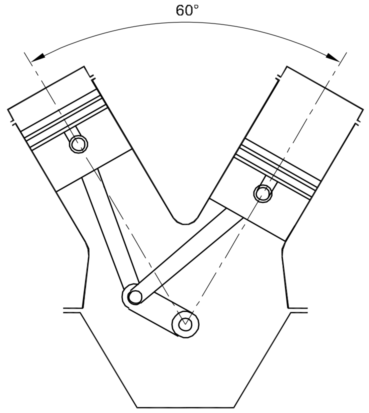


Fig 3

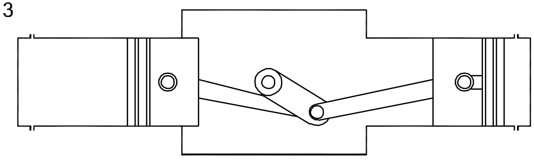
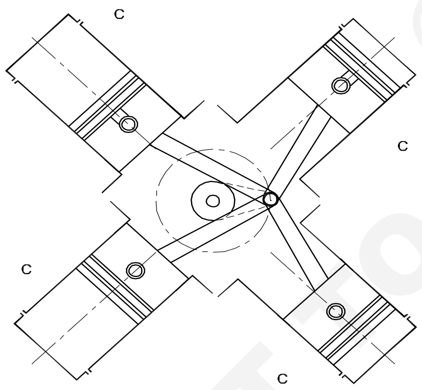


Fig 4



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

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

Cooling system

- Air cooled engine
- Water cooled engine

Strokes of engine

- Four-stroke engine
- Two-stroke engine
- Rotary engine

Function of diesel engine

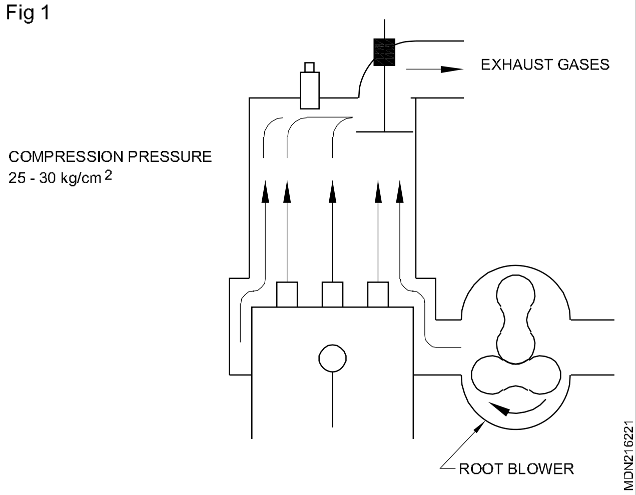
Objectives : At the end of this lesson you shall be able to
- **describe the function of a two-stroke diesel engine**
- **describe the function of a four-stroke diesel engine.**

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 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.

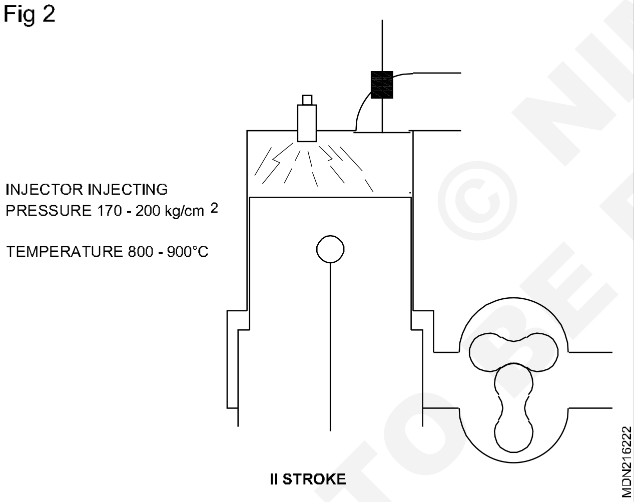
As the piston moves up from BDC to TDC the scavenging port and outlet valve closed. The piston compresses the fresh air to the compression chamber. The air temperature increases intensively.

Fig 1



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.

Compression stroke (Fig 4): The inlet and exhaust valves are closed, The piston moves from BDC to TDC. The charge air is compressed in the cylinder & air pressure and temperature is increased.

Power stroke: At the end of the compression stroke diesel fuel is injected into the hot compressed air in the combusion 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.

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 3

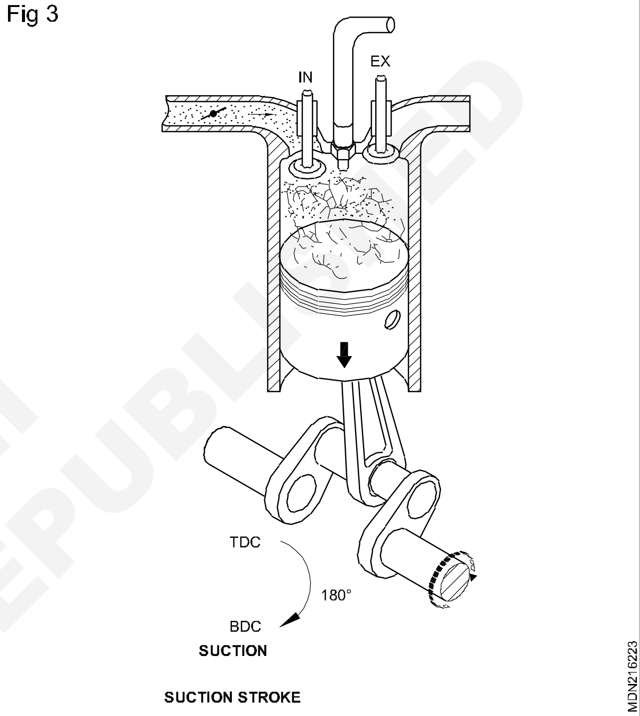
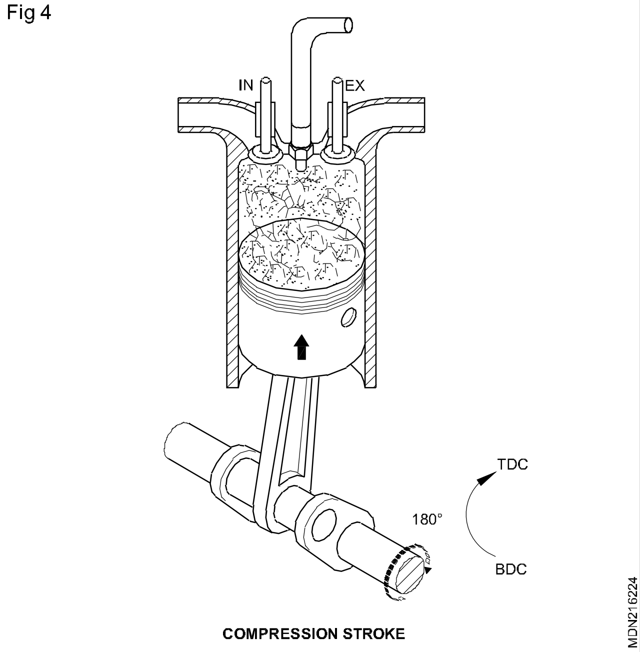
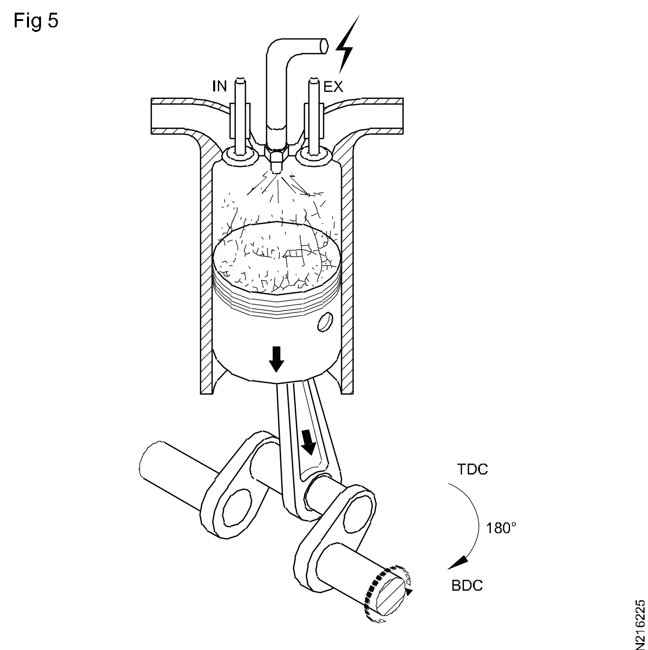
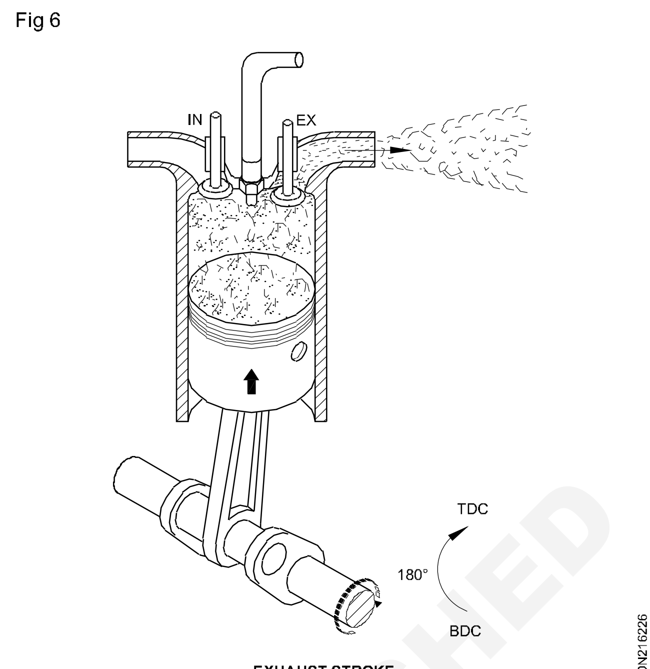


Fig 4





POWER STROKE



EXHAUST STROKE

Function of spark ignition engine

Objectives : At the end of this lesson you shall be able to
- **describe the function of a two-stroke spark ignition engine**
- **describe the function of a four-stroke spark ignition engine**
- **differentiate between a four-stroke and a two-stroke engine**
- **explain an OTTO cycle**
- **explain a diesel cycle.**

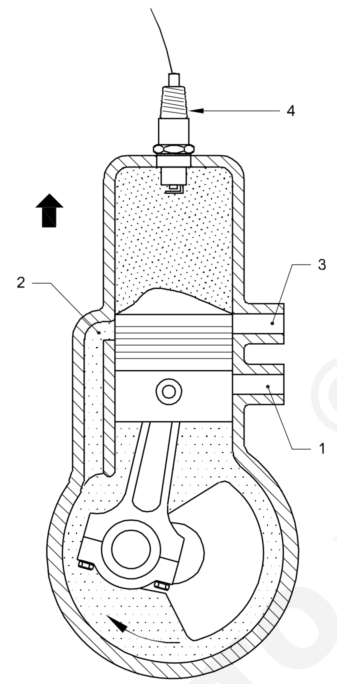
Two-stroke spark ignition engine

To produce power in two stroke engine the following operations take place in the sequence given below.

First stroke (Suction and compression)

As the piston moves up from BDC,(Fig 1) it closes the inlet port (1), the exhaust port (3) and the transfer port (2).

Fig 1



FIRST STROKE

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.

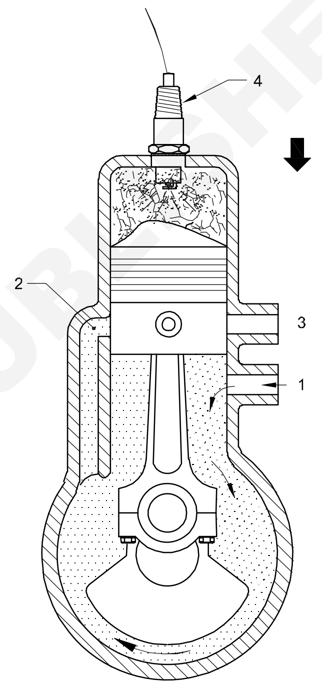
At the end of this stroke the mixture is ignited by an electric spark (4). This causes the pressure to rise.

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 2



END OF FIRST STROKE

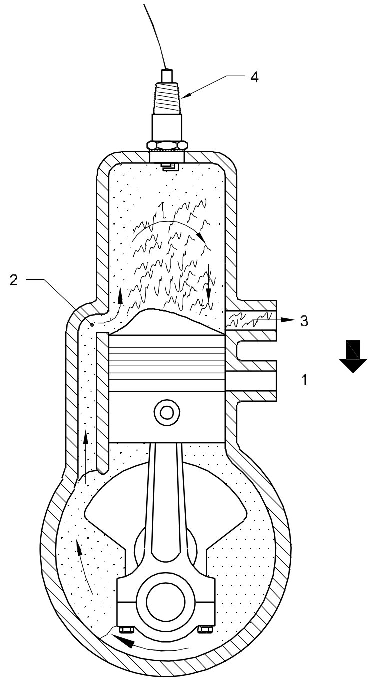
The piston head has a special shape. It deflects a fresh change of fuel mixture up into the cylinder. The mixture flows down and pushes the burnt gas out. Through the exhaust port. This process is called scavenging. Once the flywheel has completed one revolution, the cycle is repeated. In this engine one power stroke is obtained in each revolution of the crankshaft.

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 carburetor according to the load and speed. The ratio of air/fuel mixture is also metered by the carburetor. 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.

Fig 3



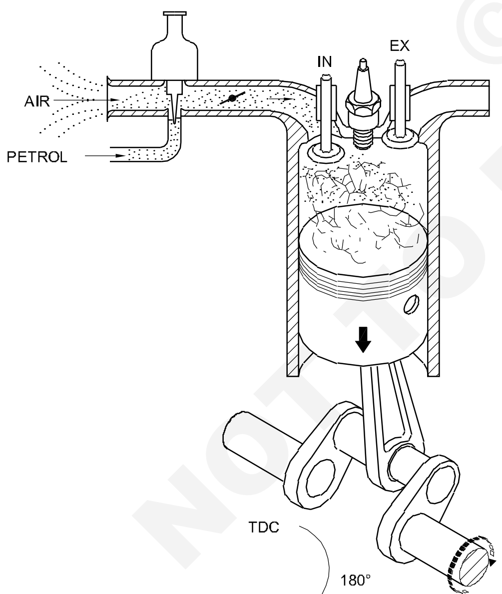
SECOND STROKE

MDN216313

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

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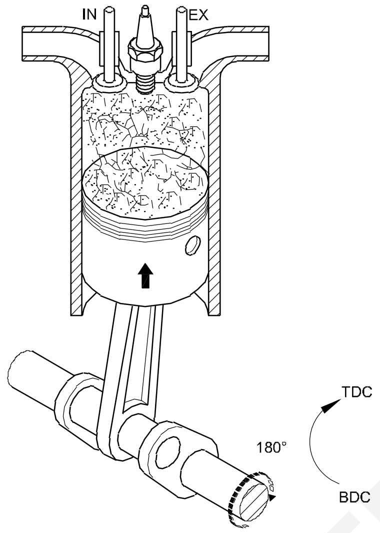
Compression stroke: The inlet valve closes. The exhaust valve remains closed. The piston moves from BDC to TDC (Fig 5). The charge air-fuel mixture is compressed. The pressure and temperature rise.

Fig 5



COMPRESSION STROKE

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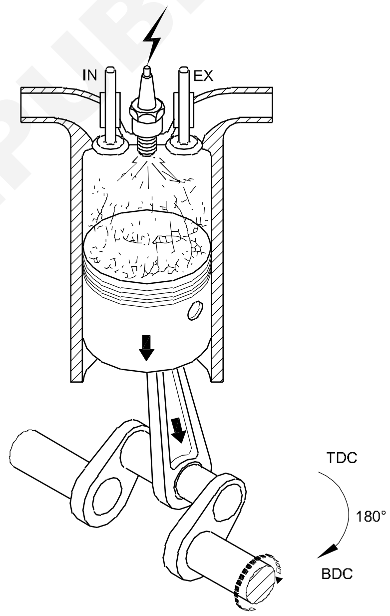
Power stroke

The compressed air fuel mixture is ignited and pressure develops inside the cylinder. The gas expands 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

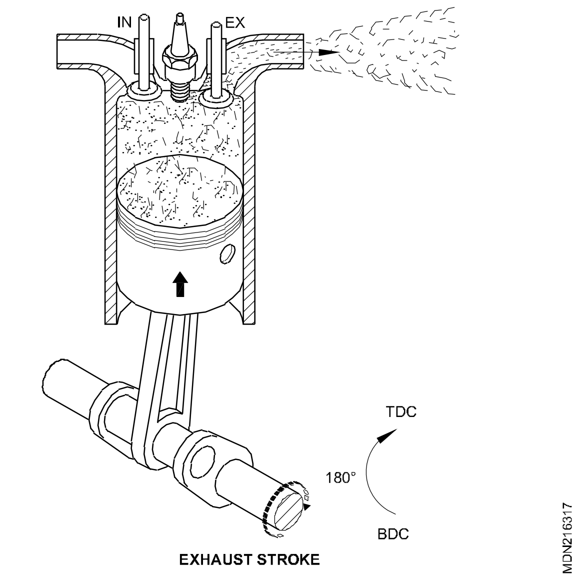
MDN216316

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



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.
- Engine design is complicated and heavier flywheel is used	- Engine design is simple
- Engine require more space	- 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.	- Engine require less space.
- More thermal efficiency.	- The engine has no valves and valve - operating mechanism
- The engine efficiency is more.	- The engine is less expensive
- Engine has heavy weight.	- The engine efficiency is less.
- Complicated lubricating system.	- Simple lubricating system

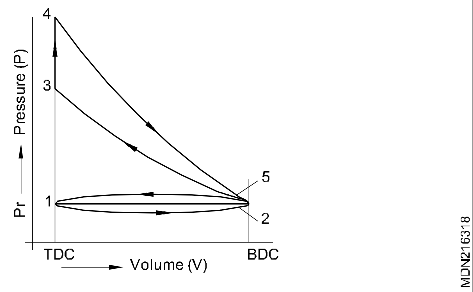
Comparison between S.I and C.I Engine

S.I engine	C.I engine
Petrol or gas is used as fuel.	Diesel is used as fuel.
During the suction stroke air fuel mixture is sucked in to the engine cylinder	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 carburetor 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.

Otto Cycle

Fig 8



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)

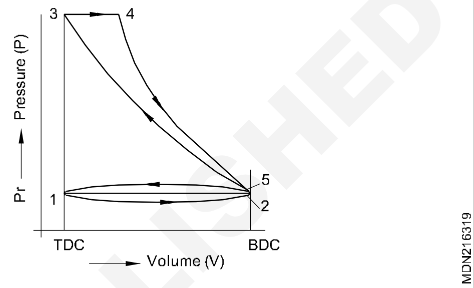
The gas expands during the power stroke (4-5), reducing both pressure and temperature.

Heat is rejected at constant volume. (5-2)

Burnt gases exhaust when piston moves from BDC to TDC. (2-1)

Diesel Cycle

Fig 9



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)

Main parts of internal combustion engine

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

Internal combustion engine parts

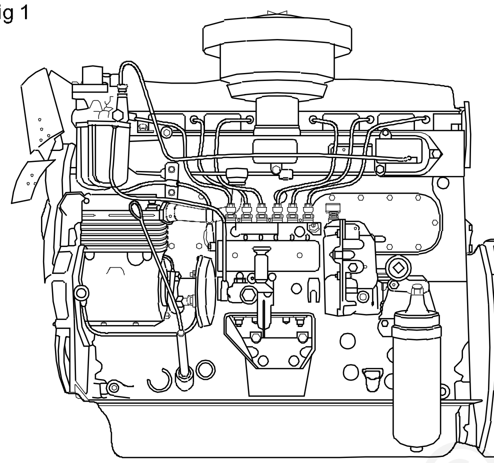
The major components in an IC engine are listed below;

Name of the components (Fig 1 to 3)

1 Air compressor
2 F.I.P
3 Injector
4 Air cleaner
5 High pressure fuel
6 Fly wheel
7 Oil filter
8 Fuel filter
9 Fan belt
10 Alternator

11 Self starter
12 Water pump
13 Cam shaft
14 Inlet manifold
15 Exhaust manifold
16 Valve door (cover)
17 Rocker assembly
18 Push rod
19 Tappets
20 Cylinder head
21 Piston
22 Timing chain / Belt
23 Oil sump
24 Strainer
25 Fly wheel housing
26 Dip stick
27 Connecting rod
28 Crank shaft
29 Timing gear
30 Turbo charger
31 Oil pump
32 Oil pipes
33 Strainer

Fig 1



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Petrol Engine

- Carburetor
- Distributor
- Super charger
- Spark plug
- Ignition coil

Fig 2

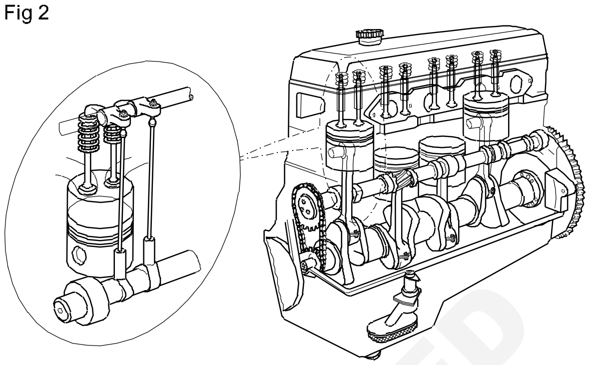

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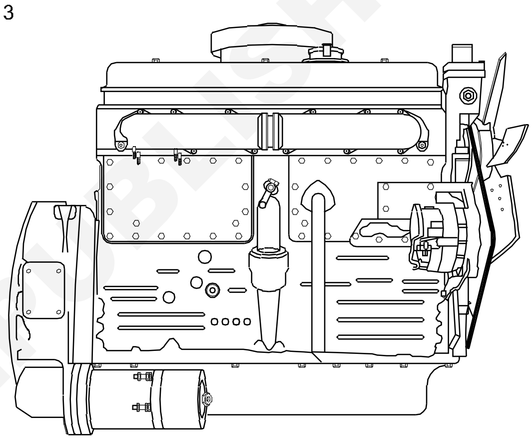
Fig 3



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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 (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.

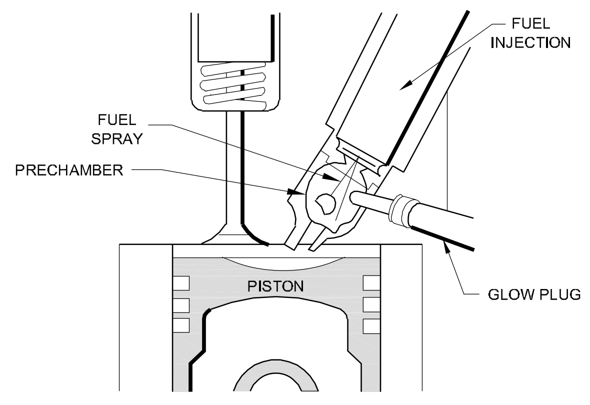
Advantages of direct fuel injection

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.

Fig 1



DIRECT INJECTION

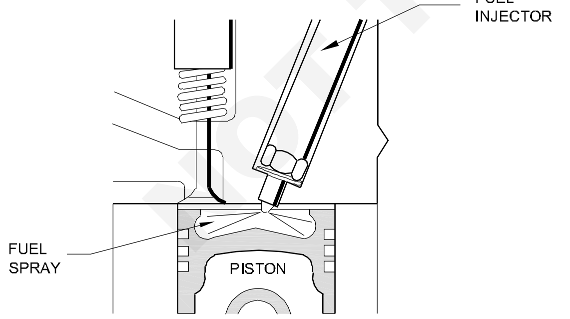
Indirect injection (Fig 2)

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. 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.

Fig 2



INDIRECT INJECTION

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.

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.

$$\text{Power} = \frac{(\text{Force} \times \text{Distance moved})}{\text{Time}}$$

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.

Indicated horsepower (IHP)

It is the power developed in the engine cylinder.

$$IHP = \frac{PLAN}{4500} \times K$$

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.

Type

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

TATA LPT - 1210 D

Specifications

Engine

Model	6692 D.I.
Number of cylinders	6
Bore	92 mm
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/cm^2
Fuel injection begins	23° before T.D.C.
Firing order	1-5-3-6-2-4
Opening pressure of the injection nozzles	200 + 10 kg/cm^2 New nozzels Min. 180 kg/cm^2 Used nozzels
Maximum variation permissible in injectionn: nozzle pressure	5 kg/cm^2
Inlect 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	MICO BOSCH
Weight (Dry)	382 kg
Capcity of cooling system	20 litres
Crankcase oil capacity	Maximum - 14 litres Minimum - 10 litres
Cooling water temperature	75°C - 95°C

Chassis

Raidator	Core frontal area..3500 sq.cm approx x551 (sq.in)
Clutch	Single plate dry friction type Diameter of clutch lining: Outside : 280 mm (11") Inside : 165 mm (61/2") Friction area (both sides) : 798 sq.cm approx (124 sq.in)
Transmission	No.of speeds: Forward 5 Reverse 1 Gear Ratio : 1st 7.37 :1 2nd 4.23 : 1 3rd 2.49 : 1 4th 1.56 : 1 5th 1 : 1 Reverse 7.15 : 1 Rear Axle ratio 7.48 - 1 : 6.8.57
Steering	Heavy duty re-circulating ball type steering with universal joint Gear ration 34.2 :1 Steering wheel diameter 550 mm $\left(21\frac{5}{8}''\right)$
Brakes	Hand brake : Mechanically operated brake acting on rear wheel Foot brake : Hydraulic brakes on front and real wheels, assisted by single chamber air pessure booster. Brake drum diameter: Front : 408 mm (16") Rear : 408 mm (16") Total braking area Front : 1440 sq.cm approx (223 sq.in) Rear : 1440 sq.cm approx (223 sq.in)
Frame	Side member of channel section Depth max : 223 mm $\left(8\frac{3}{4}''\right)$ Width : 60 mm $\left(2\frac{3}{4}''\right)$ Thickness : 7 mm $\left(\frac{1}{4}''\right)$

Springs

No.of cross members : 8
Type : Semi-elliptical
Composition of steel : silicon -manganese
No.of leaves:

	Front	rear
Main	12	12
Auxillary	-	5

Leaf thickness

Main 11 mm $\left(\frac{3}{8}''\right)$ 13 mm $\left(\frac{1}{2}''\right)$

Auxillary —
Total thickness of spring with bottom plate:

132 mm $\left(5\frac{1}{6}''\right)$ 233 mm $\left(9\frac{3}{8}''\right)$

Width of spring leaf:

60 mm $\left(2\frac{3}{8}''\right)$ 80 mm $\left(3\frac{1}{6}''\right)$

Total weight of spring
50 kg. (123 lb) 123 kg. (271 lb)

Shock Absorbers: Hydraulic telescopic type on fron and rear axles.
Wheels and tyres: No.of wheels : Total 7 : Front 2, Rear 4, spare 1.

Rim size : 7.00 x 20
No.of Tyres : Toral 6 : Fron 2, Rear 4
Tyre size : 9.00 x 20 ... 12 ply EHD

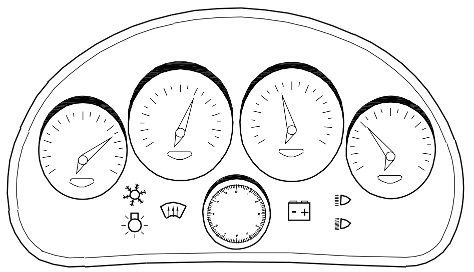
Dimensions	LPT 1210D/36	LPT 1210D/42
Wheel base	3625 $\left(142\frac{3}{4}''\right)$	4225 mm $\left(166\frac{1}{4}''\right)$
Wheel track :		
Front	1925 mm $\left(75\frac{3}{4}''\right)$	1925 mm $\left(75\frac{3}{4}''\right)$
Rear	1755 mm $\left(69\frac{1}{8}''\right)$	1755 mm $\left(69\frac{1}{8}''\right)$

Dashboard gauges, meters and warnings lights

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



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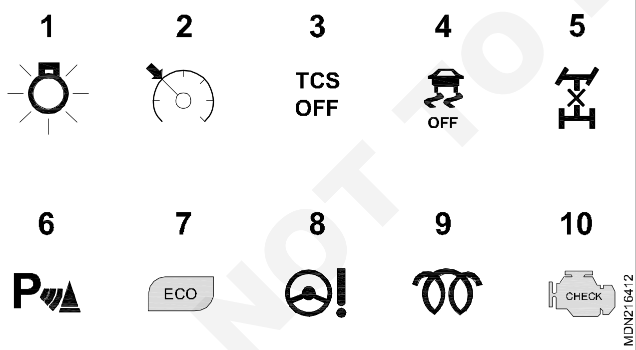
Speedometer

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



MDN216412

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.

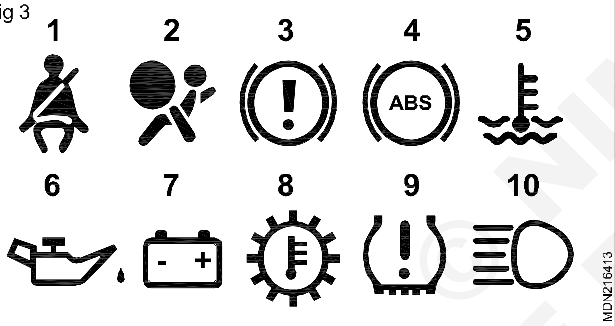
7 **Econ indicator:** This can mean different things on different cars. Some cars use it to tell you that economy mode is engaged, which means that the accelerator and the transmission are in their most relaxed mode. On some cars with cylinder deactivation, this tells you that the system is turned on (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.

Fig 3



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 indicate several things (Fig 3) such as

a Vehicle parking brake is engaged, so disengage it;

b The parking brake sensor is out of alignment, so have it fixed 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 **Tire 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 ones.

10 **High beam indicator :** While not a warning light per se, this bright icon represents a big danger to other motorists, and 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 Automobiles

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

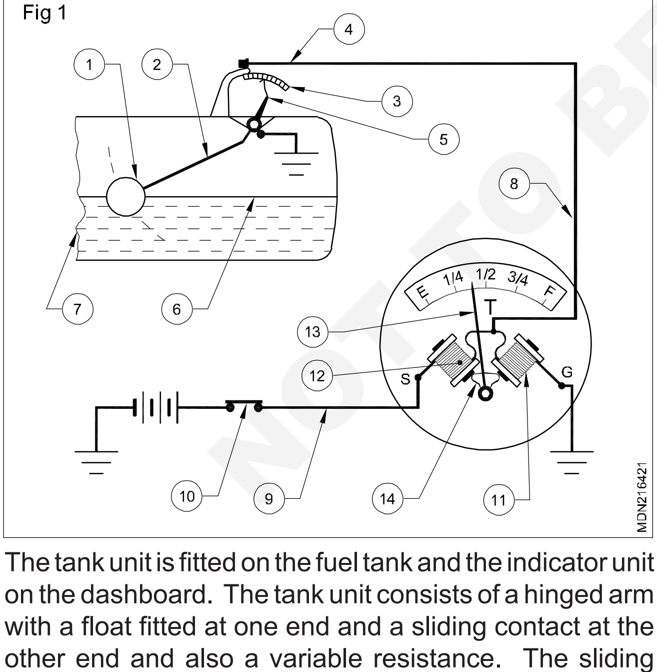
Purpose

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.

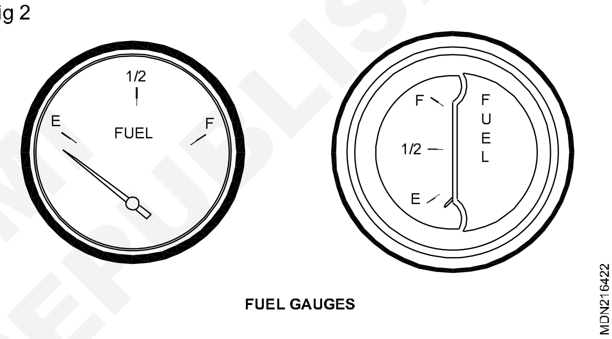
Gauge unit (Dash unit) (Fig 2)

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



Working

When the ignition switch (10) (Fig 1) is on, current from the battery flows to the coils and a magnetic field is produced. (Fig 2) 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.

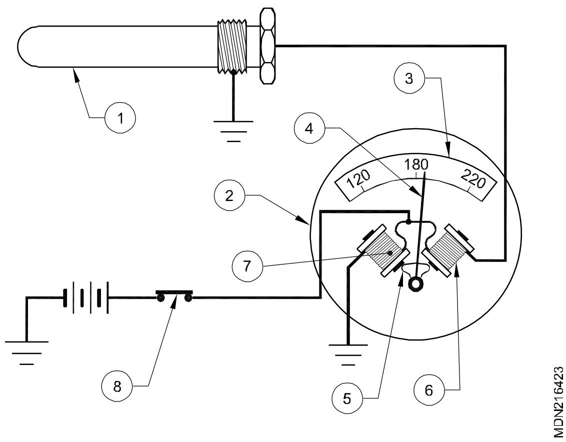
Temperature gauge

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.

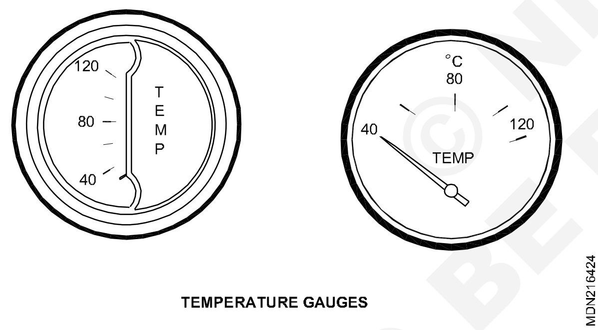
- It consists of an engine unit (1) immersed in the engine coolant in the cylinder head or cylinder block in the form of a pellet. (Fig 3)

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 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)

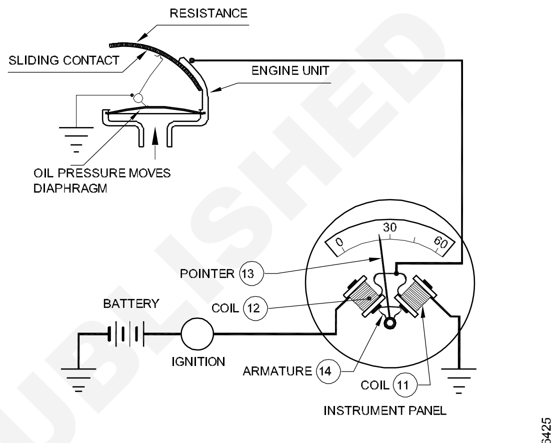
The Bourdon tube gauge is not widely used nowadays, as it has certain drawbacks i.e. the connecting tube leaks at joints.

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)

Fig 5



SCHEMATIC WIRING CIRCUIT OF A BALANCING -COIL OIL-PRESSURE INDICATING SYSTEM.

The engine unit consists of a diaphragm, sliding contact, variable resistance.

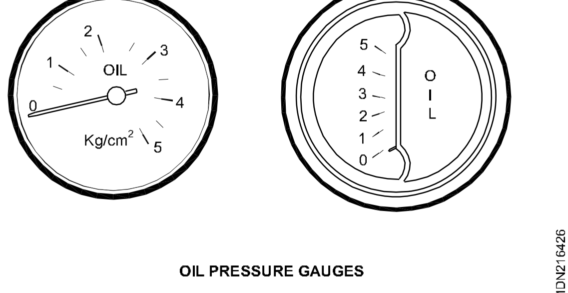
The dash unit consists of two coils (11) & (12) and a pointer (13) with a magnet (14) attached to it. Both coils are connected in series with battery through ignition switch.

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 6



OIL PRESSURE GAUGES

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

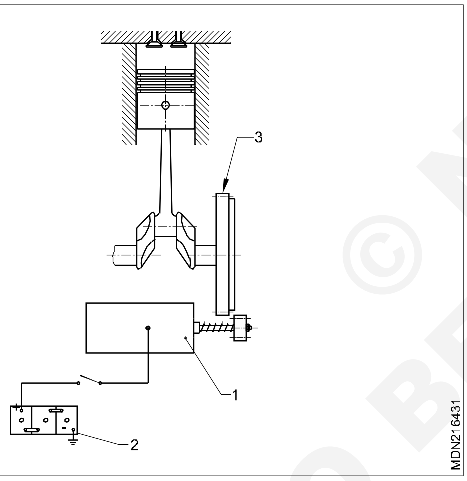
Hand cranking

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)

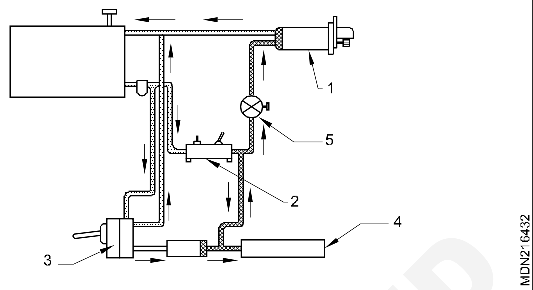
Fig 1



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)

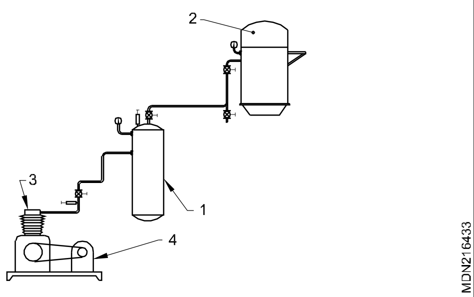
Fig 2



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)

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.

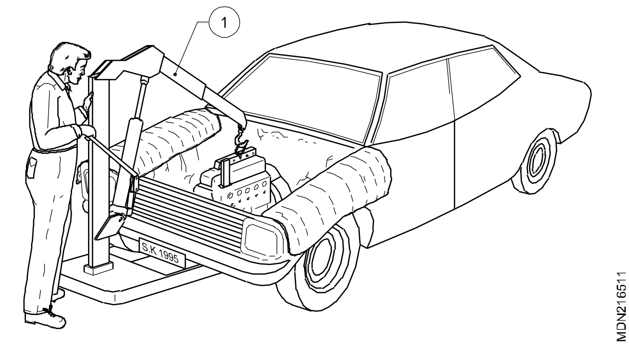
Procedure for removing of diesel engine from the vehicle

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 entering 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



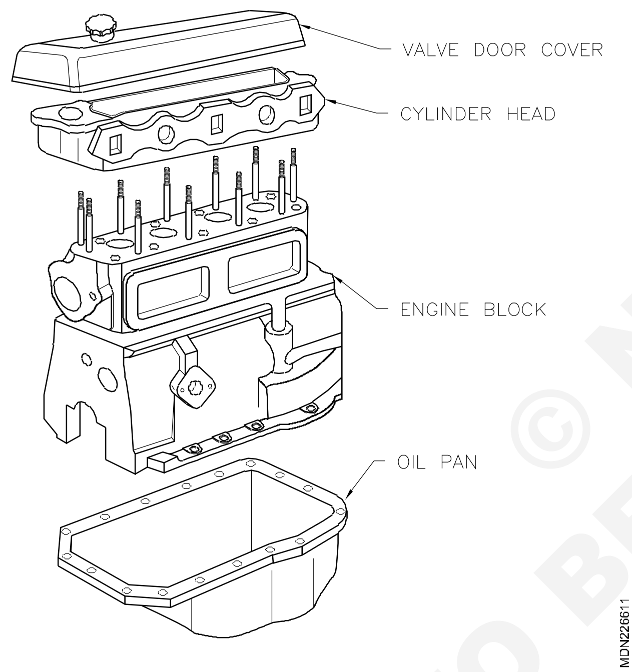
Description and constructional feature of cylinder head

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.

Fig 1



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.

In diesel engine fuel is injected into the combustion chamber against high compressions pressure in the combustion chamber of the C.I. engine cylinder. The combustion depends upon the following factors;

- Fine atomization
- High temperature for quick ignition
- High relative velocity between air and fuel particles
- Good mixing of air and fuel particles.

Atomization, preparation and spreading of fuel depends on injection system, cylinder bore and stroke, compression ratio and cooling system determine operating temperature etc. 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 2)

b Turbulence chambers (Fig 3)

c Pre combustion chamber (Fig 4)

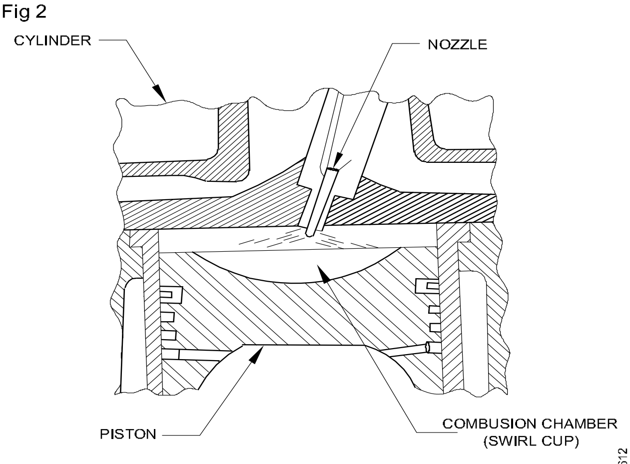
d Air cells (Fig 5)

e Energy cells (Fig 6)

a Open combustion chambers : In an open type of chamber, 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 directly 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.

Fig 2

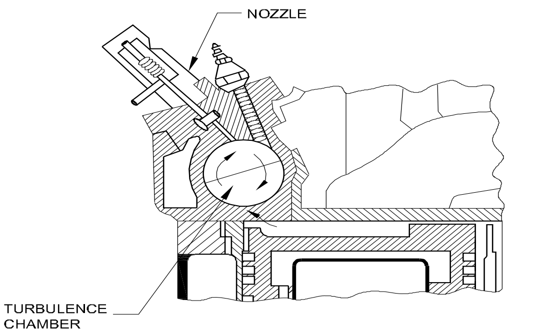


OPEN COMBUSTION CHAMBER WITH SWIRL CUP

Open combustion chambers are widely used in medium and large-bore engines operating at low and medium speeds.

b Turbulence chambers: 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 setup a rapid rotary motion. As the piston rises up, the velocity of air increases through the throat of orifice and reaches at the peak somewhat before T.D.C. At the end of compression stroke, the injector nozzle injects fuel into the turbulent air currents which results in good mixing during combustion.

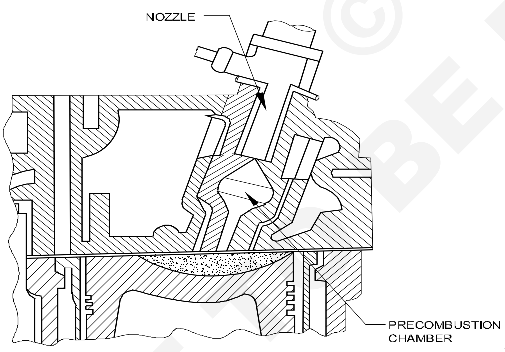
Fig 3



TURBULENCE CHAMBER OF WAUKESHA DESIGN

c Pre combustion chamber: 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 pre combustion chamber. At this moment, fuel is injected into the pre combustion 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 4

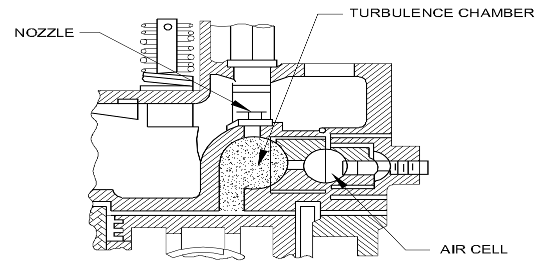


PRECOMBUSTION CHAMBER

d Air cells: The 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.

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.

Fig 5

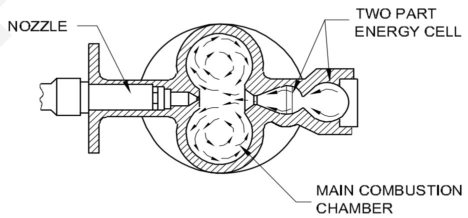


AIR CELL

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 pre combustion chamber to obtain better performance.

e Energy cells: 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.

Fig 6



ENERGY 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.

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.**

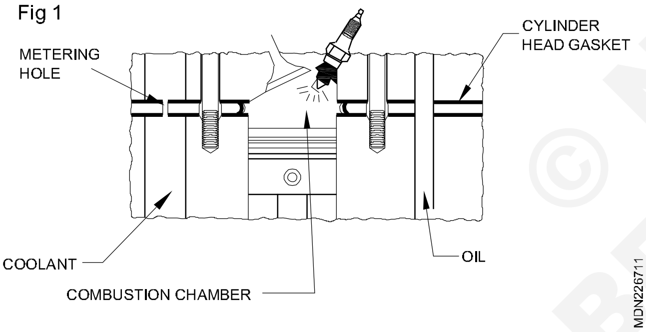
Generally, the inlet valves have larger diameter than exhaust valves, to allow more volume of charge (air or air-fuel mixture) into the engine cylinder, during suction stroke. This will result in high volumetric efficiency, and improved engine power output.

The main reason for the size difference is to avoid pre-ignition and knocking.

Cylinder head gaskets (Fig 1): Is the most critical seal in an engine between the cylinder head and the engine block deck.

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).

Fig 1



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. Engine 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. Aluminium 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

Valves

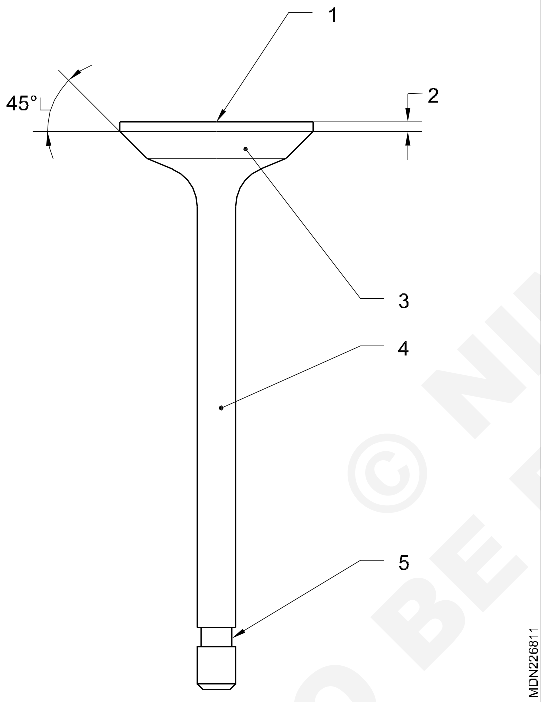
Objectives: At the end of this lesson you shall be able to
- **describe the function of the engine valves**
- **state the constructional features of valves**
- **list out the different types of valves and their material.**

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)

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.

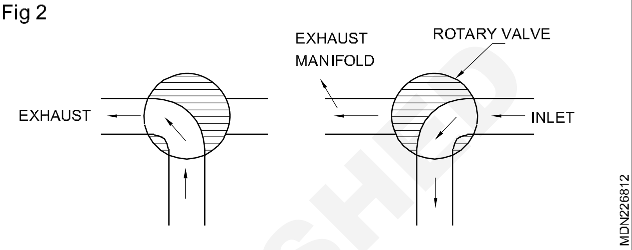
Types of valves

- Poppet-valves
- Rotary valves
- Reed valves
- Sleeve valves

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

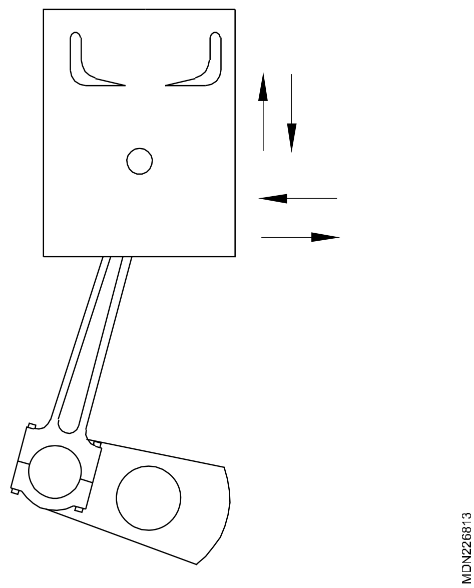
Fig 2



Rotary valve

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 & Fig 3)

Fig 3



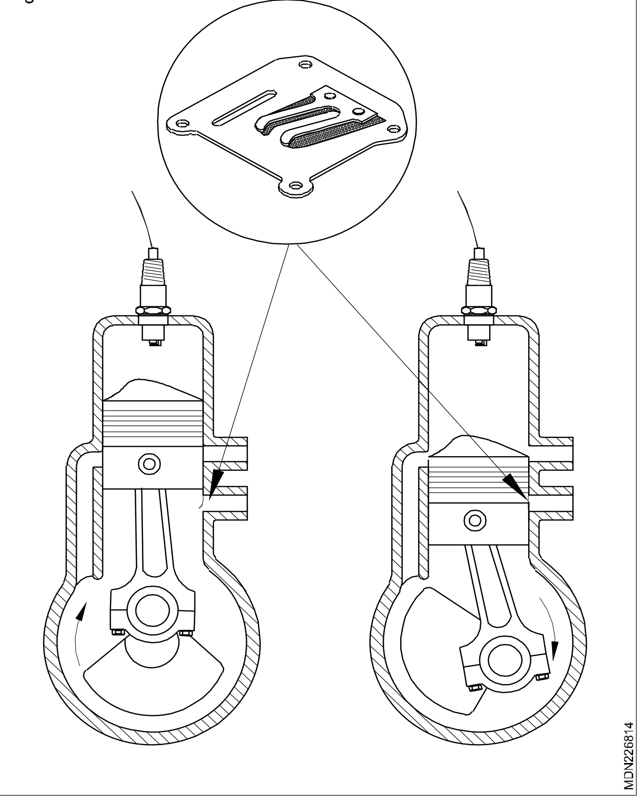
Reed valve

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)

Sleeve valve

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

Fig 4



in another sleeve. This aligns with the inlet and exhaust ports at a set time when the inlet and exhaust manifold open.

Valve Materials:

Inlet valve - Nickel steel alloy stellite facing

Exhaust valve - Silo - 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 stem and guide clearance must be correct.

Valve operating mechanisms: Two types of valve operating mechanisms are used in engines. They are;

- Side valve mechanism
- Overhead valve mechanism

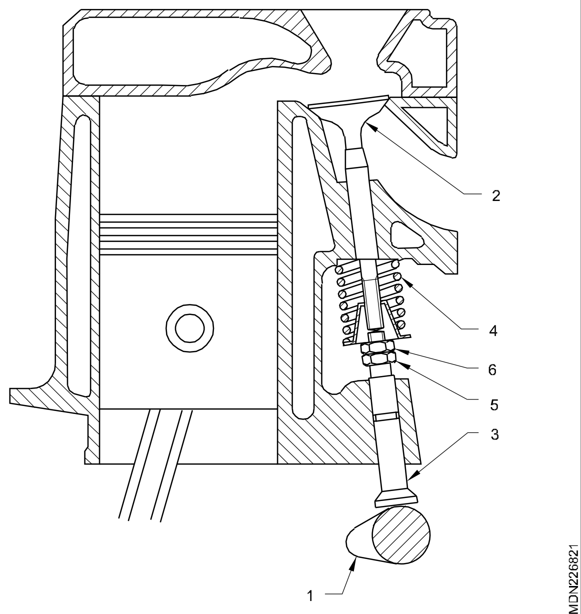
In overhead valve mechanism, the position of camshaft is considered as the types of valve mechanism i.e.,

1 Single overhead camshaft mechanism

2 Double overhead camshaft mechanism

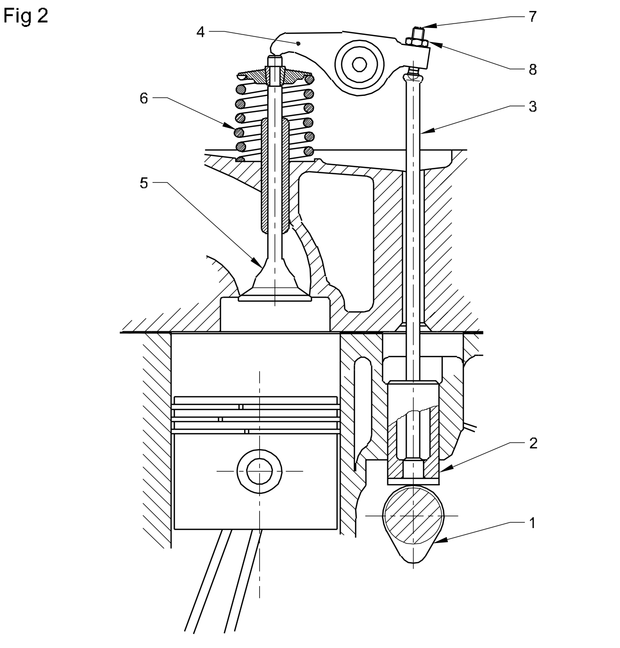
Side valve mechanism (Fig 1): In the side value mechanism both the inlet and exhaust valves are fitted in the cylinder block.

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.

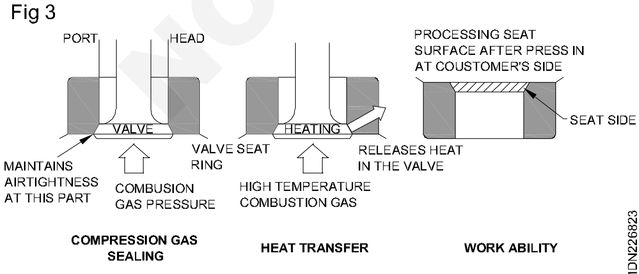
When the cam lobe (1) reaches the maximum height, the valve opens fully. Further rotation of the cam shaft causes the tappet (2) to move down and the valve is closed by the tension of the spring (6).

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 and their pivots are dispensed with and the valves are actuated directly by the camshaft through bucket type.

Importance of valve seats: Valve and valve seats(Fig 3) 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 realted to the engine performance.

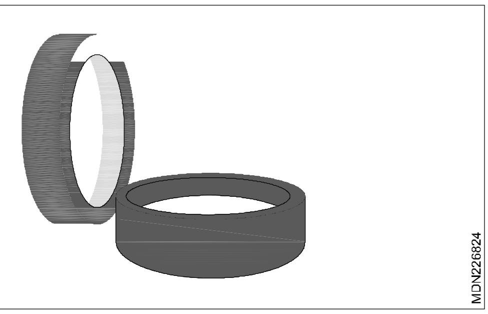
Fig 3



Function of valve seats (Fig 4)

1 Compression gas sealing prevents compressed gaseous bodies and combustion gas from leaking into the manifold.

Fig 4



2 Heat transfer releases heat in the valve to the cylinder head.

3 Strength holds tight when the valve is mounted.

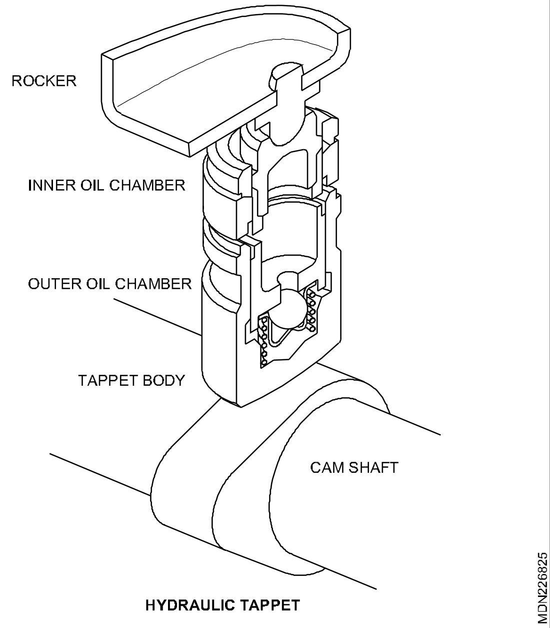
4 Wear-resistance hard to wear down under high heat and high load.

Importance of valve seats inserts in cylinder head

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 from the oil pump is forced through an oil way to the tappet.

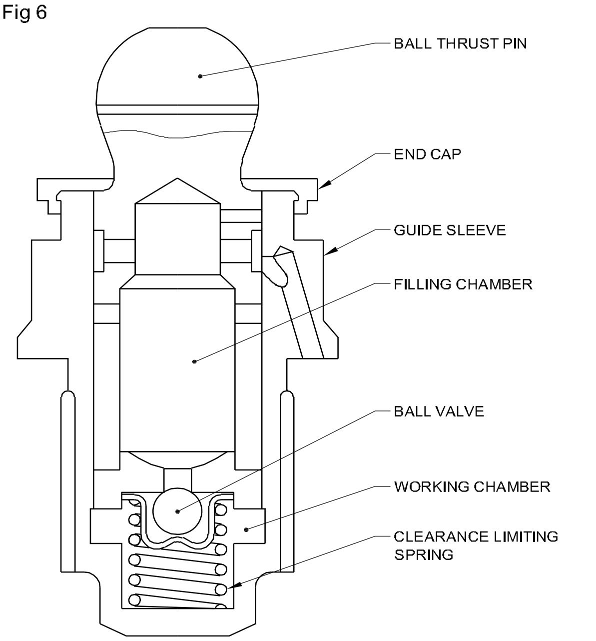
It flows through the outer chamber (to lubricate the tappet itself) and hence to the inner chamber (plunger lubrication) and to the interior of the piston. By way of a filling bore, the oil passes through the ball (check) valve to the pressure chamber.

Fig 5



The clearance limiting spring (Fig 6) forces the tappet piston to prevent any valve clearance from occuring. When the cam lifts the tappet, the ball valve closes and the oil-filling the pressure chamber acts as an almost rigit 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

Fig 6



CLEARANCE ELIMINATING ELEMENT

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.

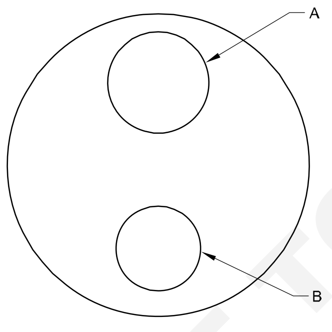
Types of valve arrangement

1 Two valve arrangement in one cylinder (Fig 7)

A One inlet valve

B One exhaust valve

Fig 7

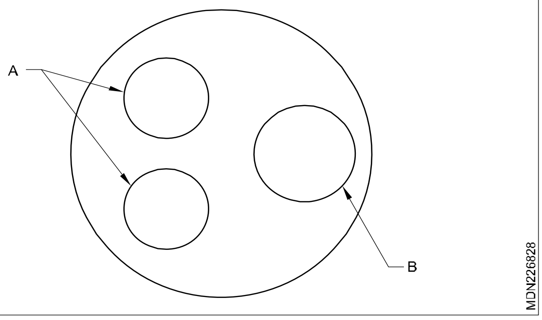


2 Three valve arrangement in one cylinder (Fig 8)

A Two inlet valves

B One exhaust valves

Fig 8

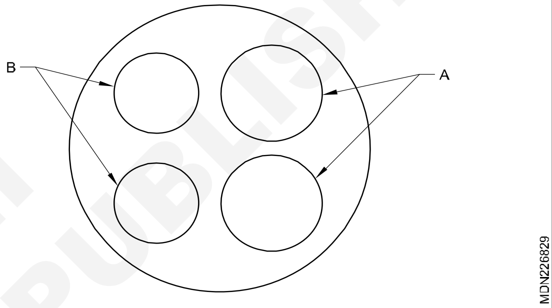


3 Four valve arrangement in one cylider (Fig 9)

A Two inlet valves

B Two exhaust valves

Fig 9

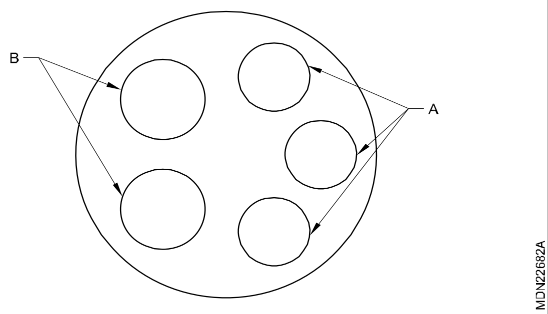


4 Five valve arrangement in one cylinder (Fig 10)

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**
- **explain of variable valve timing.**

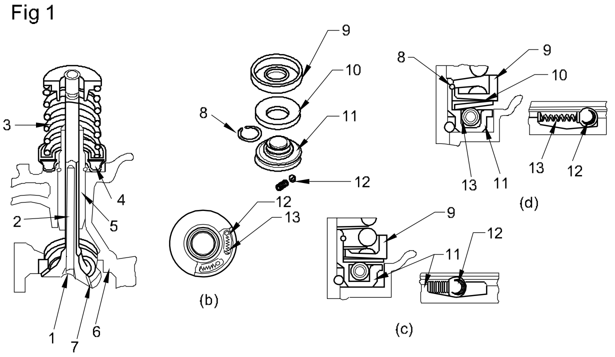
Valve rotation (Fig 1)

The main scope of the valve and tappet rotation is to reduce the wear, the friction and to increase the life period of the components and maintain the conical valve face and seat clean of carbon or soot deposit that might appear on surfaces during valve opening. To uniform the thermal stress of the valve head because of the asymmetry exhaust manifold and uniform the wear of the conical face providing a good sealing of the cylinder.

If the valve is rotating the contact point between valve head and seat will vary and in this way the wear marks or crank can be avoided. Valve rotation is the uniformity of the oil film in the valve guide on the valve stem. Auxiliary rotation system is rotate the valve during opening or closing period on those systems components are rotocap, turnomat, rotorcoil, rotomat, duo mate.

The tapper rotation reduce the wear caused by the contact with the carn, it improves the lubrication of those two surfaces and increases the tapper life.

Fig 1



VALVE MECHANISM OF AN AUTOMOBILE ENGINE

(a) EXHAUST VALVE COMPELETE WITH VALVE ROTATOR:
(b) VALVE ROTATOR:
(c) VALVE ROTATOR POSITION WITH CLOSED VALVE:
(d) VALVE ROTATOR POSITION WITH OPEN VALVE:

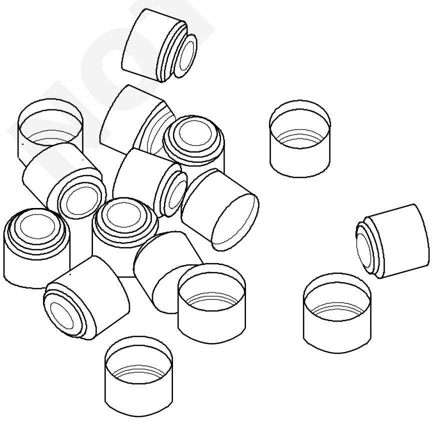
1-STOPPER
2-HOLLOW VALVE STEM
3-VALVE SPRING
4-VALVE ROTATOR
5-VALVE GUIDE
6-INSERT VALVE SEAT
7-VALVE FACE
8-SNAP RING
9-SEATING COLLAR
10-FLEXIBLE WASHER (CONE SPRING)
11-VALVE ROTATOR HOUSING
12-STEEL BALL
13-RETURN SPRING

MDN226831

Function of valve stem oil seal (Fig 2 & 3)

The purpose of the valve stem oil seal is to prevent the oil from the cylinder head entering the combustion chamber. Valve stem seals play a critical role in controlling valve lubrication as well as oil consumption.

Fig 2



VALVE STEM OIL SEAL

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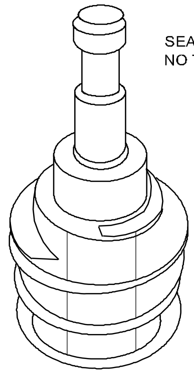
Fig 3

SEAL #3 DOES FIT INSIDE OF SPRING WHEN ON GUIDE



SEAL #4 FIT THE SAME BUT NO TEFLON

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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 variety of problems like;

- Excessive smoke
- High oil consumption
- Carbon deposited in valve and piston
- OFF - throttle braking
- Idle run stop

There are two basic valve stem seal designs

1 Deflector seals - (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.

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.

Valve train (Fig 4): 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 components required to allow the air or air fuel mixture to enter the combustion chamber, for 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 4

DEFLECTOR SEALS MOVE WITH VALVE STEM   POSITIVE SEALS ARE FIXED TO THE VALVE GUIDE BOSS

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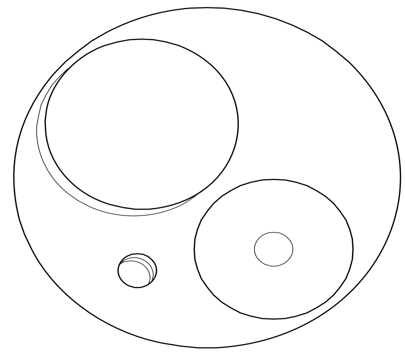
Size of intake valve (Fig 5)

Fig 5



In order to get adequate air flow into the cylinders, inlet valve need enough opening with bigger diameter of valve 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. For exhaust, you have the position pushing out the exhaust using higher positive pressure. So, there is no need of big exhaust valves.

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.

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 aur/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.

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.

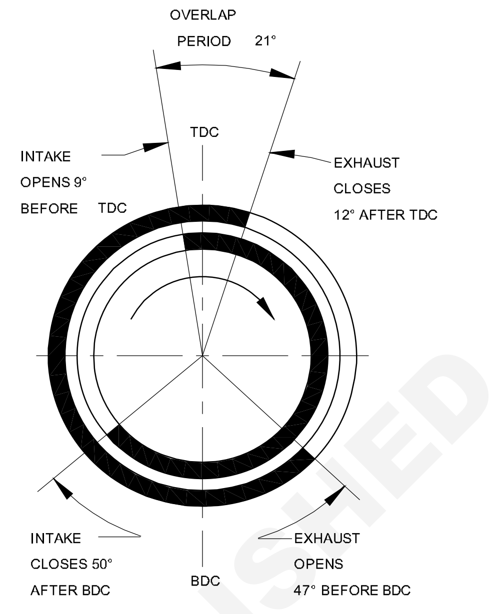
Lag: Exhaust valves are made to close certain degrees after T.D.C. to develop a suction effect by the outgoing gases. It also helps in the scavenging of the exhaust gases by using the intake charge's momentum.

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 (Fig 6)

Fig 6



The valve timing is represented by a diagram drawn on the face of the flywheel in decrees 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 for durability and performance. Engineers determine the valve material, shape, specifications, and surface coatings to match the specific 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 7)

Variable-valve (VVT) technology, became standard in engine design, variable valve timing becomes the next step to enhance engine output, no matter power or torque.

As you know, 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 optimise the breathing, engine requires different valve timing at different speed. When the valve increases, the duration of intake 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

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 VVT 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

Honda pioneered road car-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.

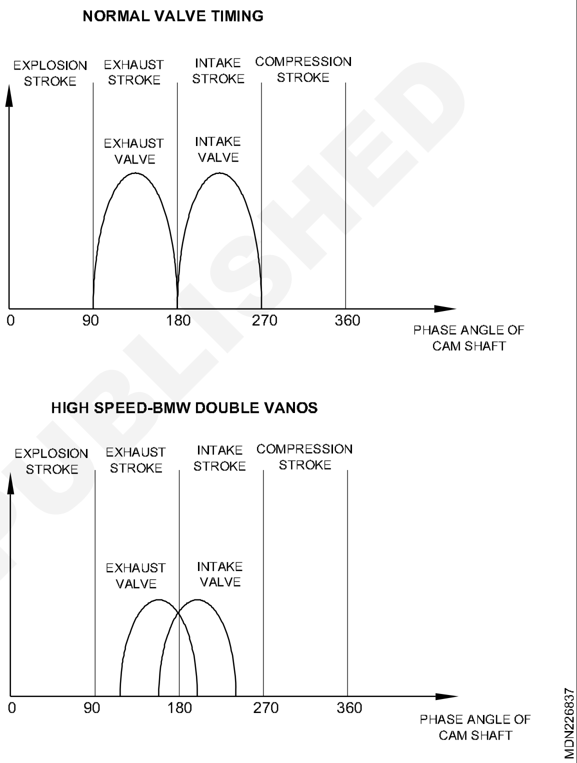
However, cam-changing system remains to be the most powerful VVT, since no other system can vary the Lift of valve as it does.

Example - Honda's 3-stage VTEC

Cam-phasing VVT

Cam-phasing VVT is 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 gears.

Fig 7



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.

Fig 1

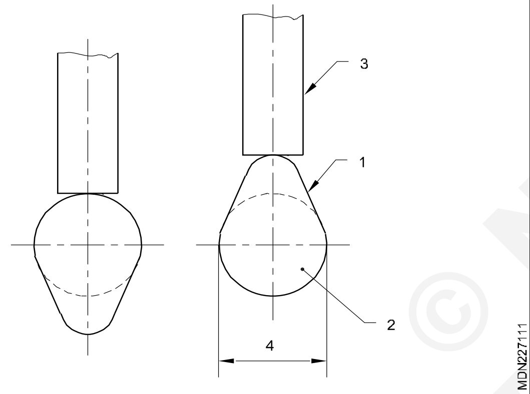
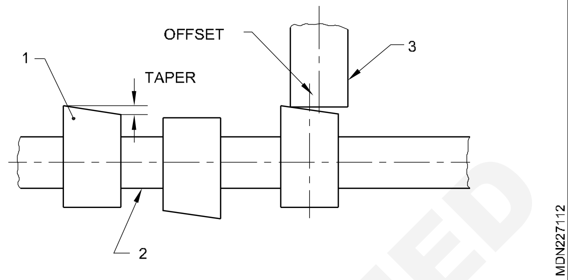


Fig 2



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

Camshaft drive mechanisms

Objective : At the end of this lesson you shall be able to
- **state the different types of camshaft drive mechanisms.**

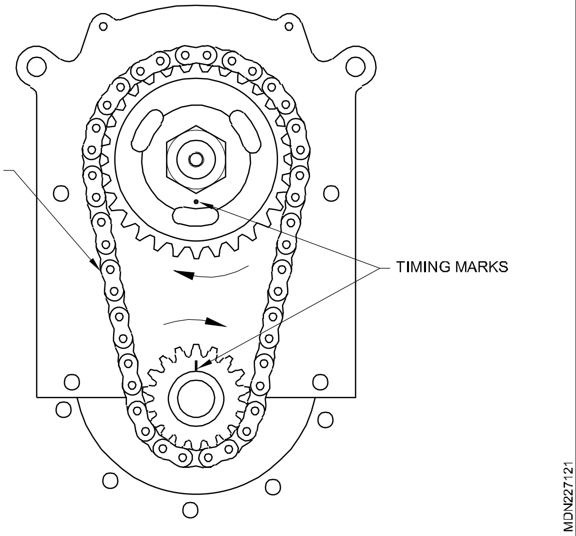
The camshaft gets the drive from the crankshaft and rotates at half the crankshaft speed, since each valve opens once in every two revolutions of the crankshaft. There are three types of camshaft drive mechanisms.

- Gear drive
- Chain drive (Fig 1)
- Belt drive (Fig 2)

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.

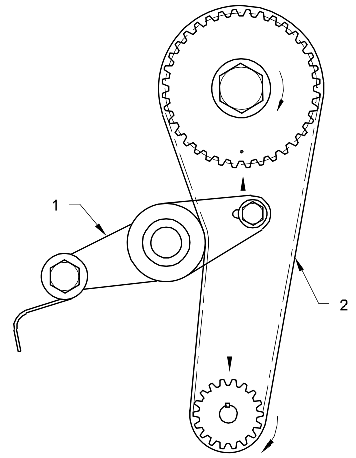
Fig 1



Chain drive: The timing gear sprockets (Fig 1) are driven by a chain (1). Hence this drive is called a sprocket drive. The direction of rotation of the crankshaft and camshaft is the same. It is used when the distance between the crankshaft and the camshaft is more. No idler gear is used in the chain drive.

Belt drive: This drive (Fig 2) 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 2



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Cam shaft calssification: Cam shaft are clssified based on its location and number of shafts

1 Bottom mounted traditional cam shaft (OHV Engine) (Fig 4)

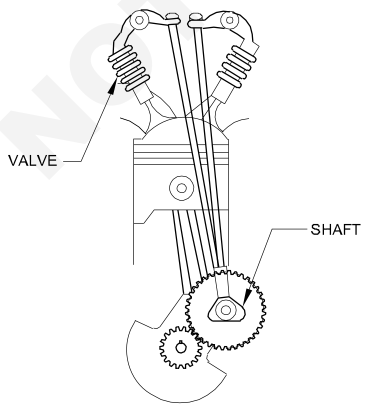
2 Single over head cam shaft (OHC / SOHC) (Fig 5)

3 Doube over head cam shaft (DOHC) (Fig 6)

The main disadvantages of an OHV design is that it'sdifficult 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 3)

Fig 3



SOHV

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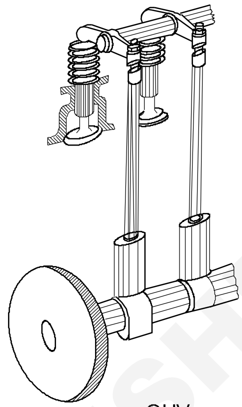
Bottom mounted traditional cam shaft (OHV Engine) (Fig 4): OHV in general means over head or valves are fitted in the cylinder head. Often the term "OHV is used to describe the engine design where the camshaft is fitted inside the engine block and valves are operated through lifters, pushrods and rocker arms. This design is also known as a "Pushrod" engine. The OHV design has been successfully used for decades.

Fig 4



OHV

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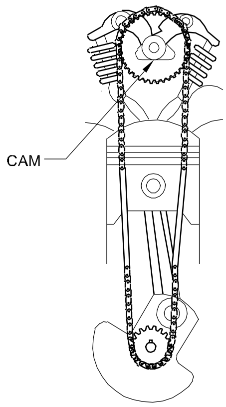
Over head cam/single over head cam shaft (OHC/ SOHC) (Fig 5): OHC means over head cam in general, while SOHC means single over head cam or single cam. In SOHC engine the camshaft is installed in the cylinder head and valves are operated either by the rocker arms or directly through the lifters.

Fig 5



SOHC

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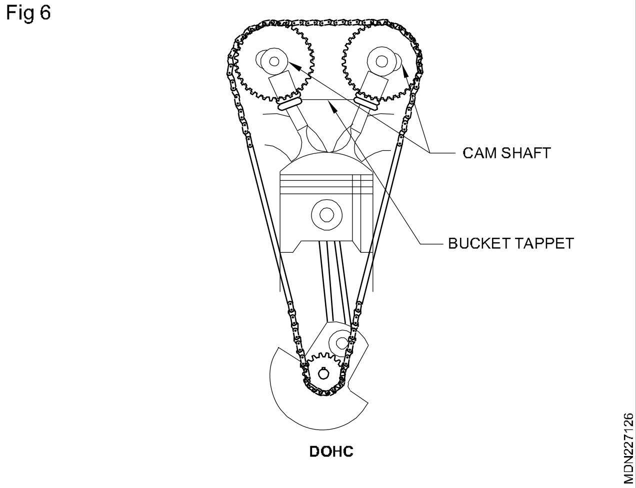
The main advantage of an OHC design is that valves are operated almost directly by the camshaft, which makes it easier to maintain precise timing at higher rpms. It's also possible to install three or four valves per cylinder.

Double over head cam shaft (DOHC) (Fig 6)

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 able from the exhaust valves, so the volumetric efficiency increases and produces more horse power out of smaller engine volume.



The main advantage of the DOHC design allow th 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.

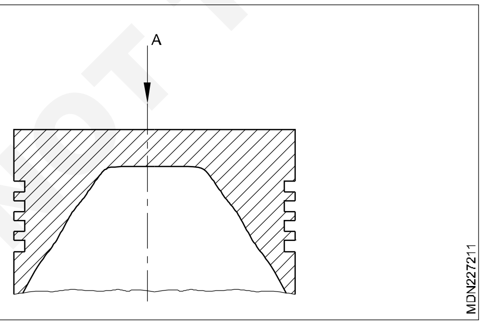
The crown or head

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

1 **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



2 **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

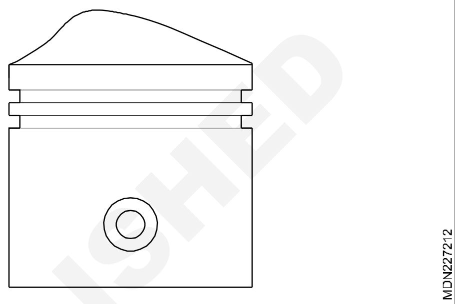
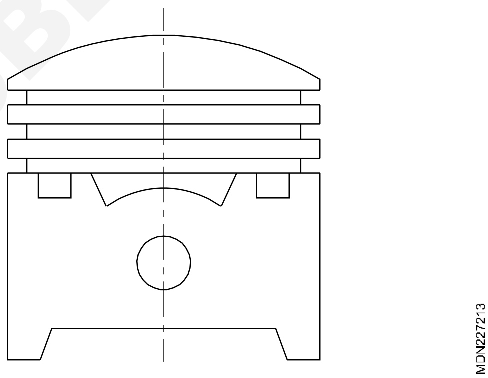
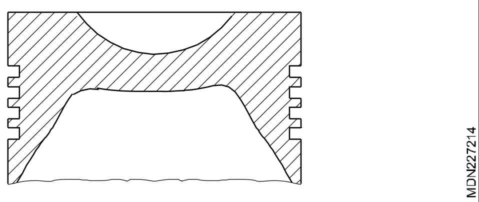


Fig 3



3 **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

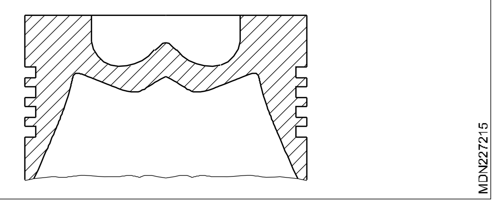


4 **Irregular head (cavity piston):** It has a cavity on the top, (Fig 5) and a conical shaped projection is provided inside the cavity. This helps in swirling of air and thereby making for it better homogeneous burning, and it improves combustion. It is used in high compression diesel engines.

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.

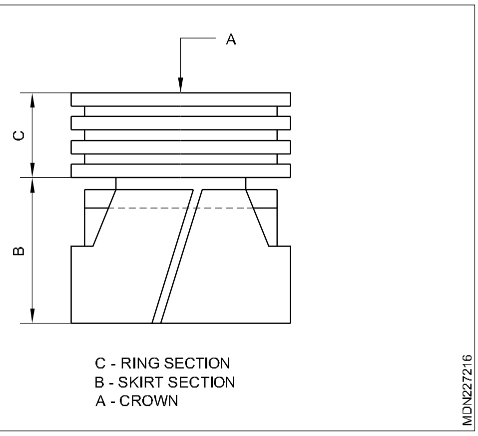
Fig 5



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

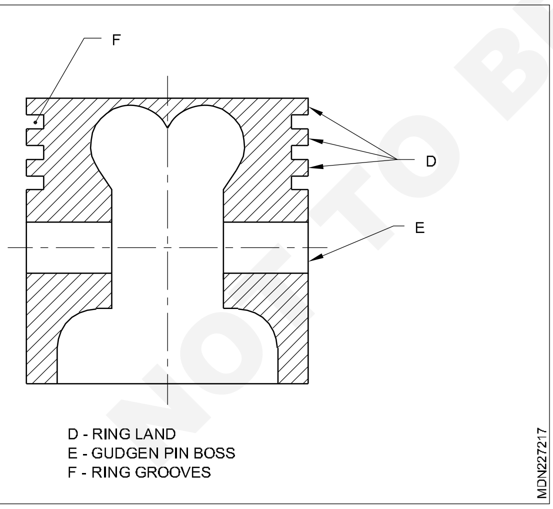


- Compression ring groove These grooves accommodate compression rings.
- Oil ring groove These grooves accommodate the oil scraper rings.

Land

This is the piston's circumference left above the top ring groove and between the ring grooves. (Fig 7)

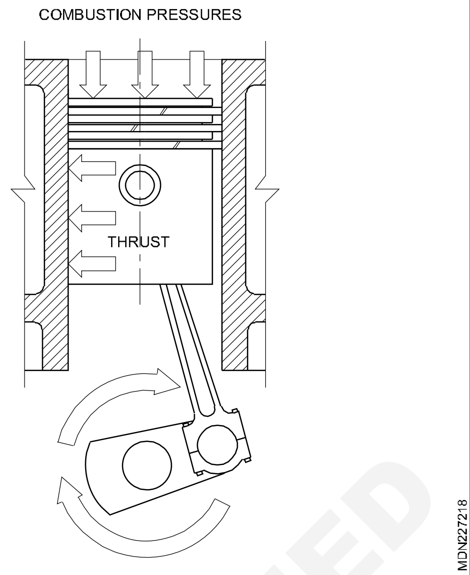
Fig 7



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.

Fig 8

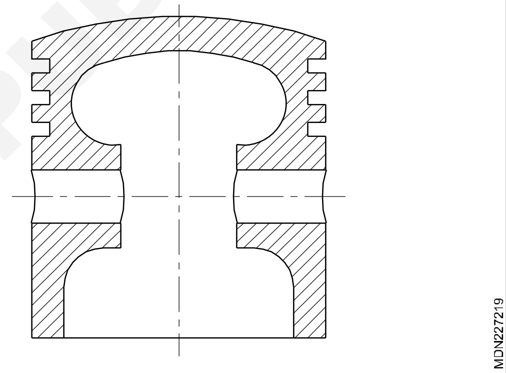


Designs/Types of pistons

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)

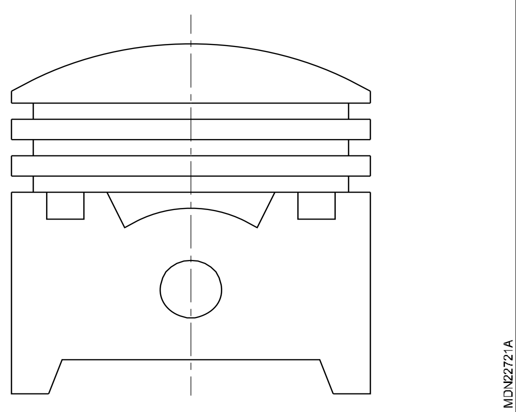
Fig 9



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)

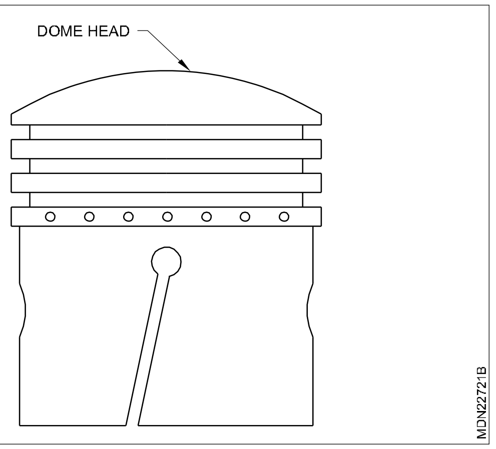
Fig 10



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)

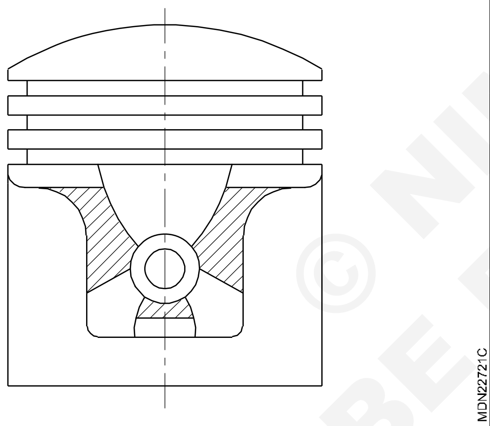
Fig 11



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)

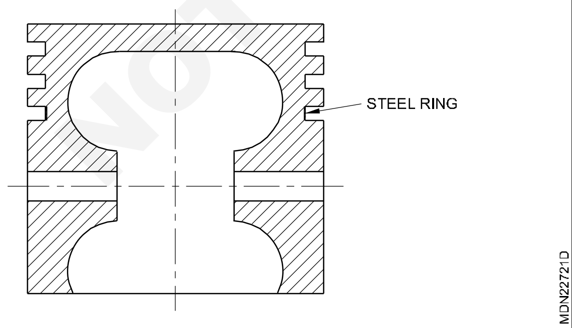
Fig 12



Steel-belted pistons

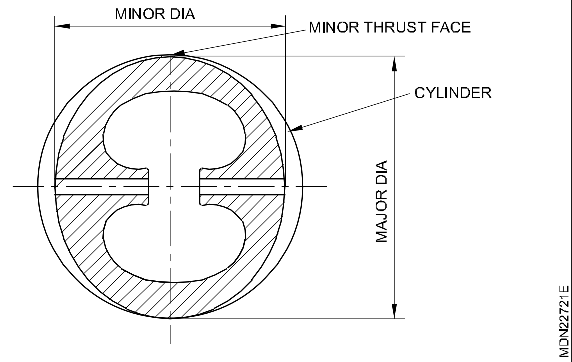
A steel ring is cast above the gudgeon pin boss for strength. It controls expansion. This type of pistons are used in heavy duty engines. (Fig 13)

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)

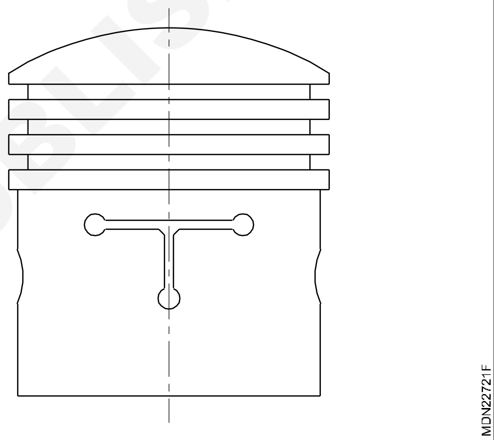
Fig 14



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)

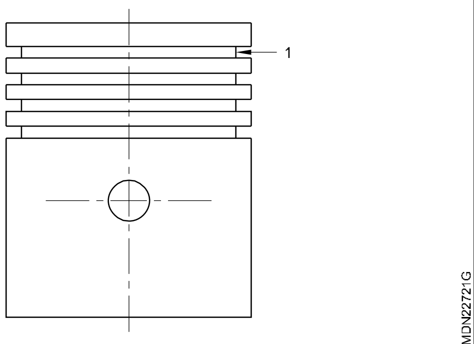
Fig 15



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)

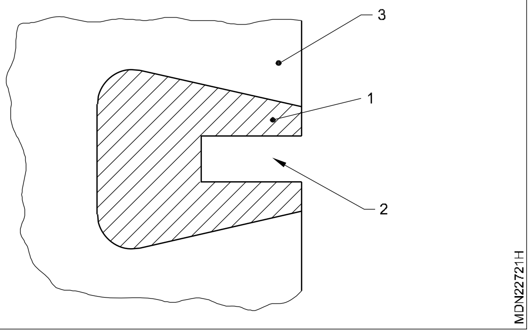
Fig 16



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

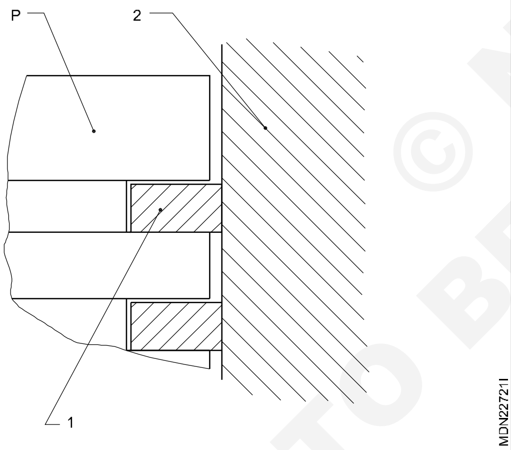
- Compression ring
- Oil control ring

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.

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 19

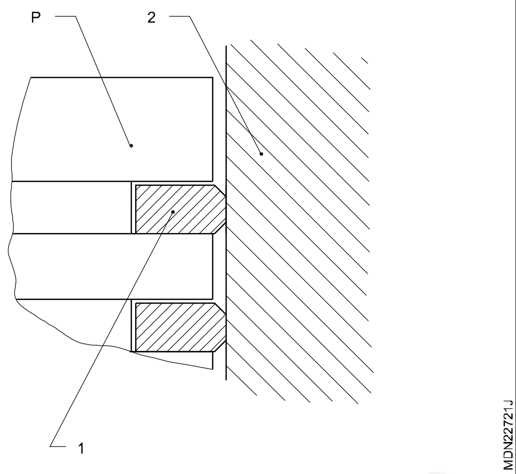


Fig 20

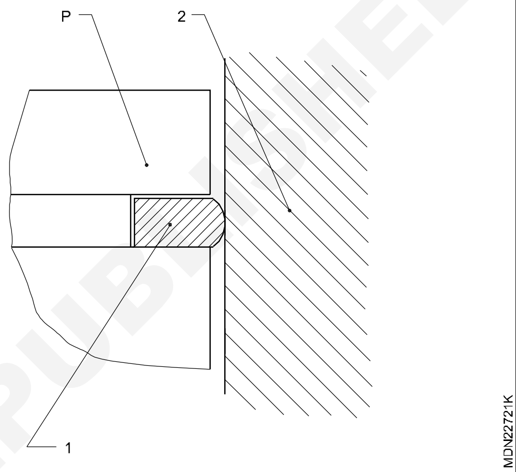
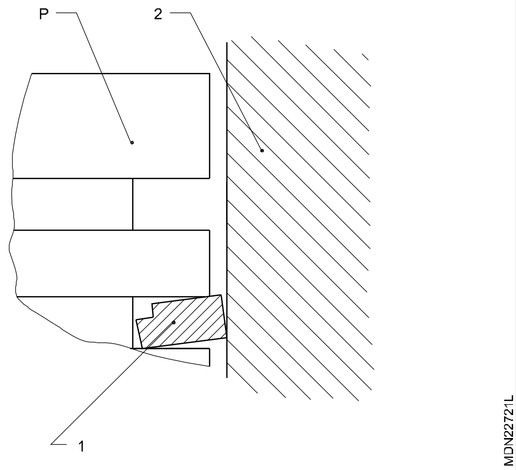


Fig 21



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)

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 Automotive. (Fig 23)

Fig 22

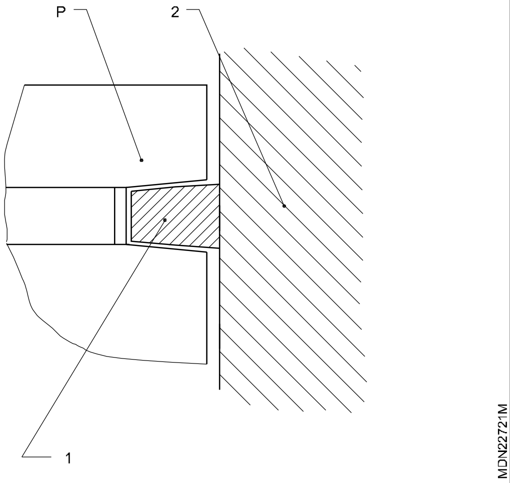
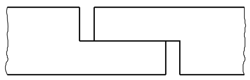


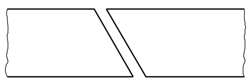
Fig 23



Angle joint (Diagonal cut)

This type of joints is easy to manufacture and the gap can be set quickly. It is commonly used in Automotive. (Fig 24)

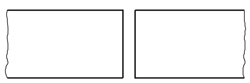
Fig 24



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



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

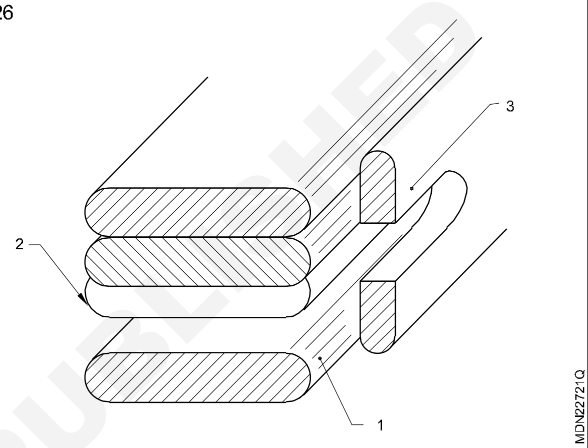
One piece (Solid rings)

These rings are easy to install. They have greater force against the cylinder wall and reduce oil consumption.

Durable 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.

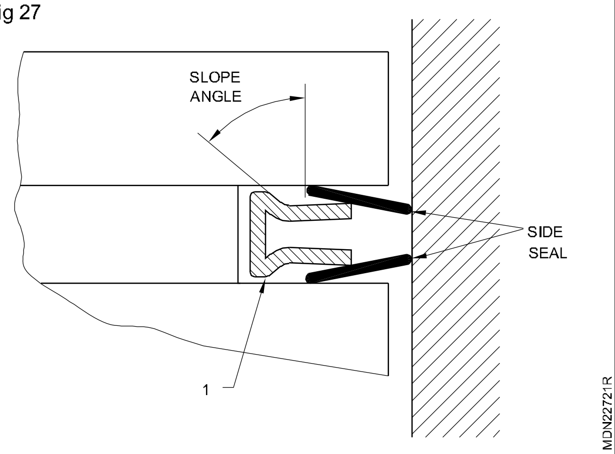
Fig 26



`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)

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.

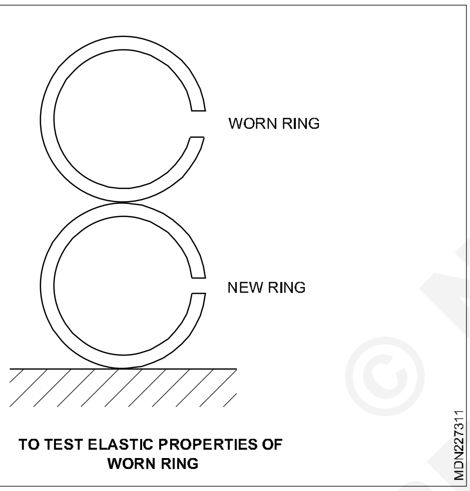
Piston ring

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 position 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 limer is measured by feeler gauge from the bottom of the limer (skirt) is 25.4 mm (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 linner.

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 frooves cleaner to remove carbon from groose.

6 Clean the piston groove, linner, rings with specified cleaning liquid.

Fig 2

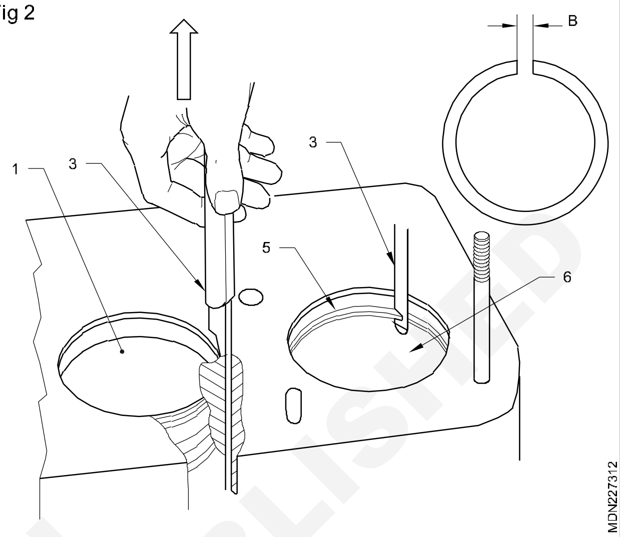
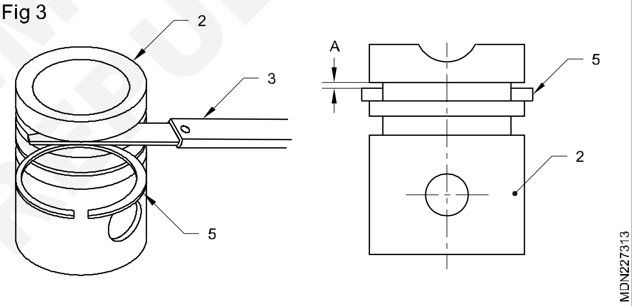


Fig 3



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 for piston clearance

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 it which radial pressure will be reduced on the cylinder wall. This 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,

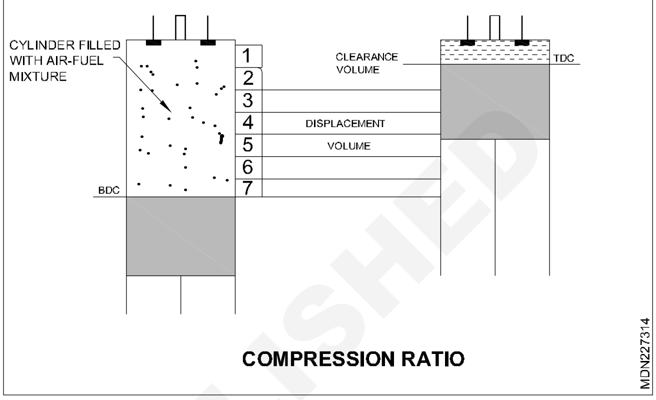
$$r - \frac{90+540}{90} = \frac{630}{90} = 7:1$$

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 11:1 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 vapurisation of the fuel and leakage past the piston rings.

Fig 4



COMPRESSION RATIO

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. 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).

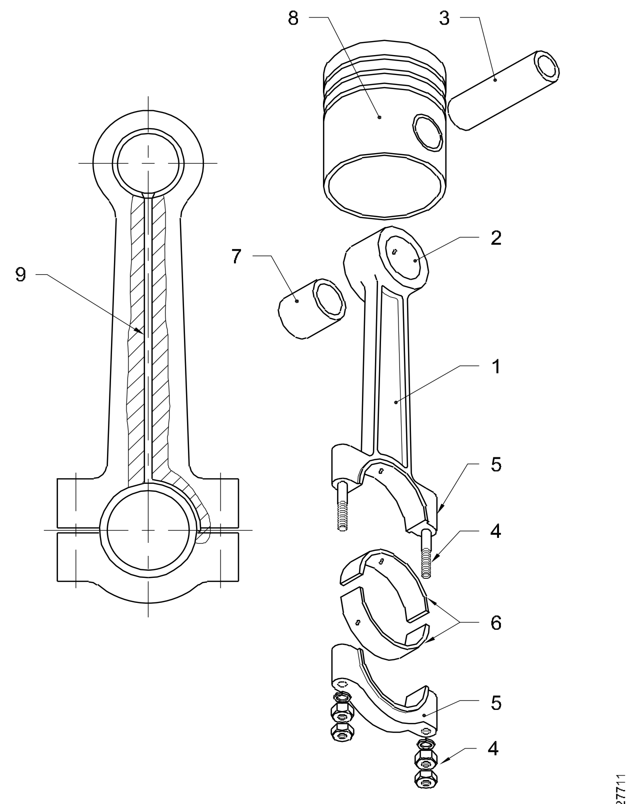
A large bearing area is provided to take the load, heat and wear. The split halves are usually fitted with babbitt bearings (6) or bearing lining steel-backed copper lead. In the upper end of the connecting rod a bronze bush (7) is fixed. The small end of the connecting rod is connected to the piston (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)

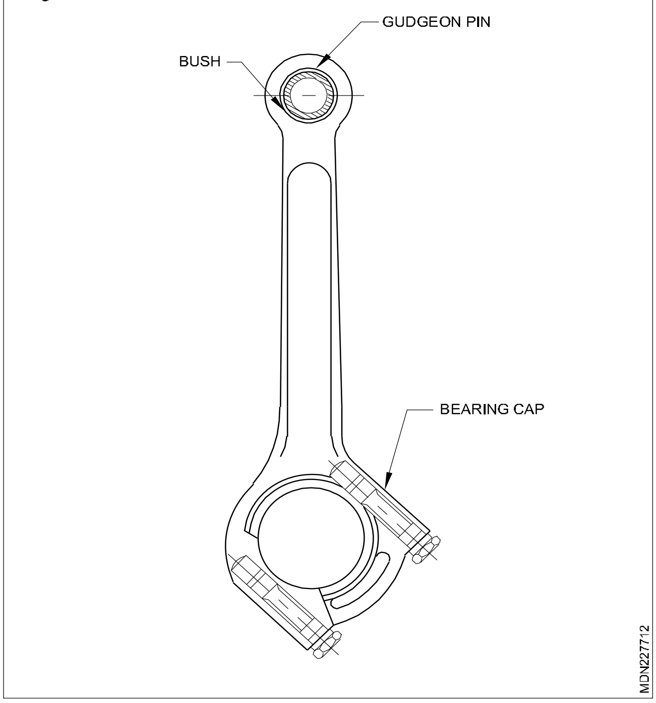
The connecting rod big end is split at an angle for assembly easily on the crankpin.

Fig 1



CONNECTING ROD SPILT AT RIGHT ANGLE

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 circles (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.

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)

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)

Piston pin materials

The piston pin are made of Nickle / chromium alloy steel. The outer surface is ground, chromium plated and case hardened.

Fig 1

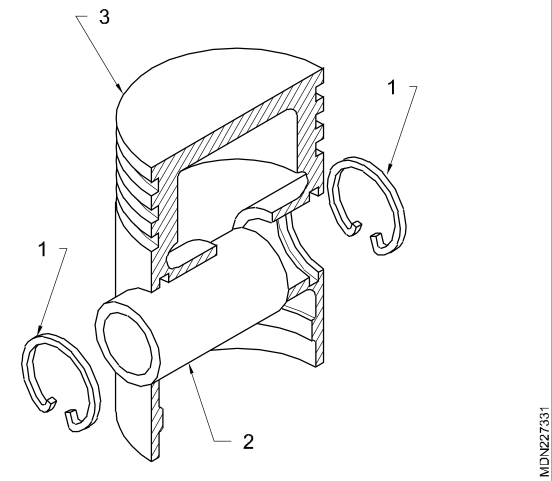


Fig 2

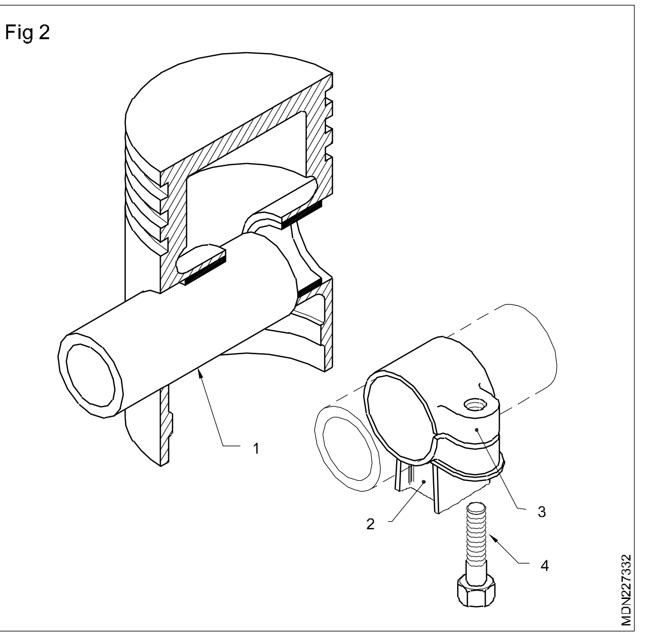
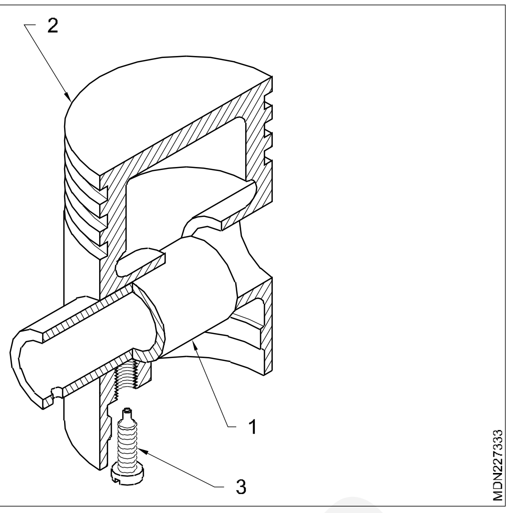


Fig 3



Description and Function of Crankshaft

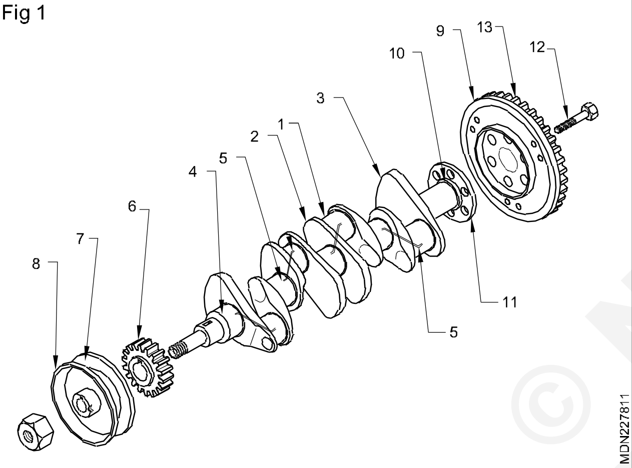
Objectives: At the end of this lesson you shall be able to
- **state the function of the crankshaft**
- **state the constructional features of crankshaft**
- **state the material of crankshaft**
- **state the necessity for heat treatment, and the balancing of the crankshaft**
- **state the constructional 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

Fig 1



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.

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.

- Nit riding
- 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, 3 & 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

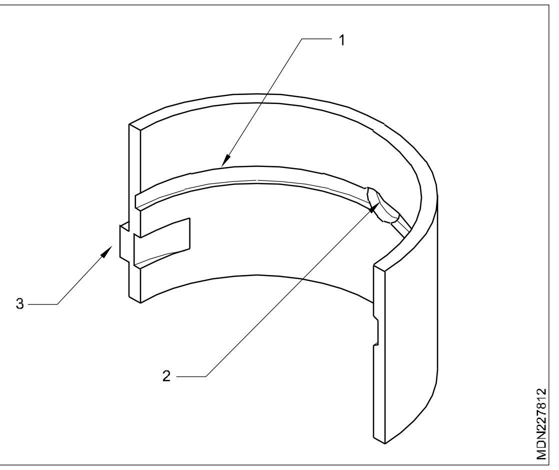


Fig 3

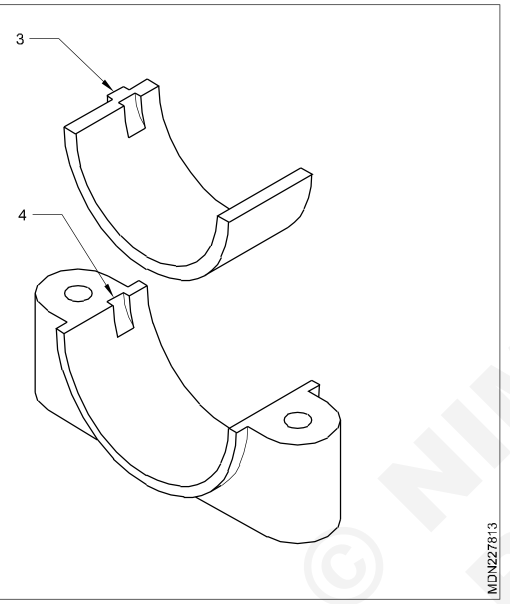
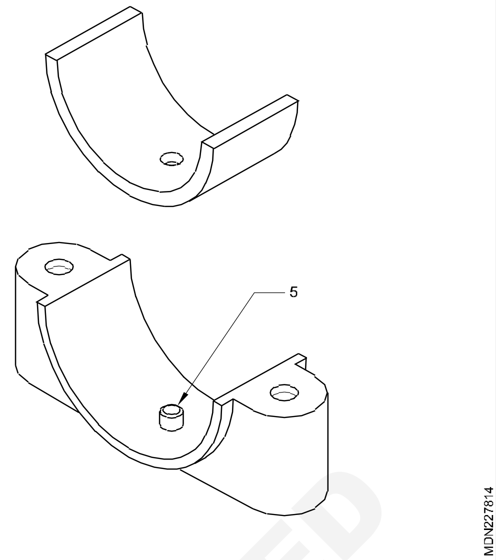
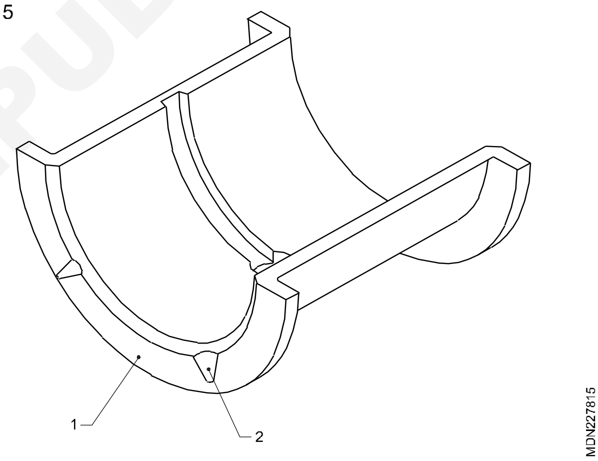


Fig 4



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



Bearings

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

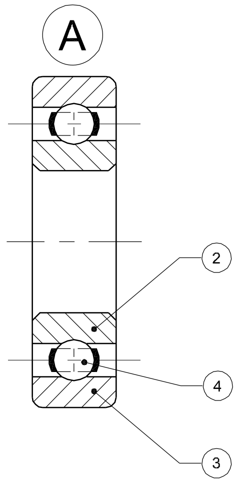
The following types of bearings are used in Automotives.

- 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.

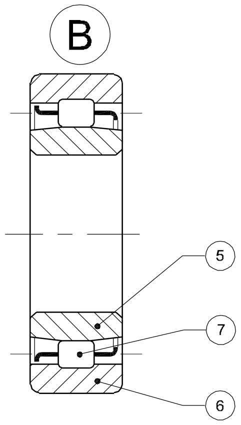
Fig 1



Ball bearings consist of an inner race (2), outer race (3) and balls (4). These bearings are used in the gearbox.

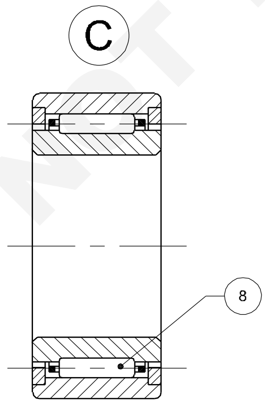
Roller bearings (B) also consist of an inner race (5), outer race (6) and rollers (7). (Fig 2) These bearings can take heavy radial load but no axial load and are used in the final drive, flywheel, water pump etc.

Fig 2



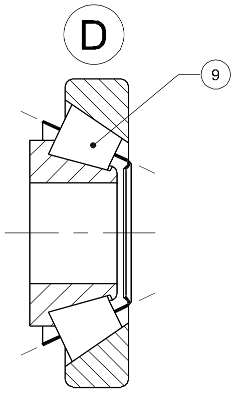
Needle roller bearings (C) (Fig 3) are similar to roller bearings except that the ratio between the length of the needle roller (8) and the diameter of the roller is much more than that of a roller bearing.

Fig 3



Taper roller bearings (D) (Fig 4) have taper rollers (9) instead of plain rollers. In Automotive, 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.

Qualities of engine bearings

The bearing should have

- Excellent fatigue strength
- Good conformability
- Fine embed ability
- Superior surface action
- High temperature strength
- Adequate corrosion resistance
- Quick thermal conductivity

Fatigue strength

The capacity of the bearing to withstand high loading and impact loads, without being crushed for a reasonable period of life is known as fatigue strength.

Conformability

The capacity of the bearing to adjust to the conditions of crankcase distortion and crankshaft warpage and conform to the journal at all times is termed as conformability.

Embed ability: The bearing should be able to absorb dirt and metal particles and keep them below their working surface to avoid abrasive wear on the journals. This aspect is called embed ability.

Surface action: The bearing should have enough self lubricating properties to withstand metal to metal contact between journals and bearings. This property is termed as surface action.

Temperature strength: Bearings are subjected to higher temperature condition during operation and as the temperature raises, they become softer. The bearing should not become too soft and loose its load carrying strength, at operating temperature.

Thermal conductivity

The bearing should quickly conduct the heat through the shell and parent bore to the block and keep its temperature low. Bearing materials are selected in such a way to suit each engine design requirements in these areas.

Bearing materials used: Different varieties of materials now in use are:

- Tin base babbitt
- Lead base babbitt
- Cadmium nickel or silver alloy
- Copper lead alloy (with tin overlay)
- Aluminium alloy
- Silver lead

Tin base babbitt

Low fatigue strength but has good conformability, embed ability, surface action and corrosive resistance. This is popularly used on heat engines.

Lead base babbitt

Improved fatigue strength compare to tin base babbitt and similar to them in other respect. This is popularly used in petrol engines.

Cadmium nickel or silver alloy

Fatigue strength is further improved but not very good in conformability, embed ability and surface action popularly used in high speed high pressure engines.

Copper lead alloy

Superior fatigue strength even at higher temperature. These are improved by overlay tin coating or tin base micro babbitt surface and popularly used in high speed diesel engines.

Aluminium alloy

Aluminium alloy excels with respect to fatigue strength, load carrying capacity, corrosion resistance and freedom from scoring tendencies. In case of seizures, only bearing get affected and journals are saved from scoring when aluminium bearings are used. The sticking bearings material can be easily removed from the journals. Due to poor embed ability, improved hardening of the journals is necessary.

Silver lead bearings

These alloys have the greatest load carrying capacity, but, prohibitively expensive. Limited to aeronautical purposes where this factor is of great importance. Embeddability is poor with these alloys.

Bearing spread and crush

Bearing spread

The bearing should have full contact with its parent bore and for this purpose bearing spread and crush are provided. Both main bearing and con-rod inserts have the outer dia. at parting forces slightly larger than the housing bore dia. This will be about .005" to .020" in the case of main bearings and .020" for con-rod bearings in excess of the bore dia. This is known as bearing spread and this helps to hold the inserts in place during assembly.

Bearing crush

The parting faces when assembled stand proud of the parent bore half. When bearing caps are tightened, a radial pressure is exerted at the parting faces and forces the inserts tightly into the housing bore to ensure complete contact. This is about .004" to .008" for main and big end bearings. This is checked by torqueing the both ends to recommendations, then loosening one end and inserting feeler gauge between cap face and crankcase face.

Camshaft bushings

Precision bearings are used for camshaft in many engines. But they are not split but pressed into the block as a full bush and held thereby means of a press fit. These bushings are designed for radial loads only. But, end thrust is being taken by a special thrust plate bolted to block.

Small end of connecting rod

The small end of connecting rod is fitted with a phosphor bronze bush and the small end is joined to the piston by a means of a piston pin passing through this bush.

Load on the precision insert bearings

- The precision insert bearing used as a main bearing in an engine take up radial and the thrust loads applied to the crankshaft.
- The connecting rod bearings are normally constructed for radial loads only. The thrust will be taken up by the crank cheeks which are machined surfaces to match the machined side faces of big end of the connecting rod.

Advantages of using precision insert bearings

- Variety of bearing materials may be used.
- Desired structure can be obtained
- Controlled babbitt thickness is possible
- Easier and quicker replacements can be done.
- Improved load carrying characteristics is possible.

Application of bearings, causes of failure and care & maintenance

Objectives: At the end of this lesson you shall be able to
- **state the application of bearings**
- **state the causes for bearing failure**
- **state the care and maintenance of the bearings.**

The device for supporting the rotating shaft is called bearing, bearings are used in all types of machineries, engines and mechanism for supporting and controlling the motion of rotating, sliding or reciprocating parts, shafts, spindles, axles, rods & pins.

The contact surface of bearings may wear out due to friction and rubbing by rotating or moving parts. To minimise the frictional resistance, bearing are lubricated and adjusted that they serve their purpose with a minimum of friction power loss and generation of heat.

Application of the bearings: Bearings are different types depending upon the construction and direction of load act on the bearings. Generally bearings are classified as three categories.

1 Radial or journal bearing (Fig 5 & 6)

2 Pivot or foot step bearing (Fig 7)

3 Thrust or collar bearing (Fig 8)

Radial bearing supports the rotating shaft in a fixed position against the load acting perpendicular to the axis of the shaft. (Fig 5&6)

Fig 5

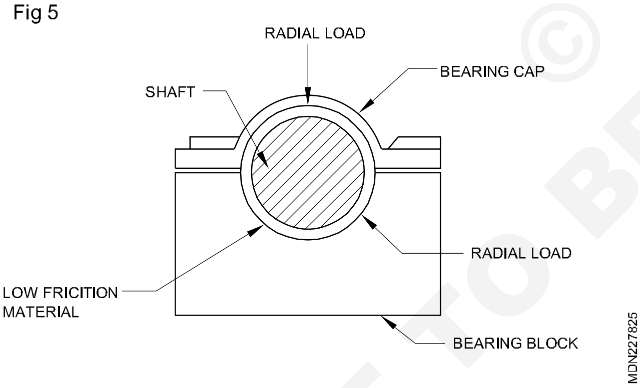
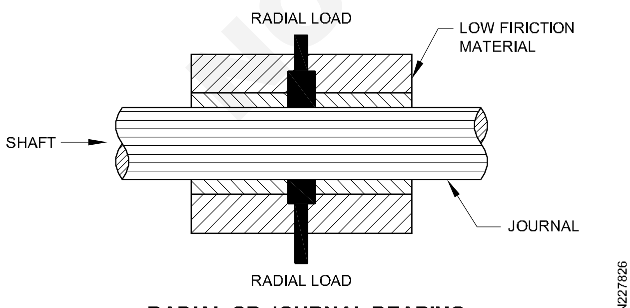


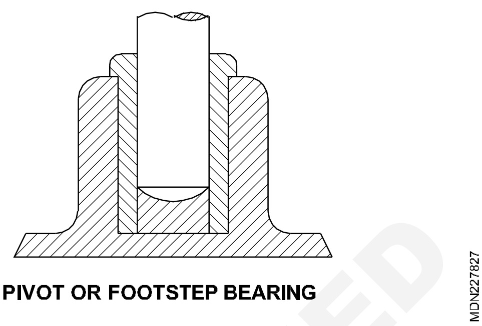
Fig 6



RADIAL OR JOURNAL BEARING

A pivot or foot step bearing supports the vertical shaft as its end. (Fig 7)

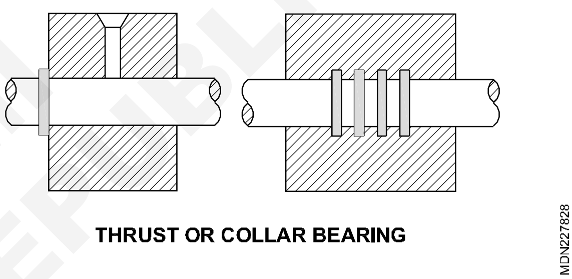
Fig 7



PIVOT OR FOOTSTEP BEARING

Thrust bearing supports the rotating shaft against the side thrust of the shaft side collar are provided on the shaft to resist the side thrust. (Fig 8)

Fig 8



THRUST OR COLLAR BEARING

Bearing failures

Fatigue failure

This is identified by small sections of bearing material detaching from the steel back and this spreads to the entire bearing. Excessive loading, detonation, inadequate lubrication, high temperature build up are the major causes for this problem.

Foreign matter on bearing surface

Dirt, dust, metal particles left before assembly, due to improper cleaning, dirty oil, due to inadequate maintenance result in suspended hard particles staying the lub. system. These find a way into the bearings under pressure with lub. oil and when they are too big to pass through the bearing clearances, they get embedded into the bearings, displacing the bearing material. continued condition of such nature, lead to the bearing surface getting full of such particles which work on the journals as an abrasive and score them. This will accelerate bearing and journal wear. Hygienic conditions in the system and also during assembly is therefore very important.

Improperly seated bearing

This is possible due to existence of foreign matter or dirt between bearing back and seating at parent bore, filed parting faces or bearing caps or shims below the bearing shells or between parting faces when not needed. This will affect full contact with parent bore, oil clearance and load distribution, thermal conductivity etc. and the problems following them. Localised wear or peeling of bearing material or seizure may be the result.

Dirt between bearing and the seat is due to improper cleaning before assembly, Bearing crush may be lost by filing parting faces and even the bearings may start working loose in the parent bore. This may lead to bearing rotation and complete seizure very quickly.

Filed bearing caps result in out of round parent bores. This is ignorantly attempted to reduce oil clearance. This may lead to excessive crush and insufficient oil clearance and landing up in a total bearing failure.

Con.rod mis-alignment

Bend and twisted con.rods wear the bearing unevenly. This affects bearing clearances also.

Shifted bearing caps: This can be caused by

- Improper doweling or by damaged dowel holes.
- Using too bigger socket spanner for the cap screws.

P.T.F.E. bearings

Poly tetrafluoro ethylent (PTFE) is extremely insert plastic material with an unusually low dry co-efficient of friction its use is limited by its thermal properties. This bearing particularly suitable for applications where corrosive liquids would attach conventional bearing materials.

Care and maintenance of bearing

- Identify correct size of bearing for selected application.
- Clean the dirt, dust, rust and metal particles on the bearing before use.
- Setting proper bearing clearance and proper seating in its place
- Specified lubricant use for bearing lubrication.
- Periodically change the lubricant for increase the bearings life.
- Replace the damaged or worn out bearings.
- Use the quality of bearings as specified in service manual.

Types of bearings damages

- Abrasive damage
- Erosion damage
- Fatigue damage
- Corrosion damage
- wiping damage
- Cracks, scoring, overheating

Types of bearing damages and causes

Damages	Causes
Edge wear	- Less clearance
Score and scratches (situational wear)	- Bad workmanship
Overheating & surface	- Insufficient lubrication
Cavitation of erosion	- Inferior quality of material
Corrosion	- water mix with lubricant
Cracks in galvanize layer	- Overheat and overload
Pitting and fretting	- Metal particals in lubricant

Factors affecting bearing clearance

- Desired operating temperature extremely critical
- Engine speed
- Oil flow rate
- Oil film thickness
- Working viscosity of lubricant
- Load carrying capacity
- Operating temperature of engine

Bearing defect symptoms

- Low oil pressure
- Reduce load capacitor
- High impact load on crankshaft
- Noise

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 trosional 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 mouring parts crankshaft connecting rod and pistons are rotating in reciprocating motion, so that crankshaft counter balance 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 intertia force. The angularity of the connecting rods produce secondary vibration, it is called secondary intertia force. The perfect static and dynamic balance of crankshaft and flywheel reduce the vibration.

Firing order: The sequence of power impulses occur in 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 and 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.**

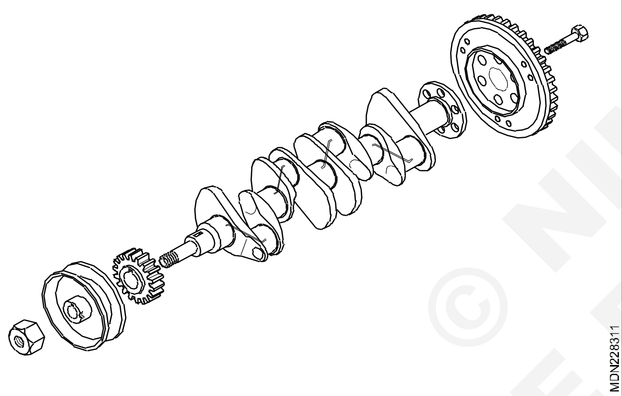
Function of Flywheel

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, teh 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 th etorque 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.

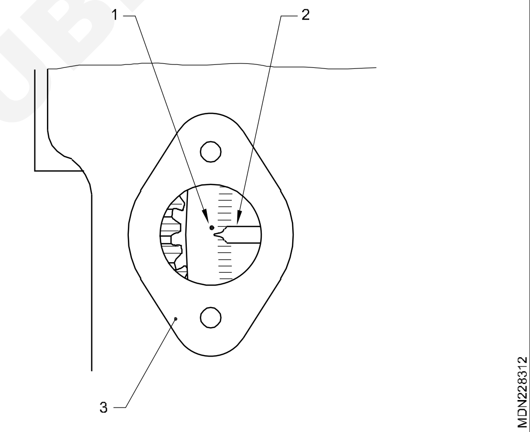
Fig 1



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 tims distributor contact should just start at open.

Fig 2



Vibration damper

Objectives: At the end of this lesson you shall be able to
- **state the function of vibration damper**
- **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

In 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

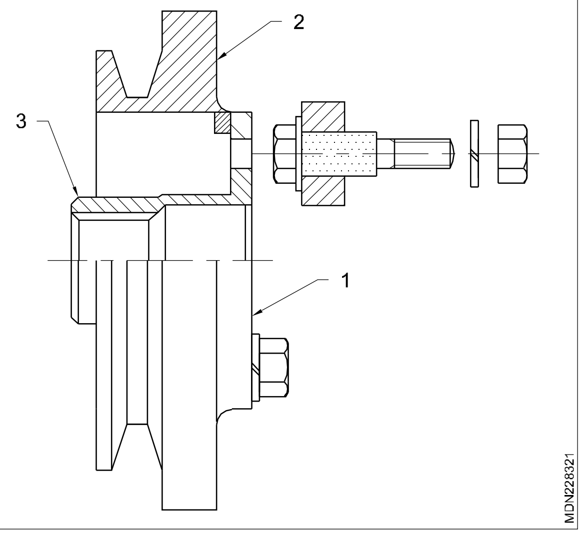
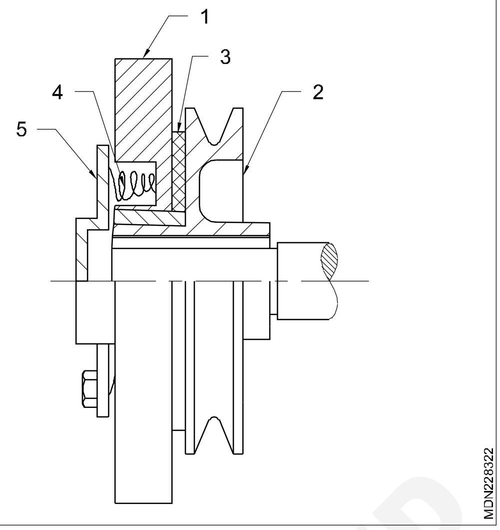


Fig 2



Timing gear drive

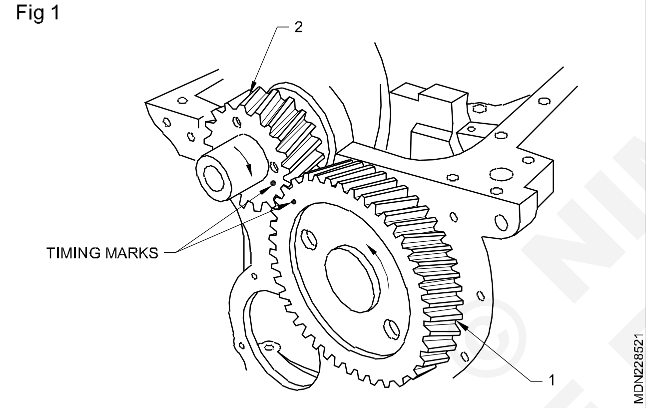
Objective : At the end of this lesson you shall be able to
- **state the timing gear drive.**

- Timing Gear drive
- Timing Chain drive

Timing 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



Timing chain (Fig 2)

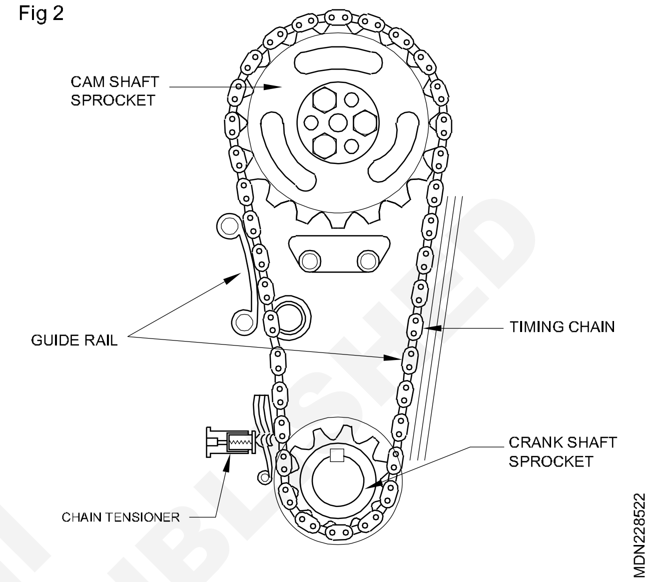
With this type of sprocket drive the camshaft is driven by means of a chain with the aid of various.

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.

Fig 2



The chain is addtionally guided in rails to the chain vibration and noise.

The direction of crank shaft and camshaft is same.

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

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: Depending upon the different loads are requiring change of speed to match the rated power available in the engine. Vehicle speed can be changed by shifting gears.

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:

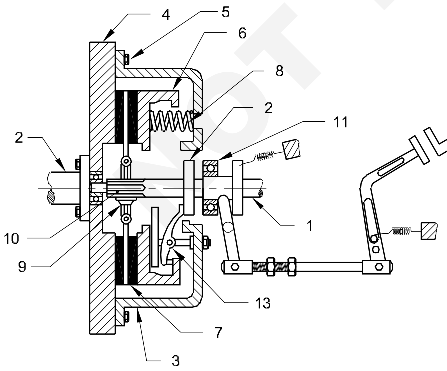
- contact area of the clutch plate.
- co-efficient of friction of lining material.
- spring pressure.
- number of clutch plate used.

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

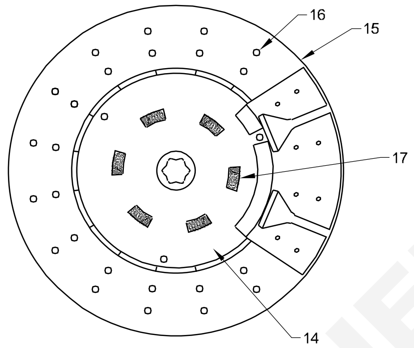


WORKING OF SINGLE PLATE CLUTCH

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.

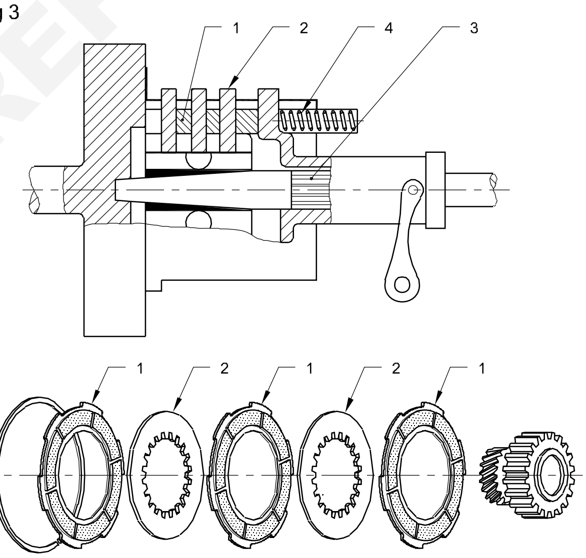
Fig 2



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.

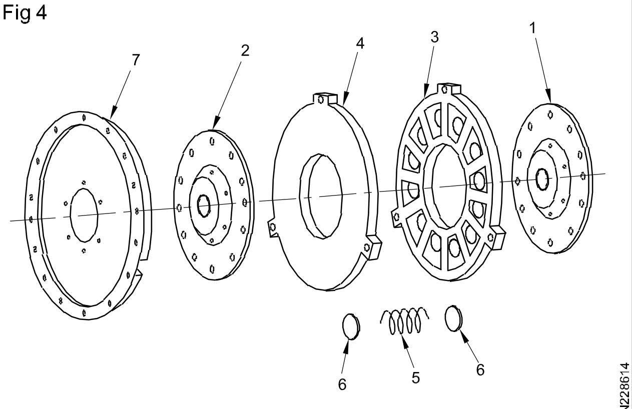
Fig 3



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) & 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



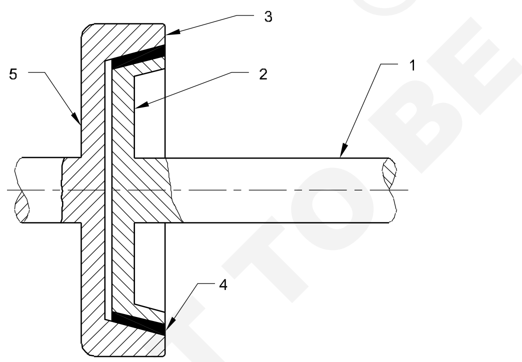
EXPLODED VIEW OF DUAL CLUTCH SYSTEM

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

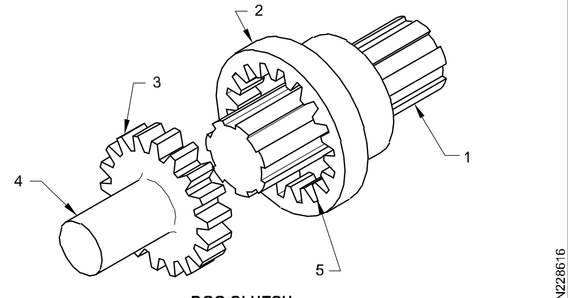


CONE CLUTCH

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.

Fig 6

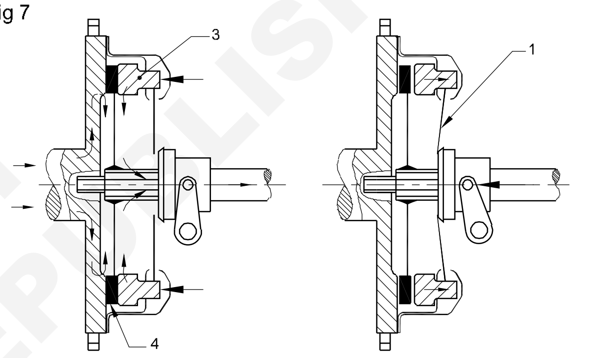


DOG CLUTCH

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 7



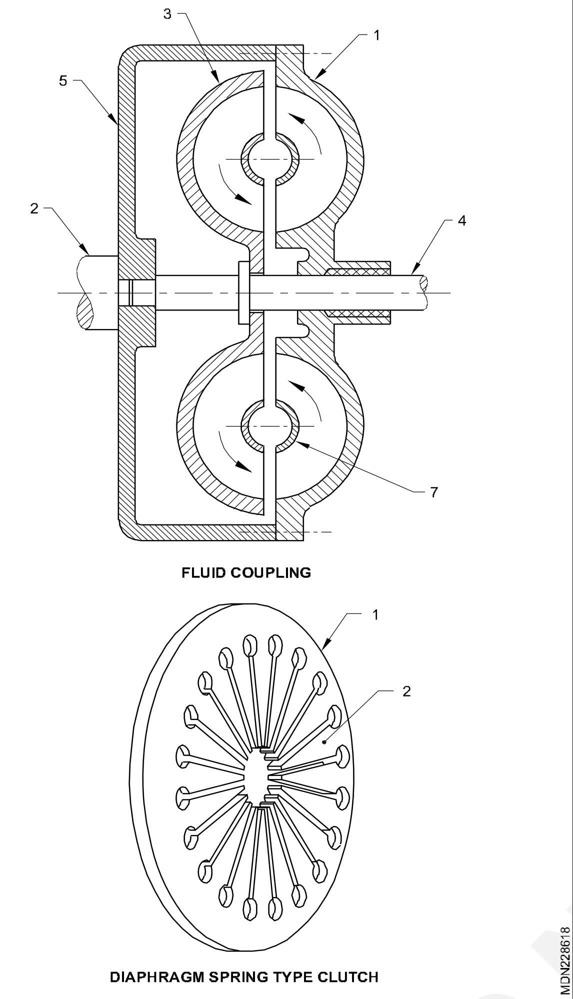
DIAPHRAGM SPRING CLUTCHES

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 epicyclical gear box as the output shaft (drive shaft) is always in motion.

Fig 8



Cylinder block and liners

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. 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.

Fig 1

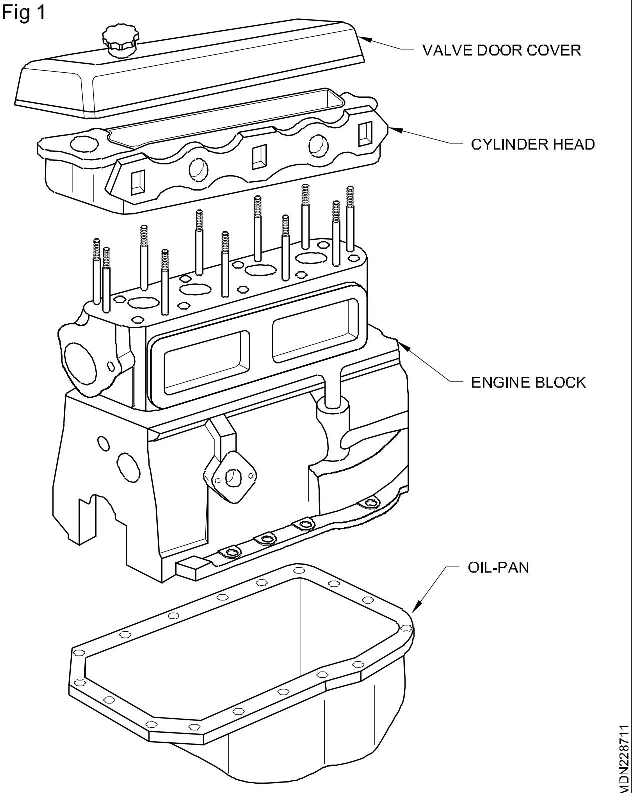
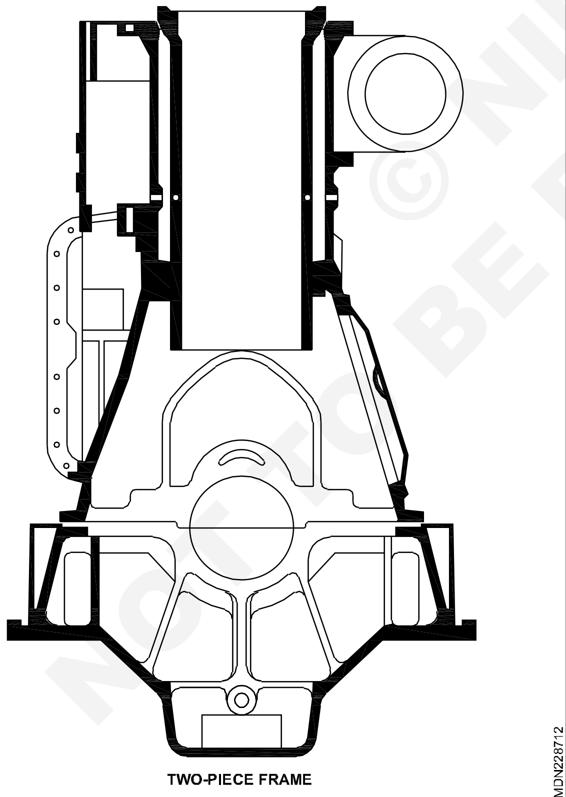


Fig 2



Crank case material

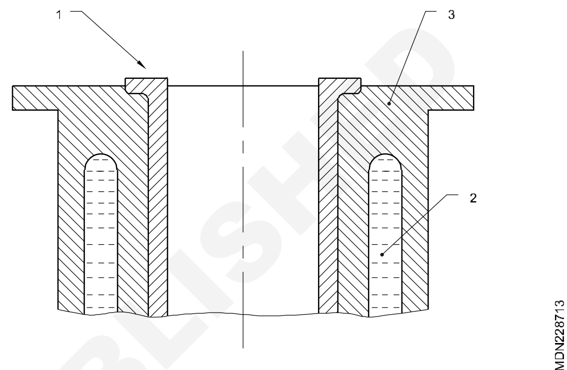
The cylinder block and upper half of the crankcase usually made of a ferrous alloy or semi steel to provide a stronger and harder casting. The use of stringer and together materials permits timer casting walls, thus saving weight and improving of cooling effect and good thermal conductivity.

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

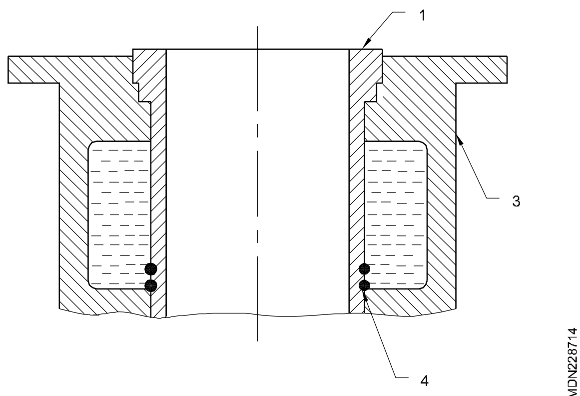
In a wet type liner (1) , the liners are in direct contact with the cooling water. (Fig 4)

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 nitride 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**
- **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.**

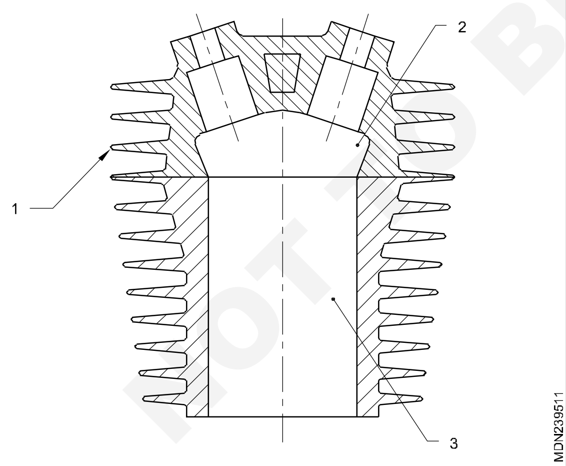
Combustion of fuel inside a cylinder develops a very high temperature (Appx. 2200^0C). At this temperature the engine parts will expand and tend to seize. Similarly the lubricating oil will loose its property. Therefore it is necessary to keep the engine temperature to operating limits. This is done 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

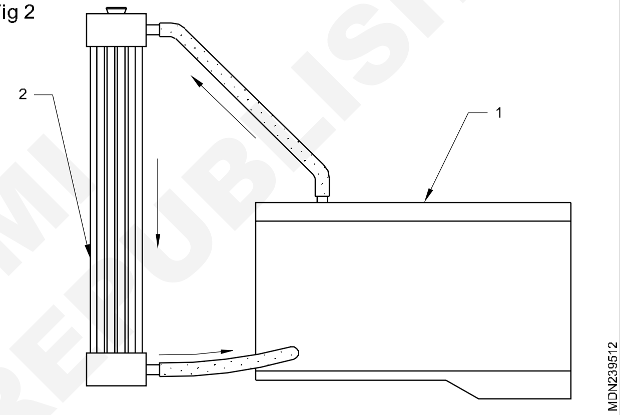


Water cooling: Two types of water cooling systems are used;

- Thermo-siphon system (Fig 2)
- Forced circulation system (Fig 3)

Thermo-siphon system (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.

Fig 2

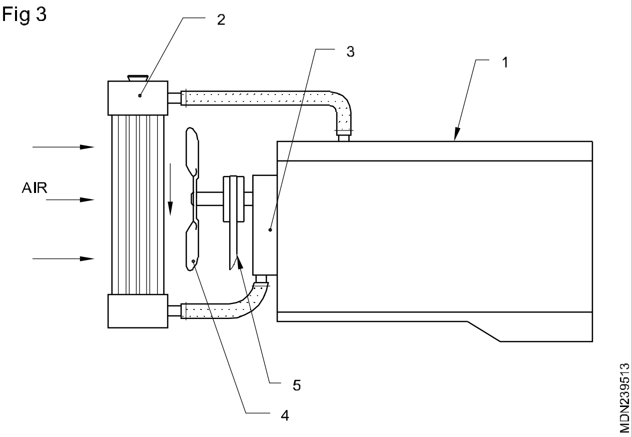


Pump circulation system (Forced feed system)

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.

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.

Fig 3



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.

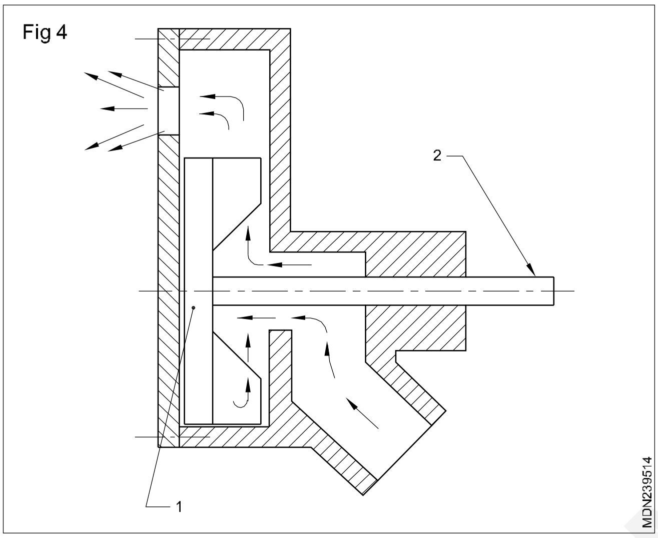


Fig 4

Thermostat: The thermostat (Fig 5) helps to bring the cold engine to the operating temperature quickly.

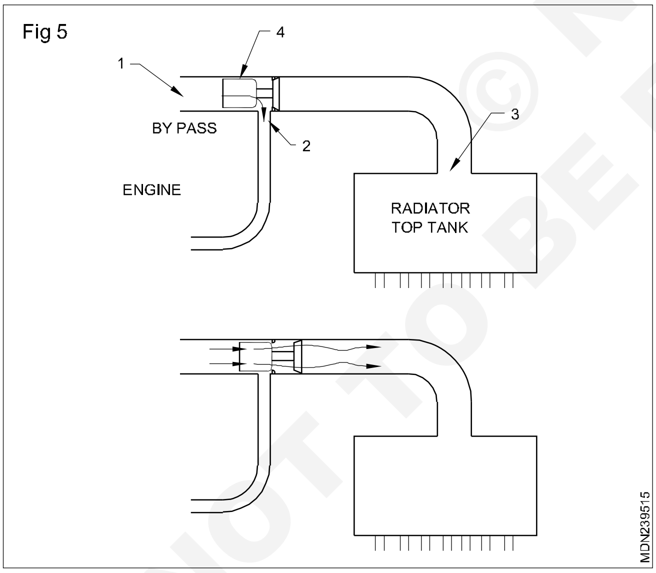


Fig 5

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.

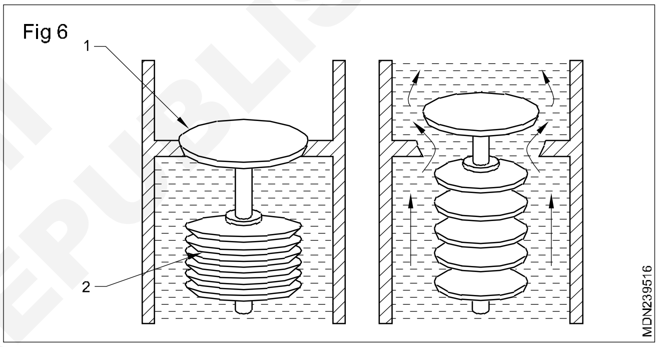


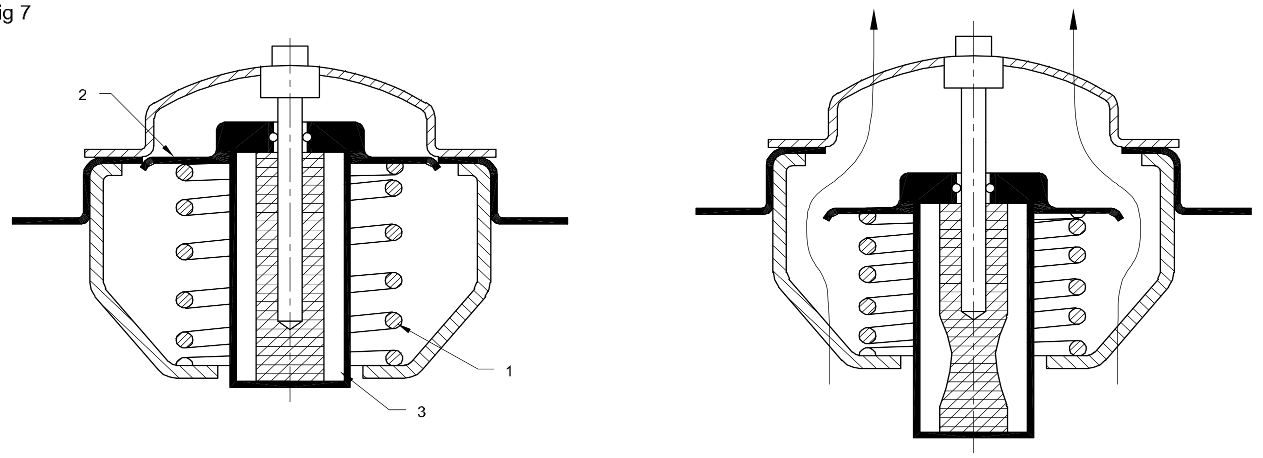
Fig 6

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 7) 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 7



CLOSED POSITION OPEN POSITION

Components of water cooling system

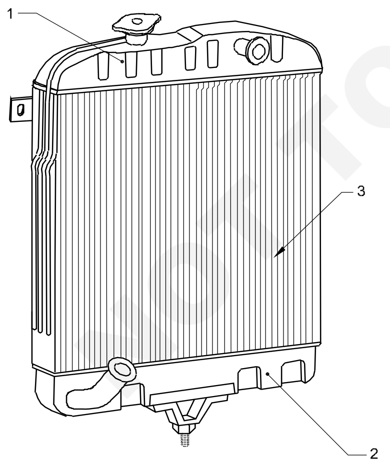
Objectives: At the end of this lesson you shall be able to
- **state the constructional features of a radiator**
- **state the need of a pressure cap**
- **explain the marine engine cooling system**
- **explain the open cooling system.**

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



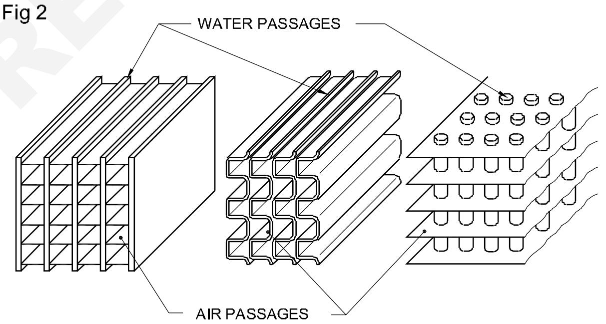
Radiator cores: They are classified into two types;

1 Tubular core (Fig 2) 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.

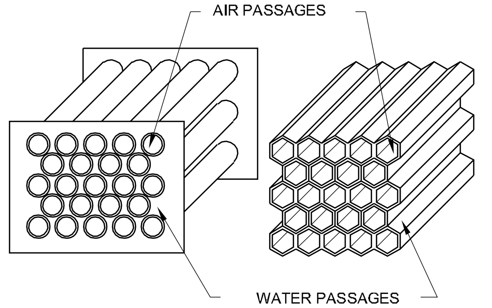
Cellular cores: In the cellular type a large number of individual air cells are provided and surrounded by water. Because of its appearance, the cellular type is known as a 'honeycomb' radiator. The material of the core is of copper and brass. The parts are normally connected together by soldering.

Fig 2



TUBULAR RADIATOR SECTIONS

Fig 3

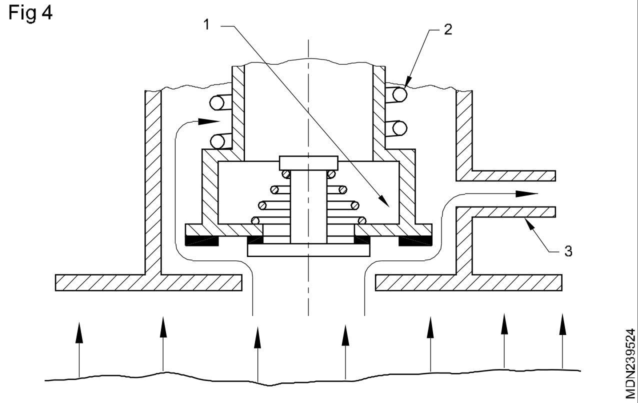


CELLULAR RADIATOR SECTION

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 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.

1 Pressure valve   2 Vacuum valve

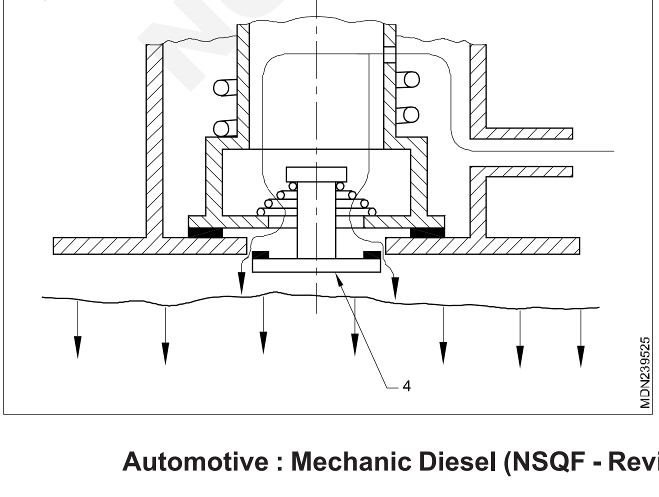
Pressure valve: If the pressure in the system rises it may damage the components. To avoid this a pressure relief valve (1) is used to release the excess pressure. It is a spring- loaded valve. The spring's (2) tension depends on the system's pressure.

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.)

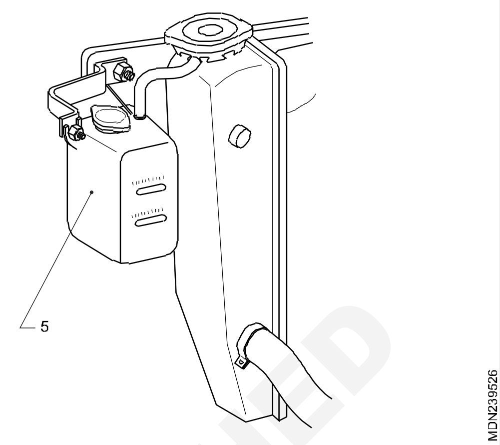
At this time the vacuum valve (4) (Fig 5) opens and air flows into the system until the vacuum is filled up in the system.

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



Coolant hoses

1 **Hose pipes:** It is made of synthetic rubber

2 **Upper hose:** It is connected between the cylinder head and radiator upper tank.

3 **Lower hose:** It is connected between the cylinder block as radiator lower tank.

4 **Bypass hose:** It is connected between the cylinder head coolant/water outlet and water pump intake side.

Fan

1 The fan is mounted behind the radiator on the water pump shaft. It is driven by the belt that drives the water pump. It drawn the air through radiator to cool the pins & pipe (core).

2 In latest vehicles the fan is mounted on the frame behind radiator. It is operated electrically by ECM.

3 Fan does not start toll the coolant/water temperature reaches at normal working temperature (Ex. 90°C).

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 thermostat, 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: 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 vaporization.
- 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 Glycerin

4 Ethylene glycol

5 Propylene glycol

6 Mixture of alcohol and glycerin

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.

The lubrication effect is not affected when the vehicle is climbing up or moving down.

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 1

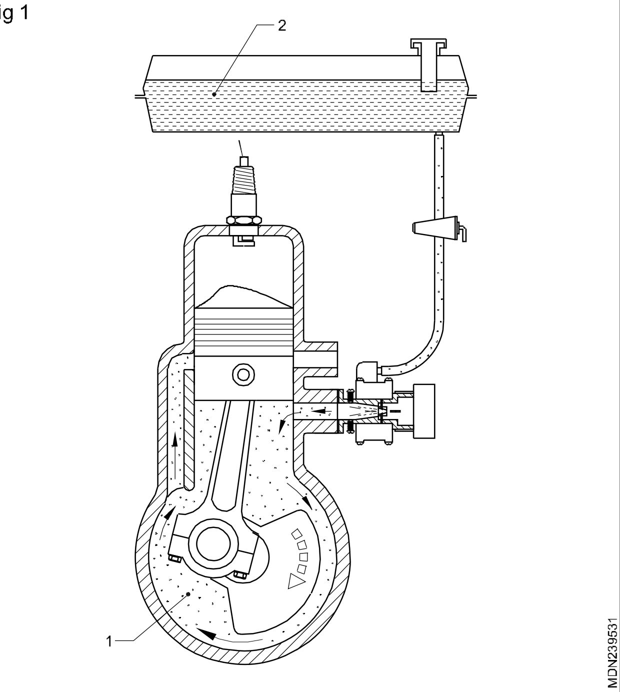


Fig 2

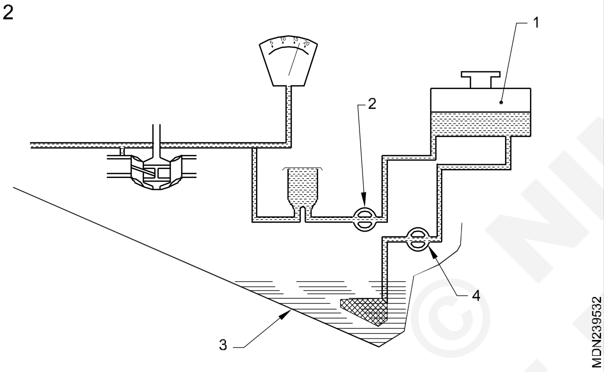
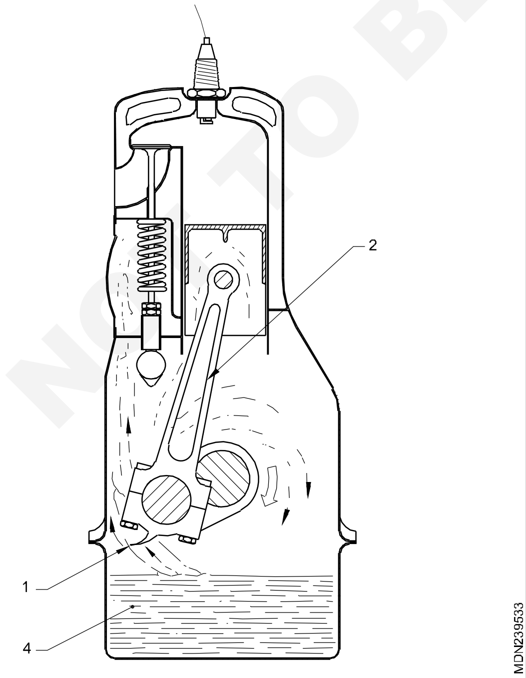


Fig 3



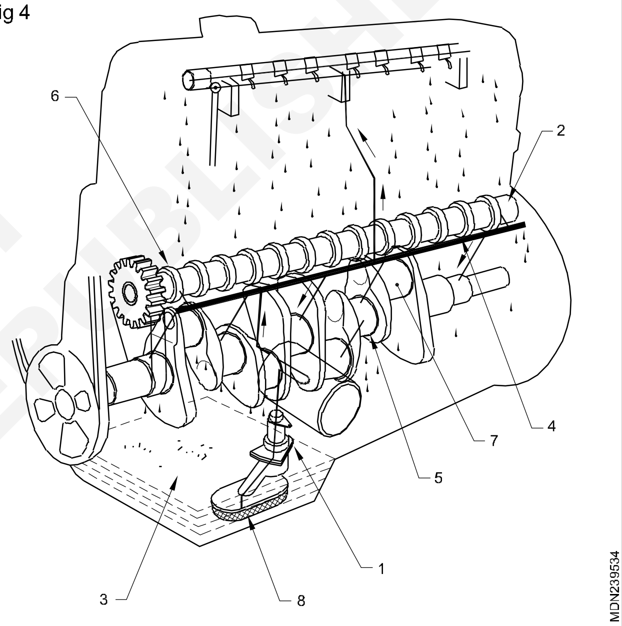
Pressure lubricating system (Fig 4)

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

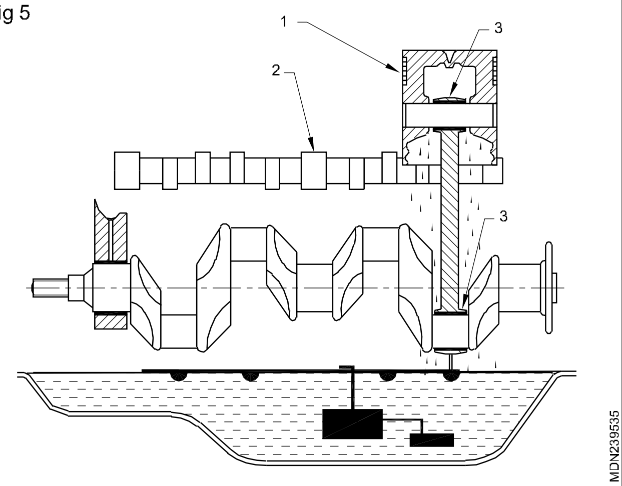
Combined lubricating system (Fig 5)

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.

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.

Fig 5

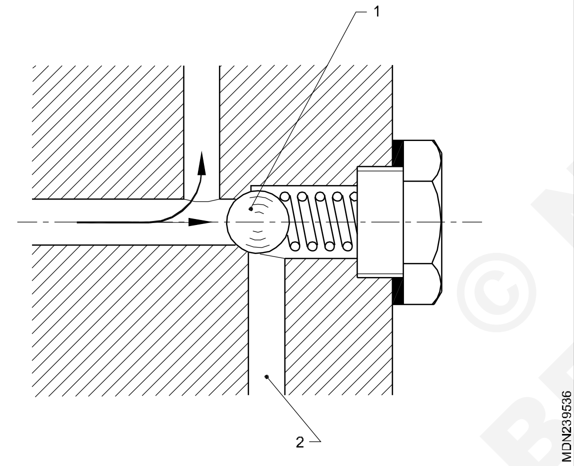


Following types of relief valves are used.

- Ball type
- Plunger type

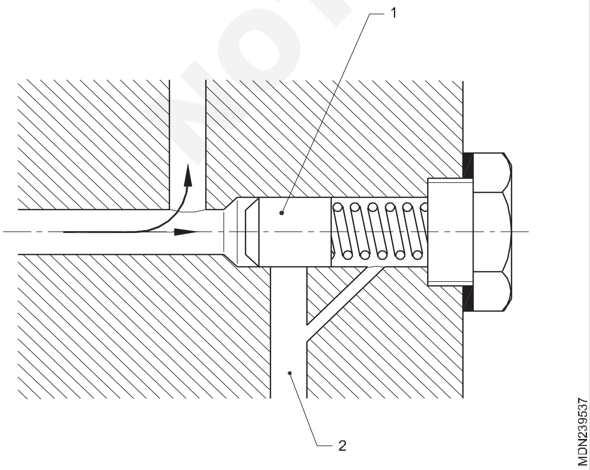
Ball type (Fig 6): In this type of relief valve a spring-loaded ball (1) opens the connection to the return channel (2) when the oil pressure over comes the spring force. The oil flows through the return channel back to the oil sump.

Fig 6



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 return passage is provided to allow oil to return to the oil sump which has passed through the plunger (1).

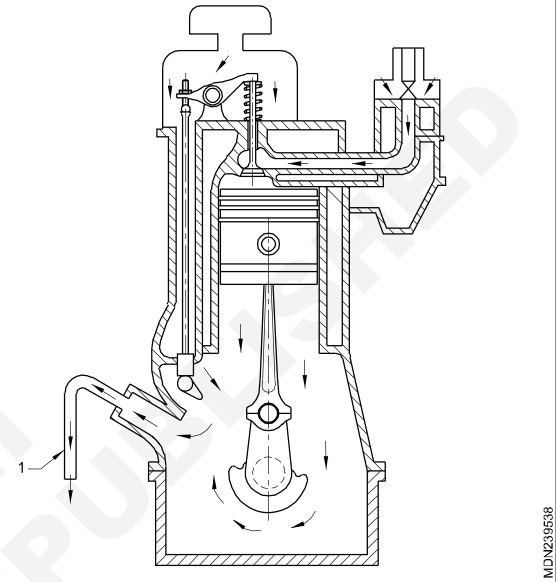
Fig 7



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.

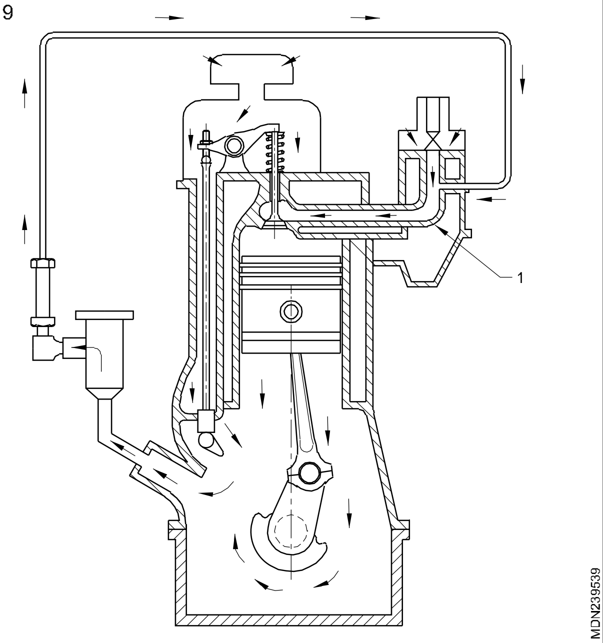
Fig 8



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.

Fig 9



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 unit sump lubricating system, the oil is taken out from the sump and after lubricating different parts oil drops in 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 condensed 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, 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 delivery pump is sent oil from dry sump to oil tank. In this system oil is not stored in oil sump.

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 strainer and oil pump.

Oil pump and filter

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

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 is working and there is sufficient oil pressure in the pressure system, the indicating light switching light switch is open due to oil pressure effect on it and no current blows to the light, during this occasion warning light is off.

When the pressure system fails due to any breakdown in the system or stoppage the engine, the warning light switch is closed and light starts to glowing.

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.

1 Gear type oil pump

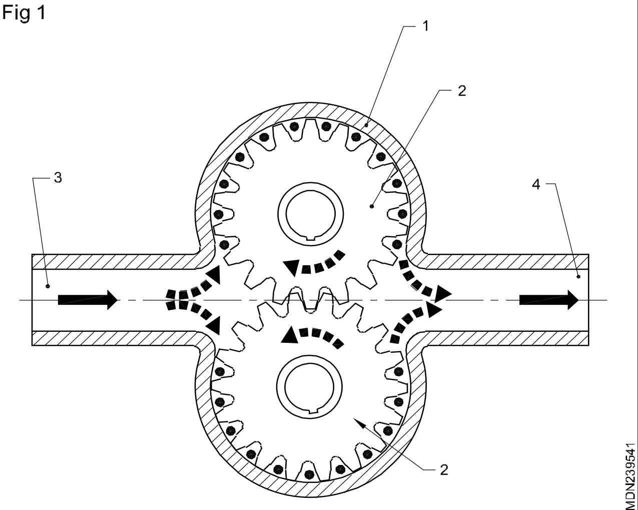
2 Rotor type oil pump

3 Vane type oil pump

4 Plunger type oil pump

1 **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. Oil is sucked through the inlet (3) and pumped to the oil gallery through the outlet (4).

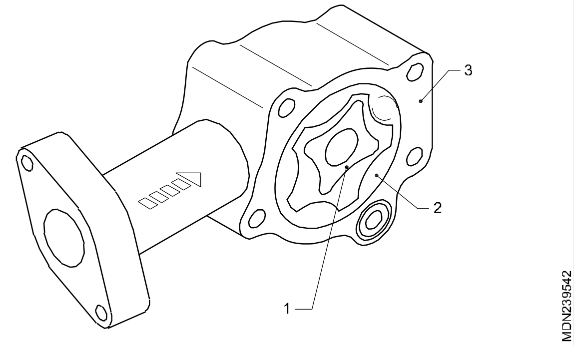
Fig 1



2 **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

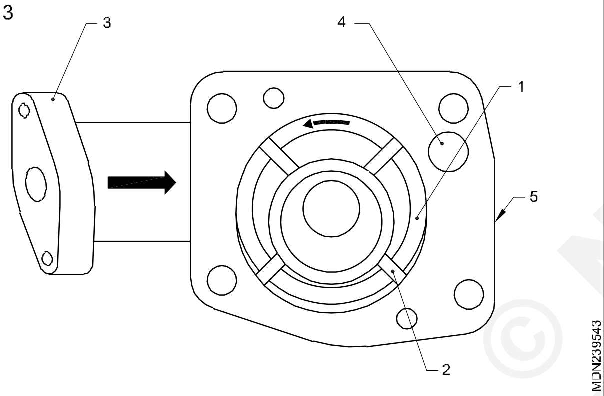
runs eccentrically in relation to the inner rotor. The oil is sucked into the pump in the side where the volume between the rotor teeth increases and is pumped out on the side where the volume decreases.

Fig 2



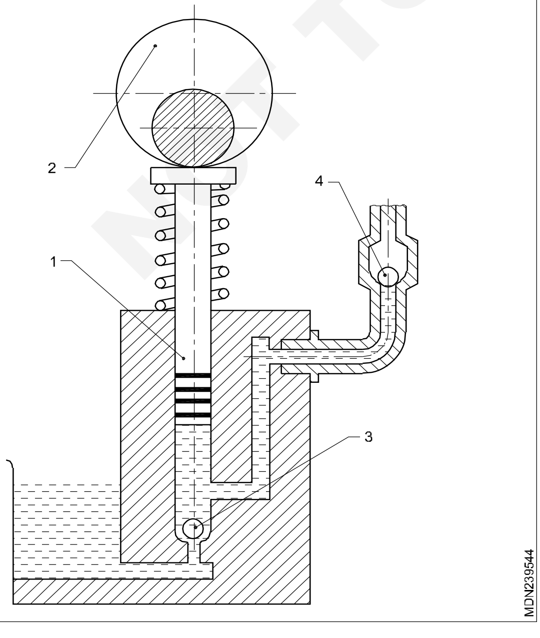
3 **Vane pump (Fig 3):** In the vane type pump the rotor (1) runs eccentrically in the pump housing (5). Spring-loaded vanes (2) slide against the pump housing walls. Suction us created by the vanes (2) when the rotor (1) rotates. Oil is sucked through the inlet duct (3) and discharged through the discharge duct (4).

Fig 3



4 **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



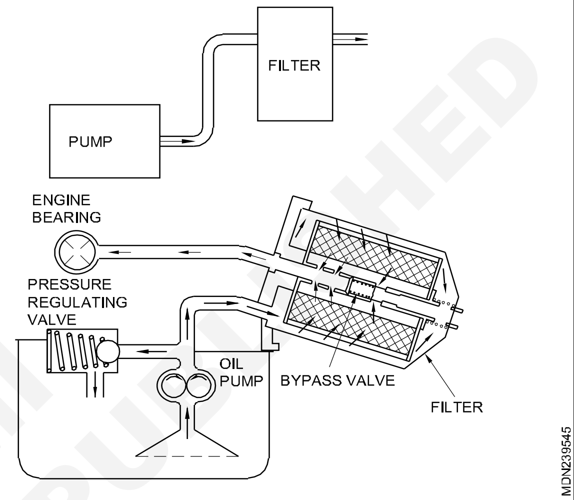
During the upward stroke the oil is sucked through the valve (3). During the downward stroke the non-return valve (3) closes. The other non-return valve (4) which is on the delivery side opens and permits the oil to flow out from the pump. This type of plunger pump is used in medium and high pressure 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 direct if the filter is choked.

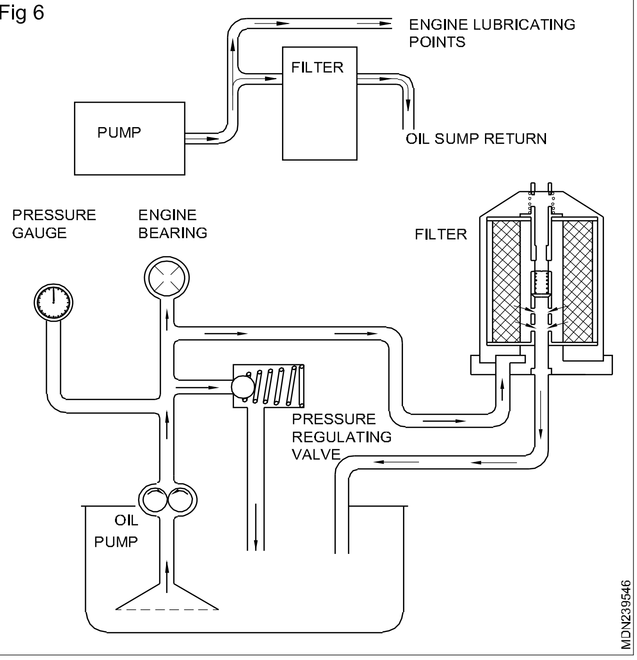
Fig 5



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

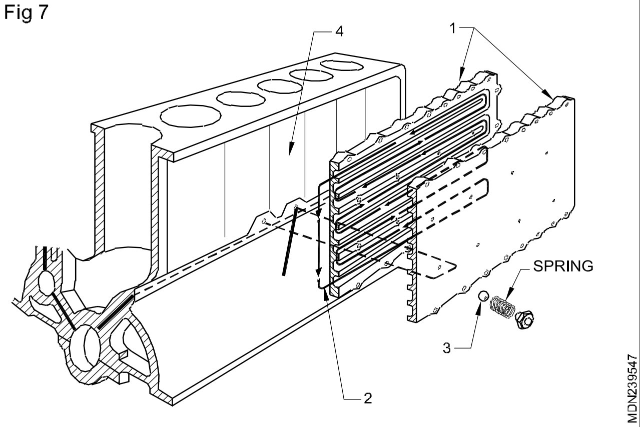


Filter element: Filter elements are made of felt, cotton waste, cloth and paper. Oil filters are replaced after certain kilometres of running of the engine as specified by the manufacturer.

Oil coolers (Fig 7): 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.

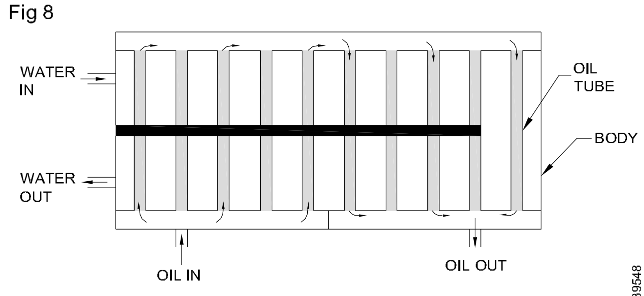
Fig 7



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



OIL COOLER

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 main gallery

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 gallery. Further the pressurised oil goes through different size of spurt holes to main bearing camshaft bearing cranks pin, rocker arm and valves, main gallery 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 dispersants
- 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 SAE 30 Some manufacturers	SAE 20W-30 or SAE10W-30
Above 90° F	SAE 30 SAE 30 Some manufacturers	SAE 20W-30 or SAE 10W -30

Description of diesel 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**

Diesel 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 valve 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

Diesel 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 charger's turbine unit. The flow of exhaust gases is as follows.

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.

Superchargers: A supercharger is a device which increase the pressure of the air fuel mixture from the carburetor before it enters the engine. It is connected between the carburetor 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:

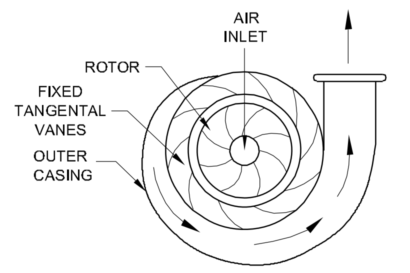
1 Centrifugal type

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.

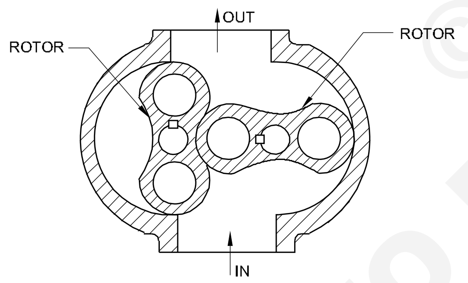
Fig 1



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

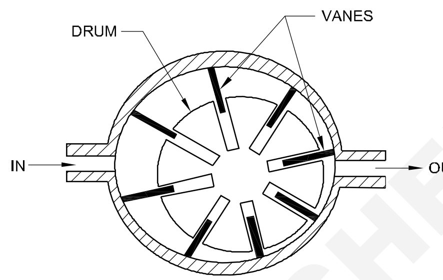
Vane type supercharger (Fig 3): It consists of a drum on which a number of vanes are mounted in such a manner that they can slide in or out against some spring force, so that all the times they are in contact with the inner surface of the supercharger body.

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.

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.

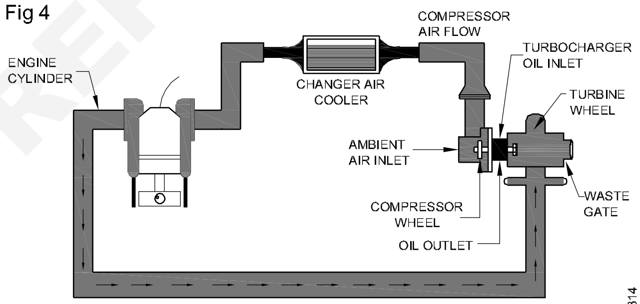
Fig 3



VANE TYPE SUPERCHARGER

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.

Fig 4



INTERCOOLER

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.

Turbo charger

Objectives: At the end of this lesson you shall be able to
- **explain constructional features of a turbo charger**
- **explain operation of turbo charger**
- **explain types of turbo charger.**

Turbo charger (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.

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 1

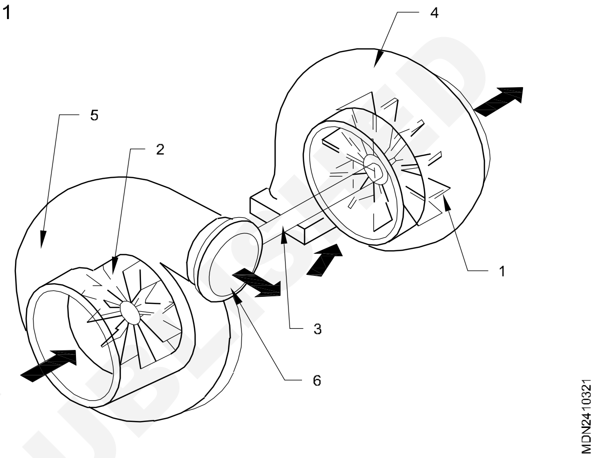
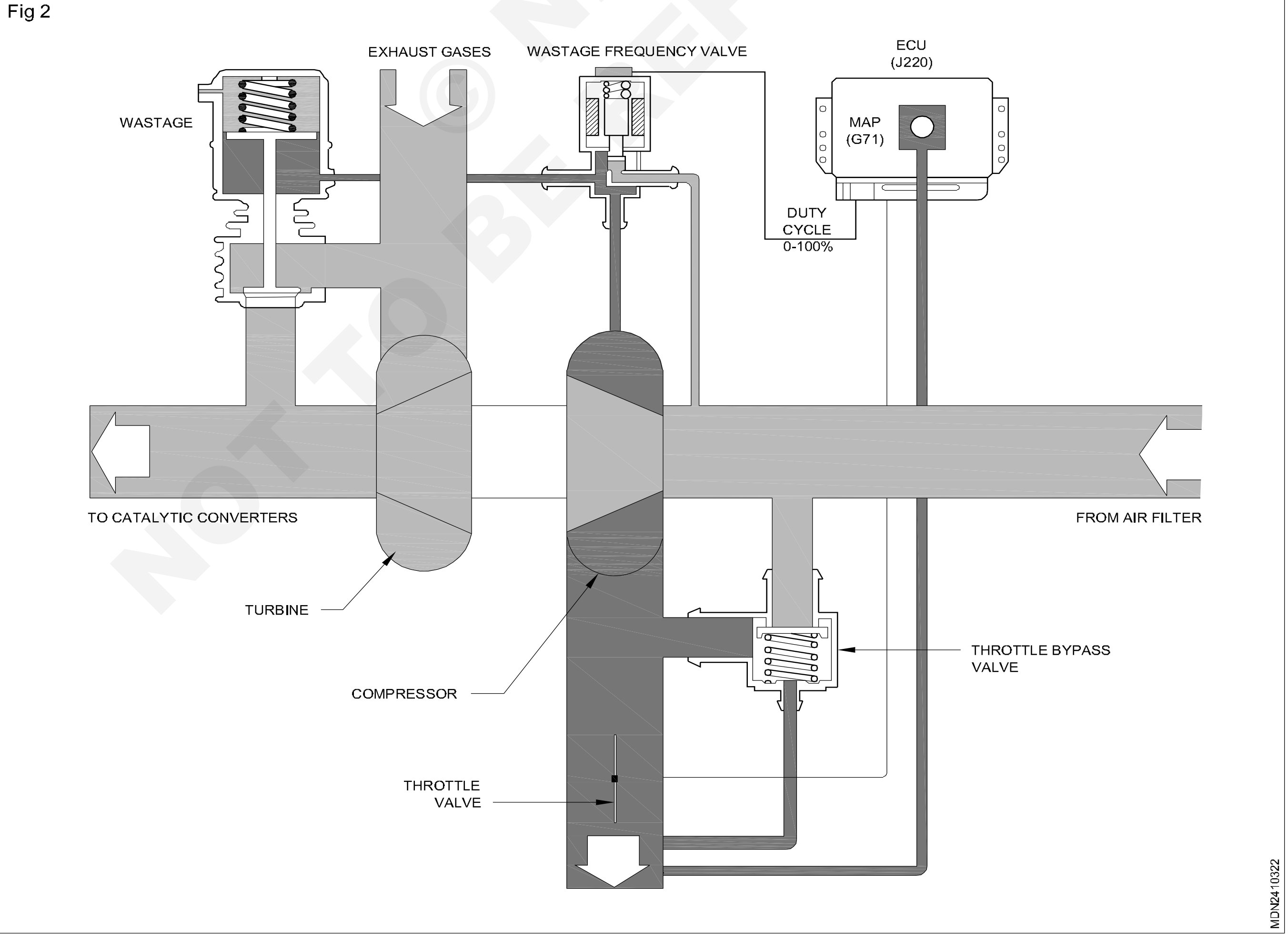


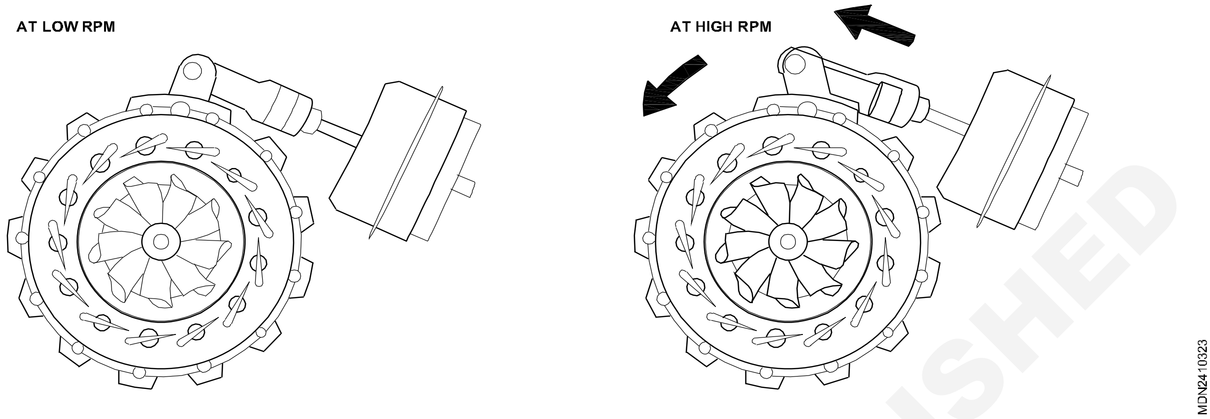
Fig 2



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

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 intake 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

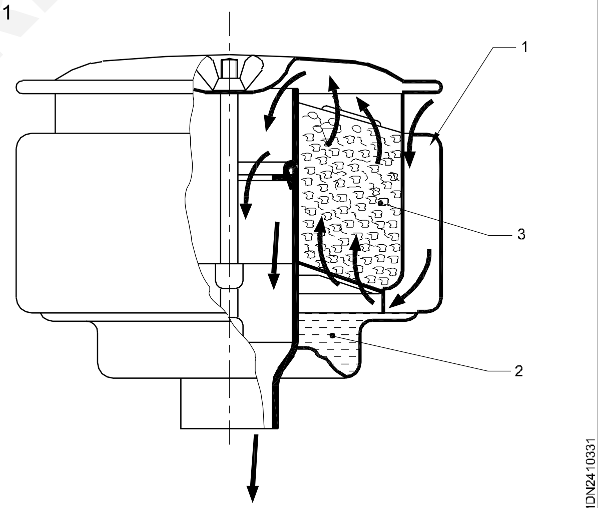
- Wet-type (Fig 1)
- Dry-type (Fig 2 & 3)

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.

Dry type air cleaner: In this type of air cleaner, a specially treated paper element is used to filter the intake air.

Fig 1



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 2

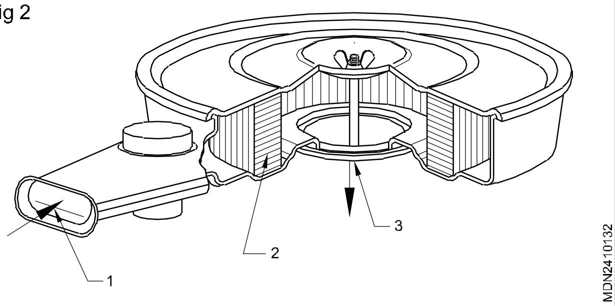
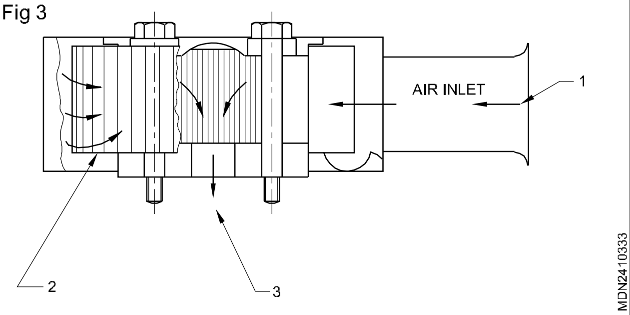


Fig 3



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 carburetor to the intake ports in the cylinder head. The inlet manifold is generally made of aluminium 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.

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 1

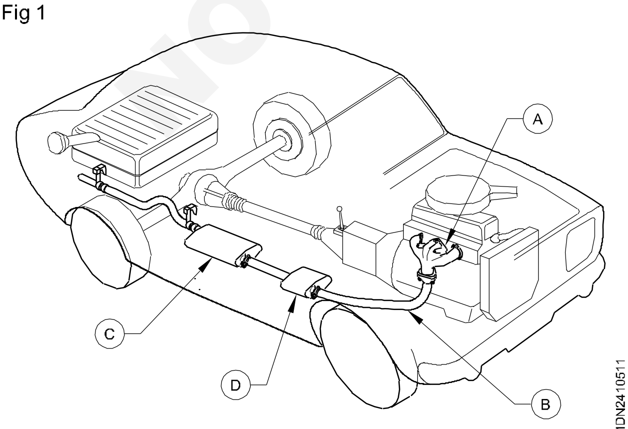
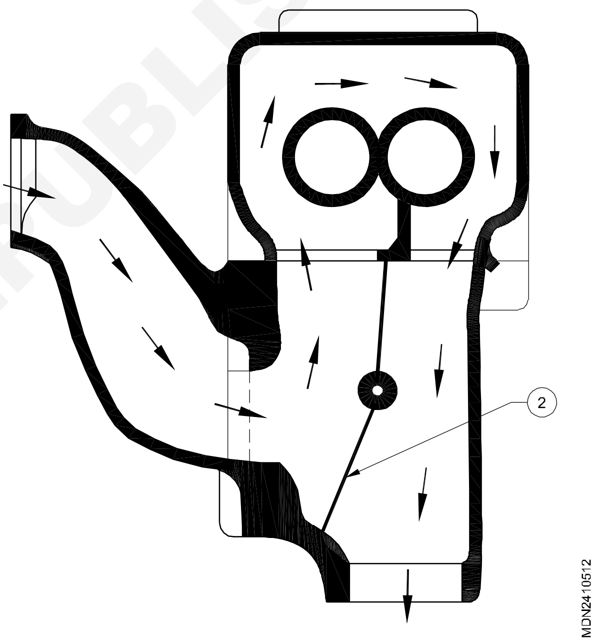


Fig 2



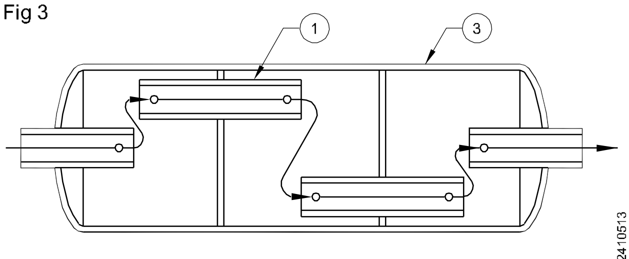
Muffler

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.

Fig 3

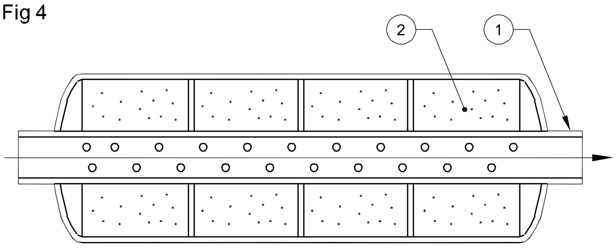


REVERSE-FLOW MUFFLER

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.

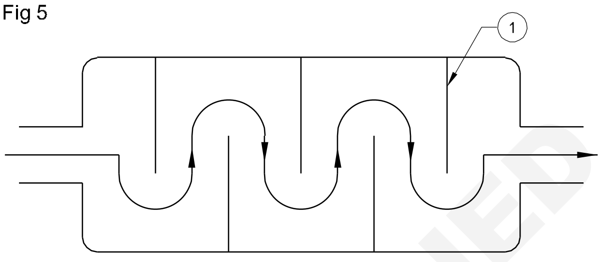
iii **Baffle type:** In this type, a series of baffles (1) (Fig 5) are placed in the muffler which causes restriction and back pressure to the exhaust gases, thereby reducing the sound of the exhaust gases.

Fig 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

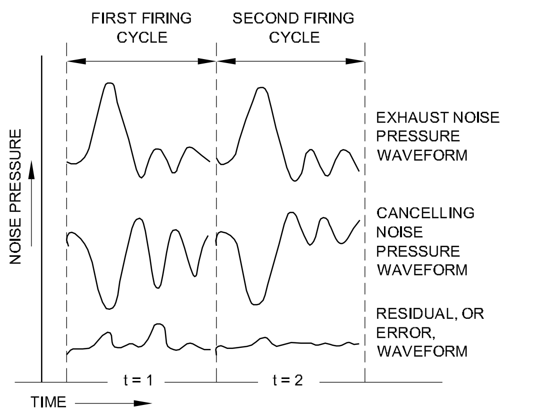
When a variable flow exhaust is added to the baffle and chamber system, quieter noise emissions are the result. This is because the system can partially respond to changes in engine speed and load.

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.

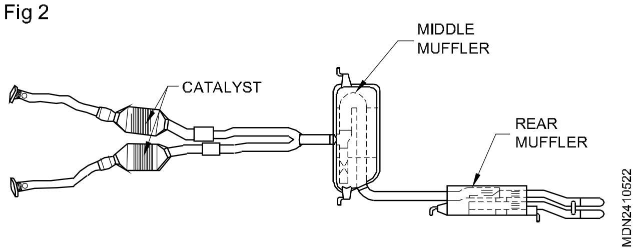
Sensors and microphones pick up the pattern of the pressure waves an engine emits from its exhaust pipe (Fig 1 & 2). This data is analyzed by a computer. A mirror-image pattern of pulses is instantly produced and sent to speakers mounted near the exhaust outlet. Opposite waves are created that cancel out the noise.

Fig 1



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 2



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 cyle.

Advatagees 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 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 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 dissipate 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 last for upto 5 years.

Ceramic coatings contain the gaseous heat with in exhaust pipes. The 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.**

In the diesel engine, atomised diesel is injected into the cylinder at the end of compression stroke.

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 diesel fuel injection should be fully atomised into fine particles for it spreads one immediately in the combustion chamber to mix up the with hot compressed air for high combustion. The fule injection should take place at the correct time, according firing order of the engine.

Fuel system must fulfill the following requirement

- Time the fuel injection and distribute the fule properly in the combustion chamber.
- Measure the correct quantity of fuel injected.
- Control the rate of fuel injection.
- Fully atmomize 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.

The most common fuel used in engines are diesel and petrol.

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 drivetrain 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.

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.

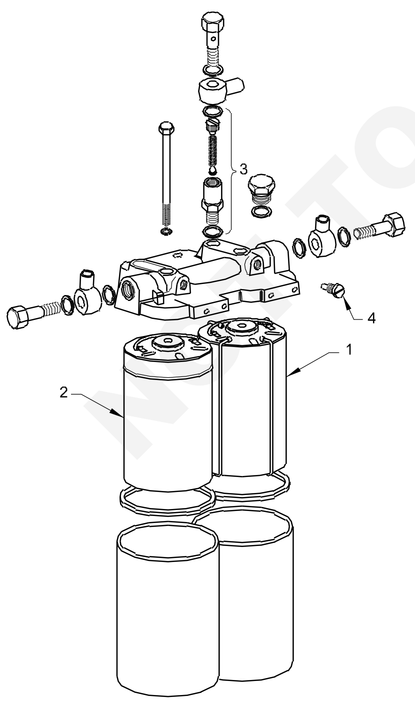
1 Single filter system

2 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 (Fig 1), primary filter (1) is used for filtering large solid contaminants and most of the water in the fuel is also removed by this filter.

Fig 1



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 neighboring 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: 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 separator is device that works to ensure clean fuel is delivered to the engine.

The fuel water separator 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 great 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 lubricate 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)

Fuel water separate filter provide a better way to filter fuel and it have twist fuel filter water separating system.

- Filter
- Water collection bowl
- Water drain valve with WIF sensor or threaded part

Benefits

- Protect the engine components
- Extend the equipment life

Features

It is easy to switch over water from fuel

- Water separating fuel filter with standard twist & drain.
- Water collection bowel for easy usual 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 & 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

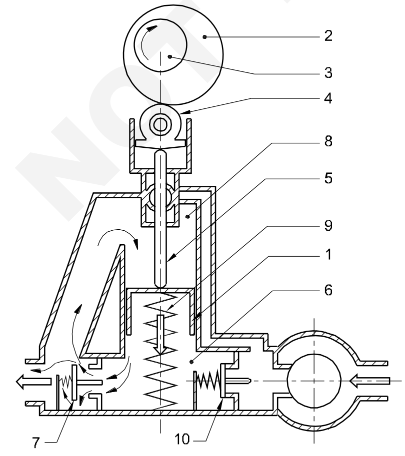
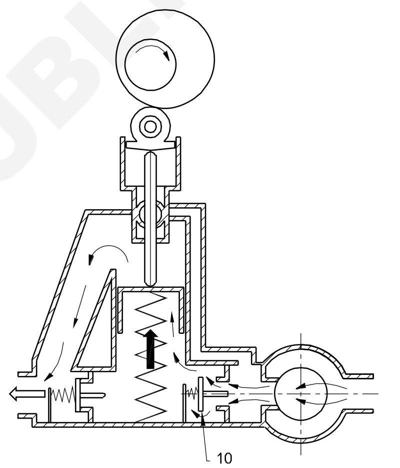


Fig 2



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.

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**
- **explain specifications shown on F.I.P plate.**

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;

1 Inline pump

2 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 inline type F.I.P

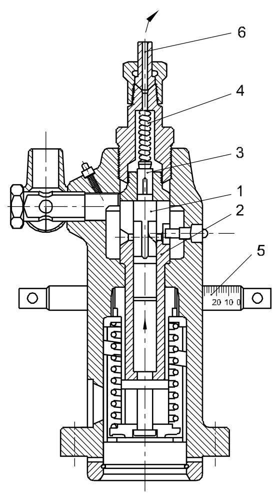
When the plunger (1) (Fig 1) is at its bottom position fuel enters through the barrel's (2) inlet port from the feed pump, fills the space above the plunger in the barrel and excess fuel flows out through the spill port. In a primed system, the barrel(2), all the pipes and the entire system is filled 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.

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.

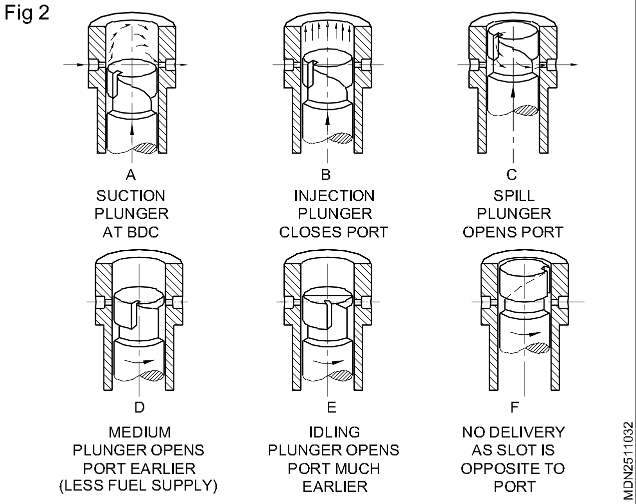
This causes a drop in pressure and delivery valve closes under its springs (4) pressure. With the consequent drop in the fuel line the injector valve also closes and cuts off the fuel injection.

Fig 1



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. (As shown in Fig 2) The rotation of the plunger is obtained by operating the control rack (5), which is in turn connected to the governor.

Fig 2



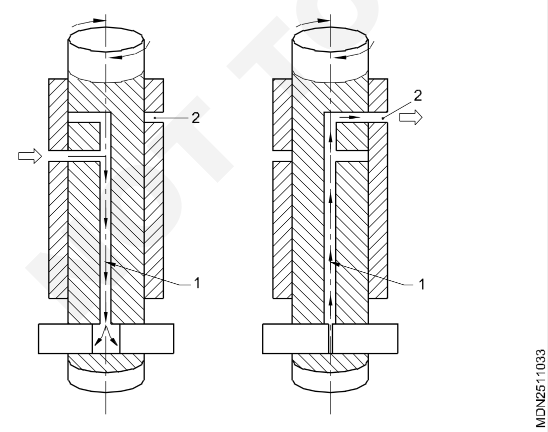
The governor controls all engine speeds upto a maximum, according to pedal pressed by driver. Different positions of the plunger and the fuel flow is given in the figure.

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

2 Mechanical injection

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.

Mechanical injection: In mechanical fuel injection system, fuel is forced in from a mechanical fuel injection pump through injectors. These are of two types;

1 Low pressure fuel supply system

2 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

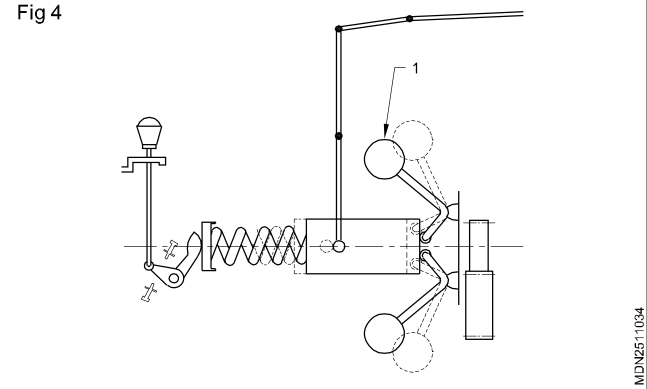
The governor is a device for holding any speed steady between idling and maximum speed. The fuel injection pump operates in conjunction with a governor, which is required to control the injected quantity of fuel so that the engine neither stalls when idling nor exceeds the maximum speed for which it is designed.

Following Types of Governors are used

- Mechanical
- Pneumatic
- Servo
- Hydraulic

Mechanical Governor: Mechanical governors have speed measuring mechanism & 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

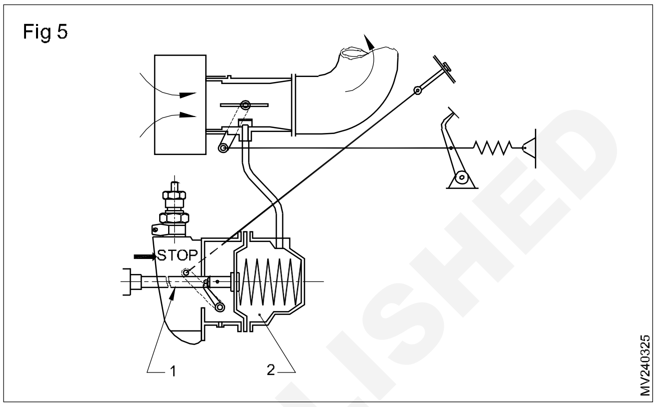


Pneumatic Governor: In this type of governors the fuel control rack (1) (Fig 5) is actuated by joint effort of the atmospheric pressure, governor spring and allow pressure chamber (2) connected through a tube to the auxiliary venture.

Servo Governor: In servo 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.

Hydraulic Governor: In this type of governors the speed sensing is solely through hydraulics and fuel metering is through a combination of hydraulics and mechanical arrangements.

Fig 5



Fuel injectors and nozzles

Objectives: At the end of this lesson you shall be able to
- **explain function of injectors**
- **list out different types of injectors**
- **explain special features of various types of nozzles**
- **explain specification of nozzle and nozzle holder.**
- **explain cummins & detroit diesel injection**
- **state the function of glow plug.**

Fuel Injectors (Fig 1): The function of the fuel injector is to deliver finely atomized fuel under high pressure to the combustion chamber for the engine. All component parts of the injector are carried in nozzle holder(10.) The main part of the injector is the nozzle comprising nozzle body (12) and nozzle valve (11) The nozzle body and needle valve are fabricated from alloy steel. They are thoroughly machined and have high surface harness necessary for operation in condition of high temperatures and elevated pressures.

The bore in the nozzle body and the nozzle needle valve are lapped to a close tolerance and are a matched set, so that neither the nozzle body nor the needle valve may be replaced individually. The needle valve is pressed against a conical seat in the nozzle body by spring (4) acting through the intermediary of stem 8. The spring pressure, hence injection pressure, is adjusted by adjusting screw (2). The adjusting screw is screwed in the bottom of the injector spring cap nut which in turn is screwed in the nozzle holder. Lock nut (3) is used to prevent the adjusting screw from unscrewing spontaneously.

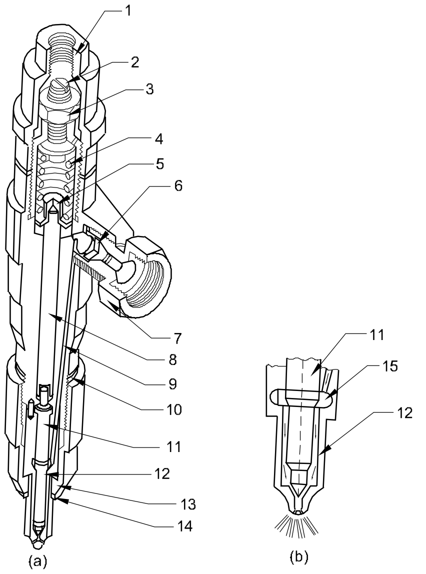
The screw is covered by nozzle holder cap nut (1) provided with a threaded hole to connect the leak-off pipe through which the leak-off fuel (used to lubricate the nozzle valve) filling the pressure spring and adjusting screw area is returned to the fuel tank or the secondary fuel filter.

In operation, fuel from the injection pump enters pressure chamber (gallery) (15) in the nozzle body through supply passage (9) and a high-pressure pipe. When the fuel pressure in the pressure chamber becomes so high that the force acting on the pressure taper of the needle valve from below exceeds the set spring force on the stem, the needle valve lifts off its seat and comes to rest with its upper shoulder against the face of the nozzle holder. Fuel is then forced out of the nozzle spray holes into the combustion chamber in a spray pattern which depends on the type of nozzle used.

After the injection of fuel has been ended, the fuel delivery from the injection pump ceases, the pressure in pressure chamber 15 of the nozzle drops instantly, and the pressure spring snaps the needle valve onto its seat, preventing unpressurized fuel from leaving the nozzle.

The fuel injector is installed in a brass injector tube, or sleeve, which is fitted in a hole in the cylinder head, and is held in place by a special clamp. Injectors are provided to atomise the fuel into engine cylinder. This is done to achieve complete combustion.

Fig 1



(a) Construction :
(b) Illustrating the operation of the injector :
1-Cap nut.
2-Adjusting screw.
3-Lock nut.
4-Spring.
5-Spring nut
6-Screen filter.
7-Inlet fitting.
8-Spindle.
9-Fuel passage.
10-Nozzle holder.
11-Nozzle needle valve.
12-Nozzle body.
13-Nozzle cap nut.
14-Washer.
15-Nozzle pressure chamber (gallery)

FUEL INJECTOR

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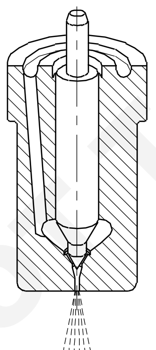
Types of nozzles are used in engine

Single hole type (Fig 2)

In this type, one hole is drilled centrally or in an angle through its body which is closed by nozzle valve.

Fig 2



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Multi hole type (Fig 3)

In this type varying number of holes are drilled at the end of the body. The actual number of holes depend upon the engine requirement.

Longstem type (Fig 4)

For providing adequate cooling for the standard short stem nozzle, a different type of nozzle with a small diameter extension has been developed. This is called long stem nozzle.

Fig 3

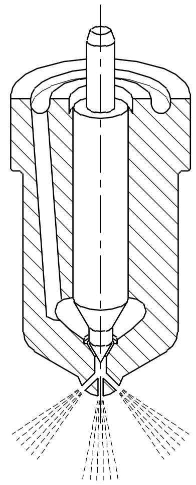

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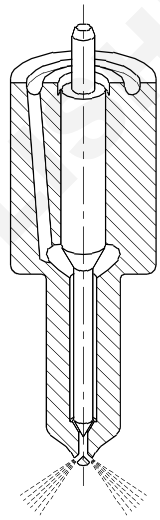
Fig 4



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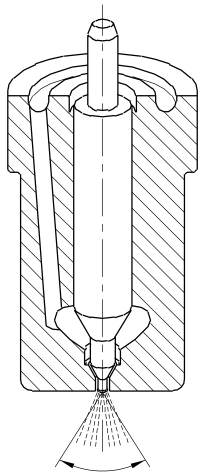
Pintle type (Fig 5): In this type the valve stem is extended to form a pin or pintle which protrudes through the month of the nozzle body.

Fig 5



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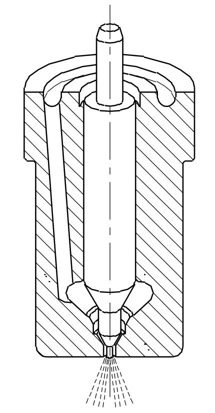
Delay nozzle (Fig 6): In this type spray pattern is controlled by the modification in pintle design. This will reduce the amount of fuel in combustion chamber, when the combustion begins. This modified nozzle is known as delay nozzle.

Fig 6

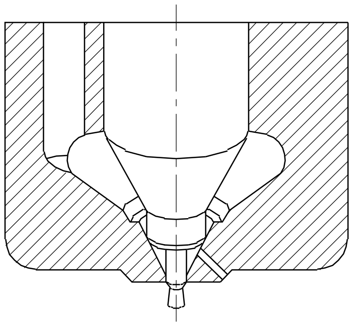


DELAY

Pintaux nozzle (Fig 7)

This is the further development of pintle type nozzle, having an auxiliary spray hole to assist easy starting under cold condition.

Fig 7



Need of a glow plug

A heater plug or glow plug is used in a Diesel engine having a pre-combustion chamber for igniting the diesel fuel spray. This arrangement makes for an easy starting of a diesel engine in cold weather. Most diesel engines use heater plugs. Figure 8 shows parts of a heater or glow plug.

Description of a glow plug (Fig 8)

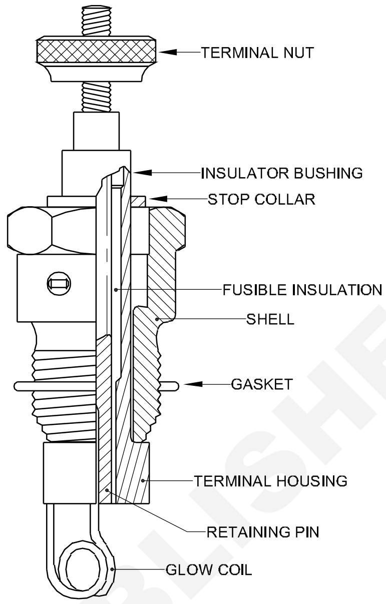
The glow plug consists of a heating element (glowing coil) and is provided with an insulator shell and other parts. One such glow plug is shown in Fig 8. In a multi-cylinder engine the number of glow plugs depends on the number of cylinders. They are connected in series (Fig 9), parallel with the battery, through a glow plug switch, (control switch) a resistor and a red indicator light and they are provided on the dashboard (panel) of the vehicle. The glow control switch is a three-way one, connecting to the starter also for starting purposes. The glow control switch serves to connect and disconnect the battery with the glow plug as and when required. The red indicator light indicates to the driver, the working of the glow plug or its failure.

Working of the circuit (Fig 9)

When the switch is closed, the heating element becomes very hot due to the passage of current from the battery, and the surrounding air is heated up. When the engine is cranked heated air is drawn into the cylinder giving the compressed air a higher temperature for ignition.

The fuel particles, which happen to be very near the hot air, will be ignited directly, thus initiating combustion. After combustion begins, the burning air-fuel mixture comes out of the pre-combustion chamber and enters into the main chamber. There it gets mixed up with the combustion chamber air and thus combustion is completed.

Fig 8



CONSTRUCTION OF THE DUAL - POLE GLOW PLUG

Precautions

- After the engine is started the glow plug is to be cut off from the circuit. Otherwise the glow coil will be heated up additionally and gets burnt up eventually, resulting in the replacement of the glow plug.
- The glow plug switch should not be operated for more than three seconds.
- The glow coil is having low electrical resistance and hence it will be very hot when connected to the circuit. Do not touch it, when it is hot.

Detroit diesel cummins diesel

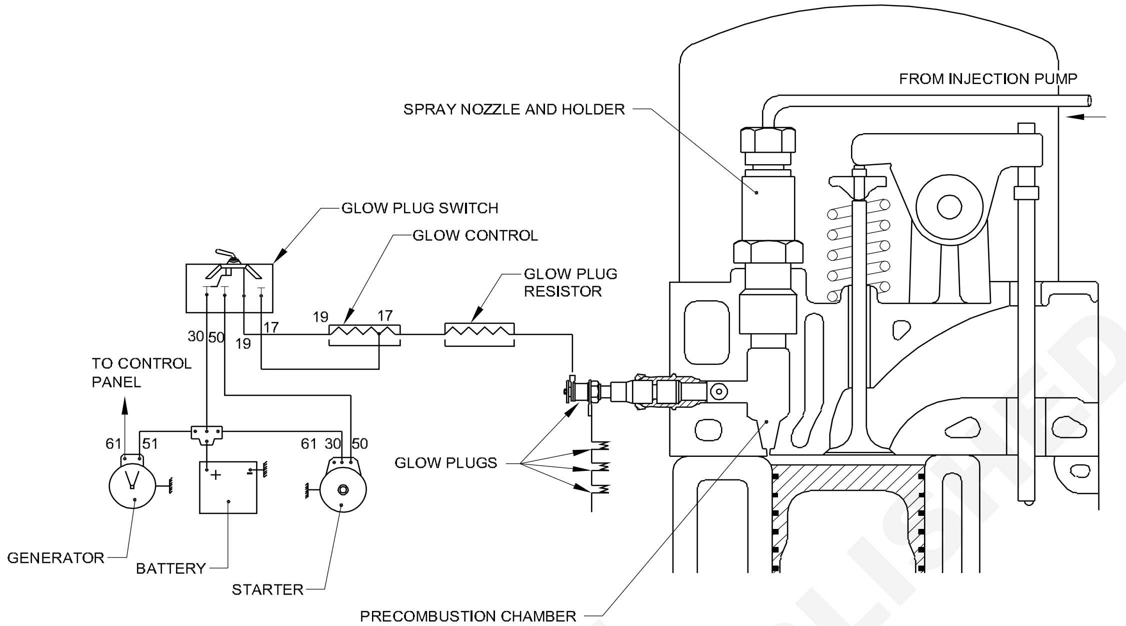
Detroit diesel cummins diesel well known for favouring unit injectors, in which the high-pressure pump is contained within the injector itself. This leads to the development of the modern unit injector.

Cummins PT (pressure-time) is a form of unit injection where the fuel injectors are on a common rail feed by a low-pressure pump and the injectors are actuated by a third lobe on the camshaft. The pressure determines how much fuel the injectors get and the cam determines the time.

Design of the unit injector eliminates the need for high-pressure fuel pipes, and with that their associated failures, as well as allowing for much higher injection pressure to occur. The unit injector system allows accurate injection timing, and amount control as in the common rail system.

The unit injector fitted into the engine cylinder head, where the fuel supplied via integral ducts machined directly into the cylinder head. Each injector has its own pumping element, and in the case of electronic control, a fuel solenoid valve as well. The fuel system is divided into the low pressure <5 bar fuel supply system, and the high-pressure injection system <2000 bar.

Fig 9



IGNITION CIRCUIT DIAGRAM OF GLOW PLUG SYSTEM IN A DIESEL ENGINE

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Electronic Diesel Control (EDC) System

Objective: At the end of this lesson you shall be able to
- **state the function of electronic diesel control device.**

EDC system

Electronic diesel control (Fig 1 & 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.

The electronic control, the system which provides greater abillity for precise measuring, data processing environment flexibility and analysis to ensure efficient diesel engine operation.

Fig 1

ELECTRONIC DIESEL CONTROL DEVICE

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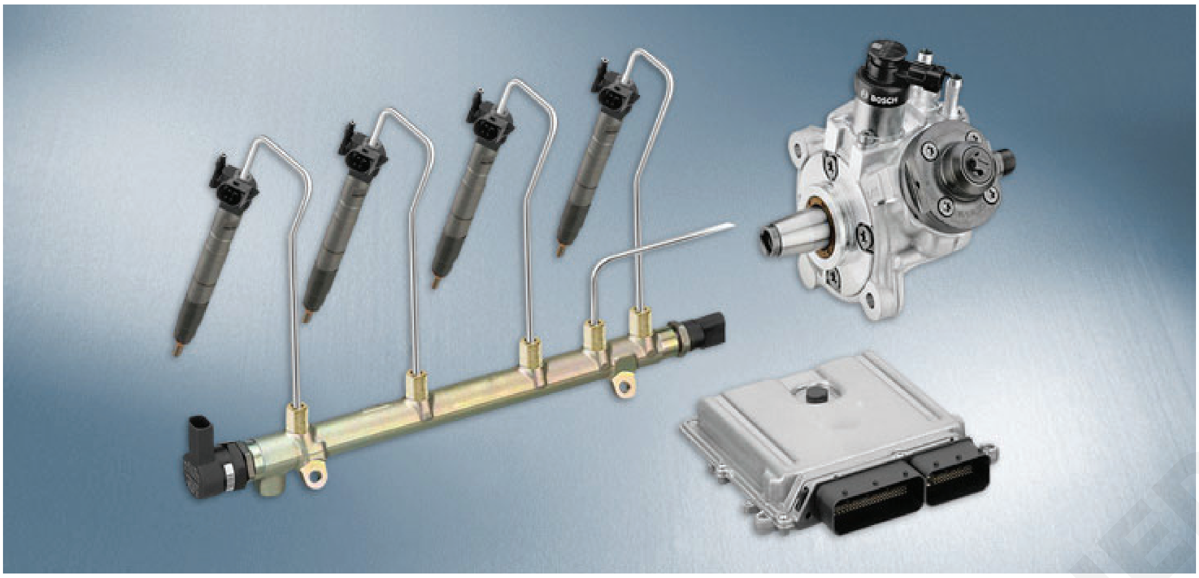
- It receives the information from sensor, analyze/ calculate it and sends the instructions to the actuators.
- It converts information from analog to digital.
- It consists of microprocessors to process the information from sensor to ECM and ECM to actuators.
- Number of microprocessors are depends 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.

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.

Fig 2



COMMON RAIL WITH FUEL INJECTORS

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Working

It gets the input from the different sensors named are as follows.

1 Throttle position **TP** (intake air quantity)

2 Cam position **CMP** (for valve timing)

3 Crank positon **CKP** (for RPM and firing order)

4 Engine coolant temperature **ECT** (Cylinder temperature)

5 Inlet air temperature **IAT** (temperature of inlet air)

6 Manifold absolute pressure **MAP** (inlet air pressure)

7 Oxygen **O2** (percentage of oxygen in exhaust gas)

After recieving 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.

Note

- **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.

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 sensor G31
Fuel temperature sensor
Fuel pressure sensor
Exhaust gas recirculation potentiometer
Lambda probe
Exhaust pressure sensor
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 Electronic Control Module (or) system (E.C.M)**
- **state the various control devices**
- **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 (Fig 1 & 2)

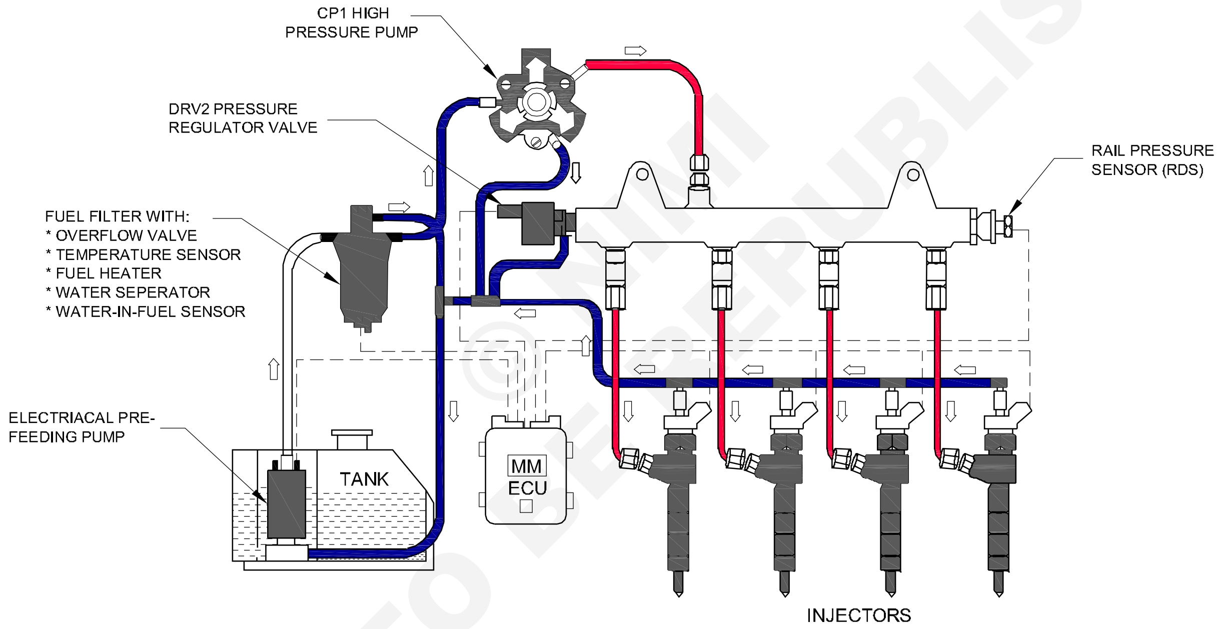
The common rail consists of fuel tank, electrical fuel pump (low pressure) is placed inside the fuel tank, It develops pressure upto 6 bar and supplies to the high pressure fuel pump (CRDI) through fuel filter and water separator.

The high pressure fuel pump develops pressure 200 to 2000 bar and supplies to the common rail and common rail to fuel injectors. The injectors inject fuel into the combustion chamber. Fuel injectors are operated 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 ($\leq$ 1 bar pressure) Common rail pressure sensor will give the information to ECM /EDC the existing pressure in the common rail. Then 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.

Diesel Direct injection system (Fig 1)

Fig 1



DDIS -- FUEL SYSTEM LAYOUT

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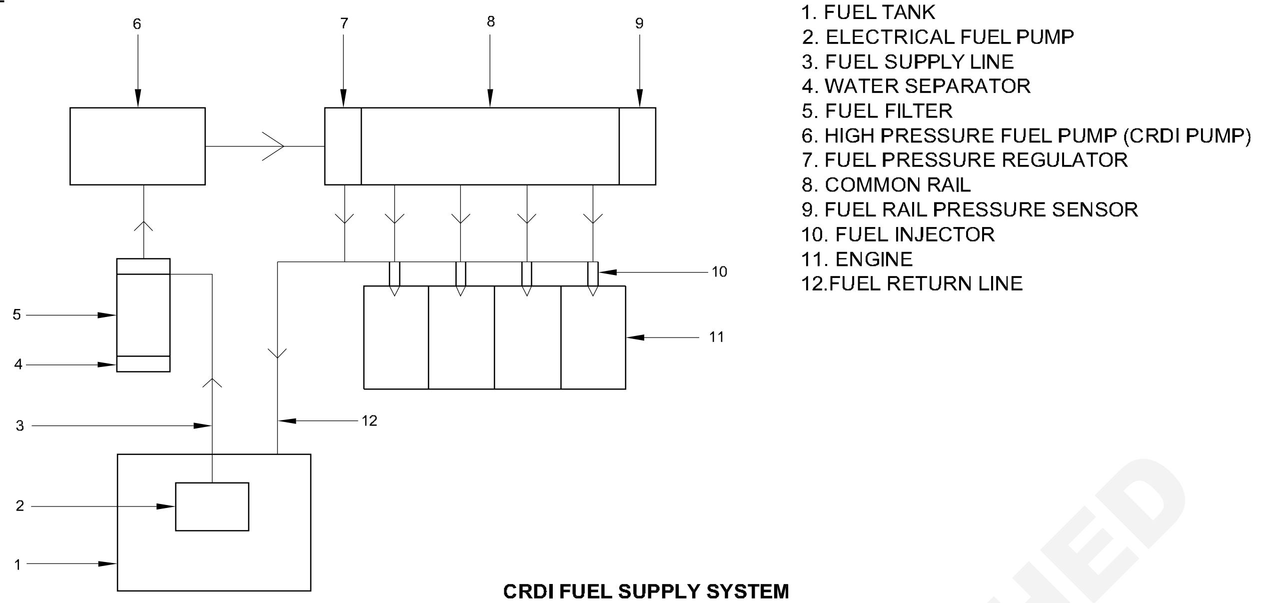
Fig 2



CRDI FUEL SUPPLY SYSTEM

Hydraulically Actuated Electronically Controlled Unit Injector (HEUI)

Objectives: At the end of this lesson you shall be able to
- **describe the HEUI (Hydraulically Actuated Electronically Controlled Unit Injector)**
- **explain basic components**
- **explain its working principle**
- **advantages of HEUI.**

HEUI (Hydraulically Actuated Electronically Controlled Unit Injector)

HEUI Fuel System represents one of the most significant innovations in diesel engine technology in the diesel technology. HEUI made easy of many limitations of mechanical and conventional electronic injectors, and sets new standards for fuel efficiency, reliability and emission control. The highly sophisticated HUEI system uses hydraulic energy instead of mechanical energy to operate fuel injectors. Working along with the engine's ECM (Electronic Control Module), the HEUI system provides extremely accurate control of fuel metering and timing, so that it ensures unmatched engine performance and economy.

In the traditional common rail fuel system, the entire fuel line is under high pressure. With the HEUI system, fuel remains at low pressure until it is injected into the cylinder. Fuel pressure is created hydraulically in response to a signal from the Electronic Control Module (ECM).

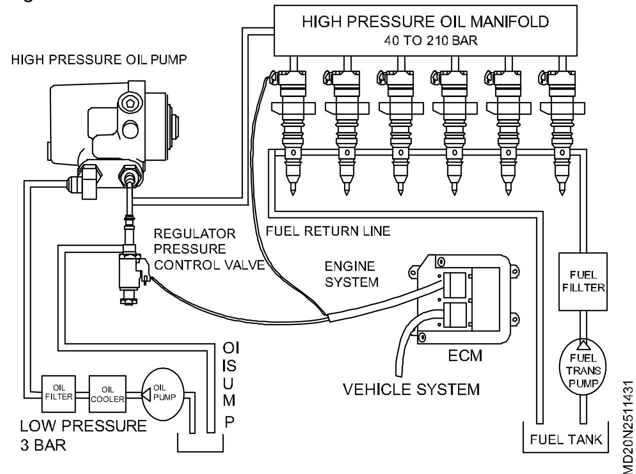
The HEUI fuel system consists of four basic components: HEUI (Fig 1) Injector Uses hydraulic energy (as opposed to mechanical energy from the engine camshaft) from pressurized engine lube oil for injection. The pressure of the incoming oil (800 to 3300 psi) controls the rate of injection, while the amount of fuel injected is determined by the ECM.

Electronic Control Module (ECM): This sophisticated on-board computer precisely manages fuel injection and other engine systems. The HEUI injector solenoid is energized by an electronic signal generated in the ECM. Using input from multiple sensors, the ECM's dual microprocessors use proprietary software and customer supplied performance parameters to produce maximum engine performance under any conditions.

High Pressure Oil Pump: The variable displacement axial pump features a built-in reservoir to immediately supply oil at cold starts.

Injector Actuation Pressure Control Valve: This electronically operated valve controls oil pump output and injection pressure.

Fig 1



Working principle

HEUI is divided in two sections. One is low pressure fuel chamber. Another one is high pressure oil chamber, fuel is supplied at low pressure and oil is supplied at high pressure to the respective chamber.

At the time of injections allows the high pressure oil in to the injection body and actuates the intensifier. The intensifier in turn pressurizes the diesel on the other side of it. So that the intensifier pressurizes seven times of the oil pressure and increases the pressure of the diesel. After then the injector lifts the spindle and injects the diesel through the holes of an injector.

Improved fuel economy The ability to inject fuel at any crank angle results in up to 2.7 percent better fuel economy compared to scroll mechanical injectors. Optimum fuel economy also means reduced gaseous emissions and less white smoke during cold engine starts.

Optimum performance The control of fuel delivered during ignition delay and main injection, known as rate shaping, is made possible by the HEUI's ability to operate independent of engine speed. Rate shaping modifies engine heat release characteristics, which also helps reduce emission and noise levels. Rate shaping optimizes engine performance by varying the idle and light load rate characteristics independent of rated and high load conditions.

Reduced smoke and particulate emissions

Since the HEUI injector's performance does not depend on engine speed, it can maintain high injection pressures through a wide operating range. Electronic control of these pressures helps improve emissions and low-speed engine response.

Reduced engine noise A split injection feature leads to a more controlled fuel burn and lower noise levels. Additional benefits include reduced shock loads as well as less wear and tear on drive train components.

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

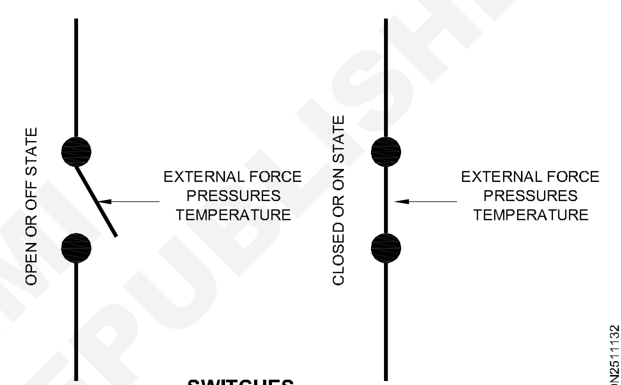
Apart from the above so many other sensors are using in the vehicle. In modern vehicles 10 to 100 plus sensors are using.

Classification & working principle of sensors

- Switches
- Resistive sensor
- Current generating sensor
- Hall effect sensor
- Hot film air mass meter
- Lambda sensor

Switches (Fig 2): 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.

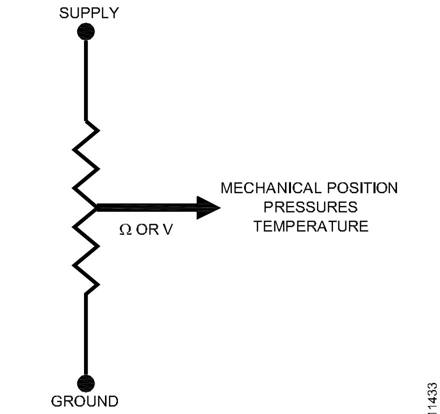
Fig 2



SWITCHES

Resistive sensor (Fig 3): 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.

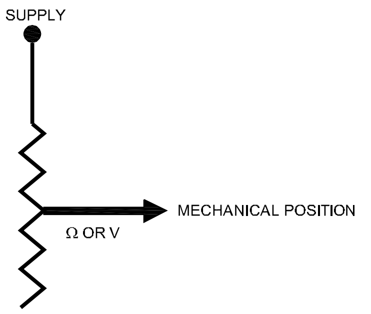
Fig 3



RESISTIVE SENSOR

Rheostat (Fig 4): 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 4

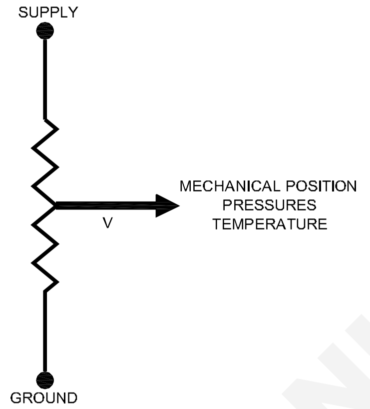


RHEOSTAT

2 Potentiometer (Fig 5)

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 5

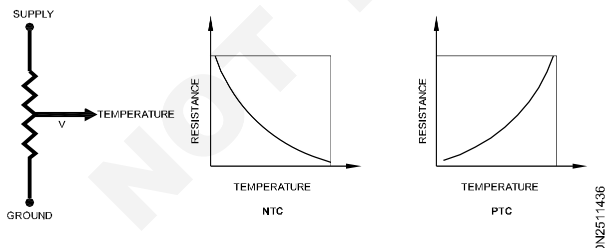


POTENTIOMETER

Thermister (Fig 6)

Thermister are those sensors whose resistance value changes due to change in temperature. Thermister are supplied with constant voltage. Out put voltage changs due to change in resistance which is continuously monitor by control unit to decide the temperature value. Thermister can have either negative temperature co efficient [NTC] or positive temperature co efficient [PTC].

Fig 6

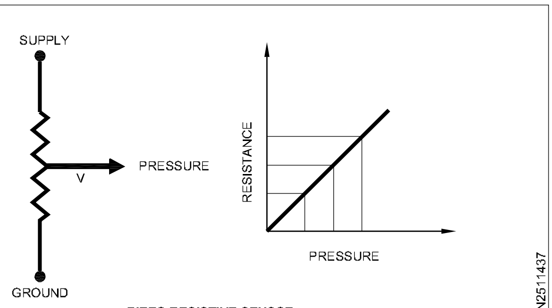


THERMISTER

4 Piezo resistive sensor (Fig 7)

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 7



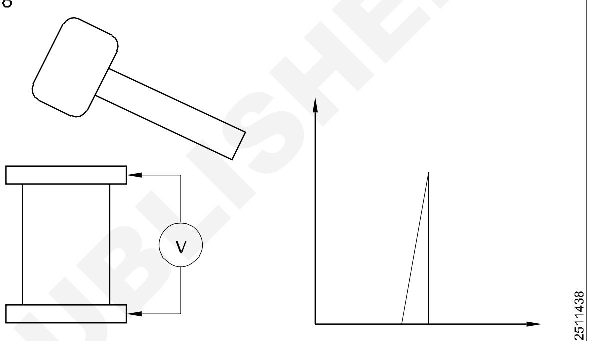
PIEZO RESISTIVE SENSOR

Certain sensors generate the voltage when subjected to change is physical phenomenon such as pressure, position etc. They are mainly classified as follows.

1 Piezo electric sensor (Fig 8)

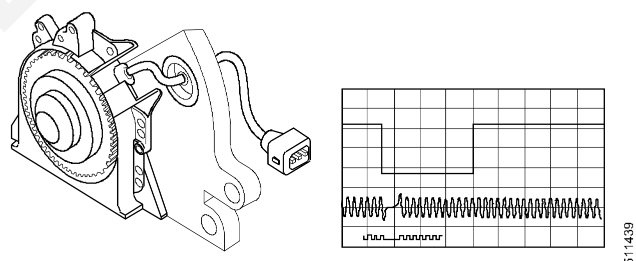
2 Magnetic induction sensor (Fig 9)

Fig 8



PIEZO ELECTRIC SENSOR

Fig 9



MAGNETIC INDUCTIVE SENSOR

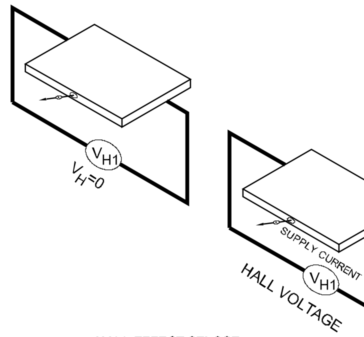
Certain crystal such as quartz when subjected to a pressure generate potential difference on its surface. The phenomenon is reversible.

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.

Hall effect sensor (Fig 10)

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 semiconductor.

Fig 10

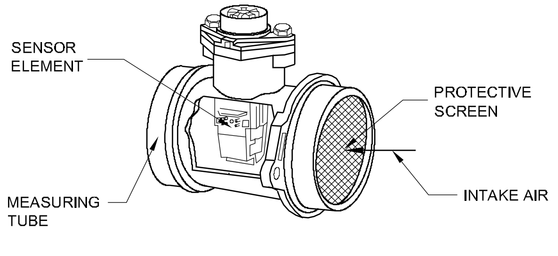


HALL EFFECT SENSOR

Hot film air mass meter (Fig 11)

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 thermister R1 & R2, & intake air temperature sensor.

Fig 11

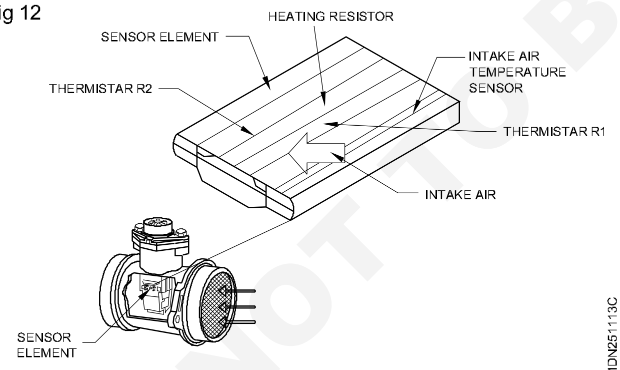


HOT FILM AIR MASS METER

Thermistor (Fig 12)

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 12



Lambda (oxygen) sensor (Fig 13)

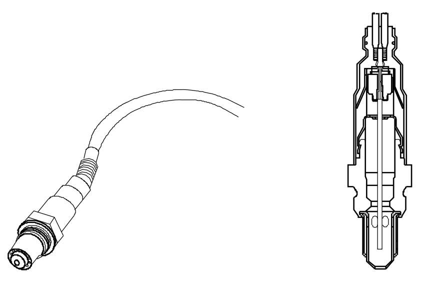
This sensor is normally used in petrol engine to decide the oxygen content in exhaust gas. Based on the input from this sensor the ECU do minor correction to the amount of fuel being metered.

12 Lambda (oxygen) sensor (Fig 14)

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.

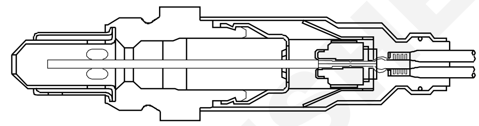
In connection with OBD II, second lambda sensor is connected after catalytic converter. It test correct functioning of the catalytic converter.

Fig 13



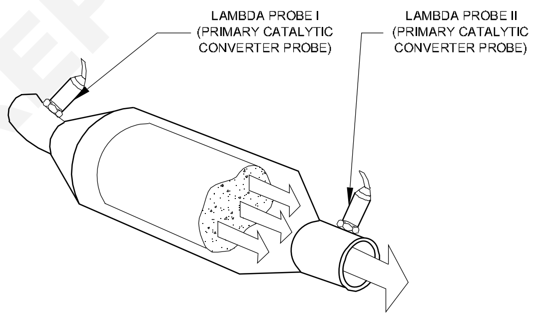
LAMBDA (OXYGEN) SENSOR

Fig 14



LAMBDA (OXYGEN) SENSOR

Fig 15



Actuators

1 Injectors

2 Power windows

3 Wiper motos

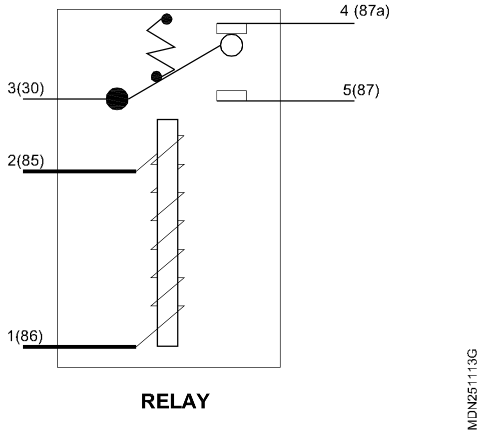
4 Relays etc

Number of actuators depends upon the devices to be operated.

14 Relay (Fig 16)

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.

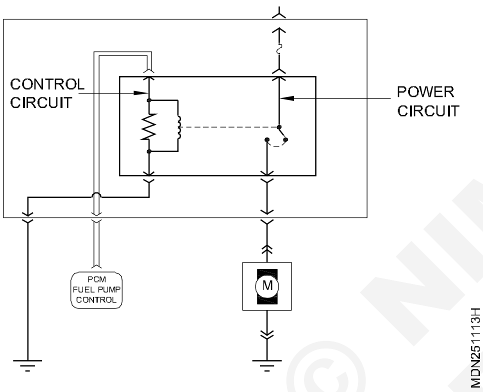
Fig 16



1 **Control circuit:** Control the operation which are activated by control unit or switch. It required very less power to activate. (Fig 17)

2 **Power circuit:** Connected to the load. Main current flows through this circuit. (Fig 17)

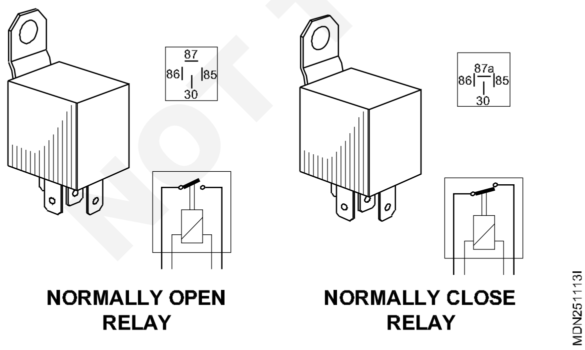
Fig 17



1 **Normally open relay [NO]: (Fig 18)** Power circuit is in open position. Circuit closes when control circuit is activated.

2 **Normally close relay [NC]: (Fig 18)** Power circuit is in close position. Circuit opens when control circuit is activated.

Fig 18



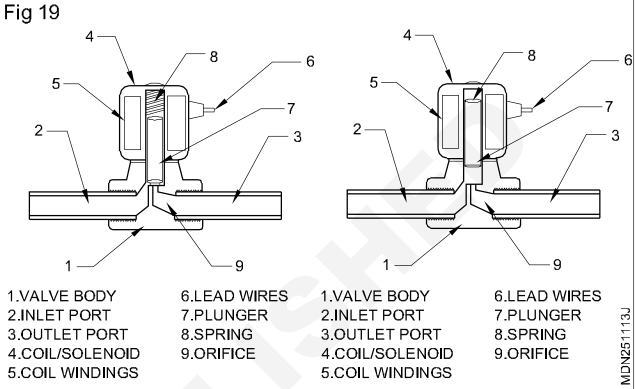
Working principles of acturators

DC Motors

Solenoid (Fig 19)

A solenoid is an electro mechaincal 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 pass through it. This magnetic field affects the state of the solenoid valve, causing the valve to open or close.

Fig 19

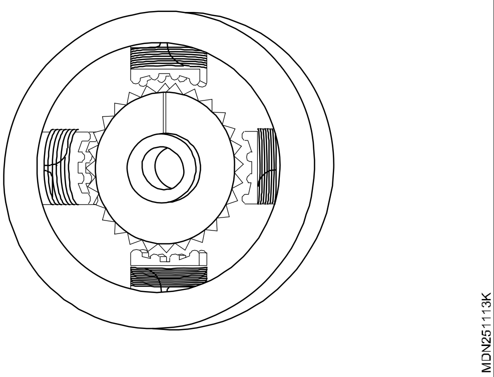


Stepper motor (Fig 20)

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 20



Marine engine

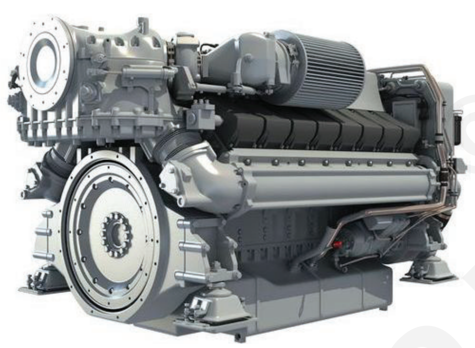
Objectives: At the end of this lesson you shall be able to
- **explain double acting engine**
- **explain opposed piston engine**
- **state the starting system**

Marine engine (Fig 1)

Marine automobile engines are types of automobile petrol or diesel engines that have been specifically modified for use in the marine environment. The differences include changes made for the operating in a marine environment, safety, performance, and for regulatory requirements. The act of modifying is called 'marinisation'.

Marine automobile engines are water-cooled; drawing raw water in from a pickup underneath the boat. In an open cooling configuration, the raw water is circulated directly through the engine and exits after passing through jackets around the exhaust manifolds. In a closed cooling configuration anti-freeze circulates through the engine and raw water is pumped into a heat exchanger. In both cases hot water is released into the exhaust system and blown out with the engine exhaust gasses. The transmission oil cooler is also cooled by raw water.

Fig 1



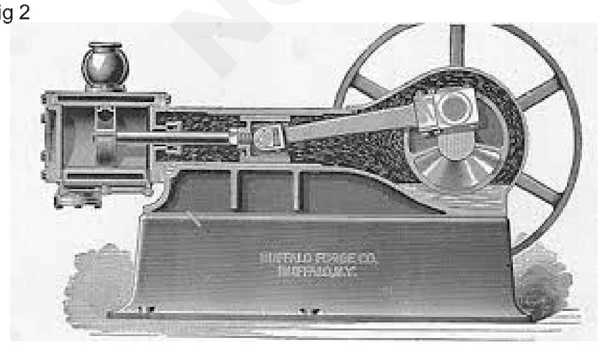
MERINE ENGINE

MDN2611511

Double acting engine (Fig 2)

A double-acting cylinder is a cylinder in which the working fluid acts alternately on both sides of the piston. In order to connect the piston in a double-acting cylinder to an external mechanism, such as a crank shaft, a hole must

Fig 2



TYPICAL HORIZONTAL STEAM ENGINE
WITH DOUBLE-ACTING CYLINDER

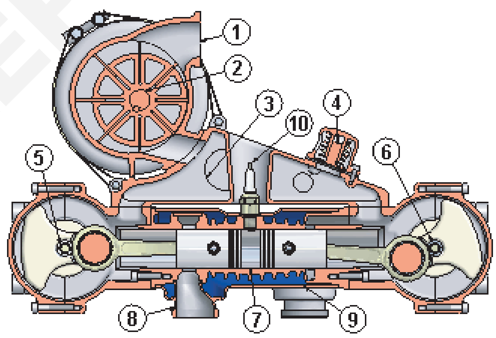
MDN2611512

to provided in one end of the cylinder for the piston rod and this is fitted with a gland or 'stuffing box' to prevent escape of the working fluid. Double-acting cylinders are common in steam engines but unusual in other engine types. Many hydraulic and pneumatic cylinder use them where it is needed to produce a force in both directions. Engine which is fitted to produce a force in both directions. Engine which is fitted with double acting cylinders referred as double acting engine.

Opposed piston engine (Fig 3)

Opposed Piston Engine is a type of diesel engine which has two pistons working in the same cylinder. Technically, opposed piston engine is just a variation in the design of conventional engine. Each of the cylinders of the engine has two pistons, one at each end. The main advantage of opposed piston arrangement over others is that they have a higher power to weight ratio.

Fig 3



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As mentioned earlier, in an opposed piston engine, there are two pistons at both the ends of the cylinder. The cylinders of opposed piston engine are generally longer in size than those of the conventional engines. The arrangement of cranks is also such that both the pistons move towards and away from each other simultaneously. Moreover, the system works on a two stroke cycle and a uniform method of scavenging. In opposed piston engine the combustion chamber is the space left between the two pistons when both are at inner dead centre positions. It is this place between the pistons where in the fuel injection valve, air starting valve pressure relief valve and indicating cocks are fixed.

Most of the opposed piston engines have two crankshafts, one for the upper piston and other for the lower one. Both the crankshafts are arranged as trunk piston engines and through a series of connected gears. However, the earliest opposed piston engines used to have just one crankshaft in their design. Such arrangement would have three cranks, one at the center which is attached to the lower piston with connecting rod and cross-head. The other two cranks are arranged on the same line as that of the center crank and are connected with the top piston with connecting rods, tie rods and crossheads. The exhaust and scavenge ports at the top and bottom of the cylinder, operates because of the reciprocating motion of the piston. Other equipment such as supercharger, air box etc are attached similar to any conventional diesel engine.

The air fuel mixture is pushed into the space in between the pistons. The ignition of the mixture pushes both the pistons downwards, leading to power stroke. The ignition is usually provided using a spark plug. As both the pistons move downwards, one of the pistons opens the outlet valve, which pushes the gas out of the exhaust, whereas the other piston opens the inlet valve, pushing in the fresh gas mixture. The compression stroke then takes place and the cycle repeats itself.

Advantage - Better power to weight ratio

The main advantage of opposed piston engine is that unlike conventional engines, where the stresses generated due to firing loads are transferred from the cylinders to the bedplates of the engine, no stresses are transferred and thus it have an excellent power to weight ratio. Moreover, the arrangement of opposed piston engines provides a higher degree of balance than the conventional engine.

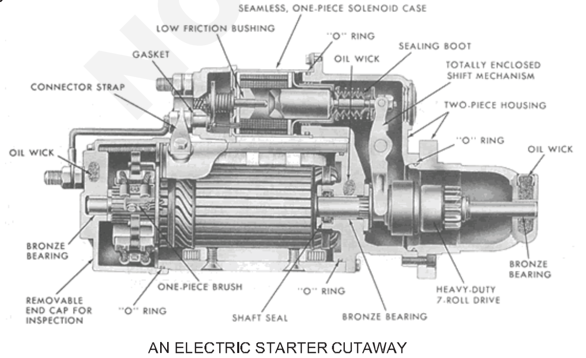
Marine & stationary engine starting system

The purpose of the starting system is to provide the torque needed to achieve the necessary minimum cranking speed. As the starter motor starts to rotate the flu wheel, the crankshaft is turned and starts piston movement. Small diesel engine; does not need to be a great deal of torque generated by a starter. But marine diesel engine need huge amount of torque to requires to cranking speed. The most common type of starting system uses electrical energy, compressed air and hydraulic energy.

Electric starter motor (Fig 4)

An electric starter motor take stored electrical energy from battery and covert it into torque at the starter piston gear. The pinion then engages with fly wheel ring gear and gly wheel rotates the engine crankshaft as Fig 4.

Fig 4



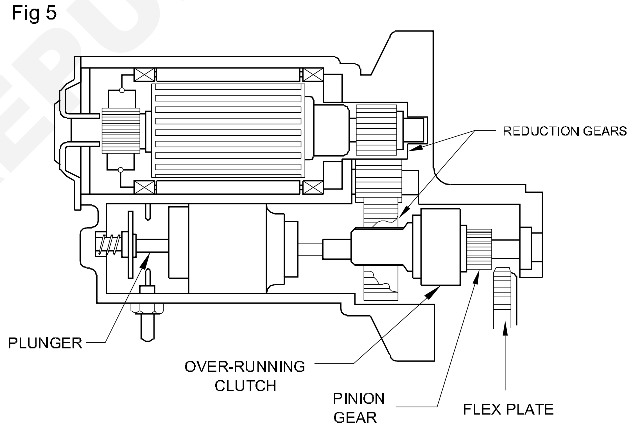
AN ELECTRIC STARTER CUTAWAY

Gear reduction starter motor (Fig 5)

In this starter motor components car nature, brushes, brush holder, field coils, pole shoes desolders are the same as direct drive starter. The arnature shaft have a gear output that will drive an intermediate gear that drive other pension gear.

Electric starting system	Air starting system	Hydraulic starting system
Electric starter motor assembly	Air motor starter assembly	Hydraulic motor starter assembly
Battery cables	Air lines	Hydraulic hoses
Starter relay	Relay valve	Directional control valve
Starter interlock system	Starter interlock system	Starter interlock system
Battery (ies) or capacitor	Air tank	Hydraulic accumulator
Starter switch	Starter switch or valve	Starter switch or valve
Wiring harness	Wiring harness (optional)	Wiring harness (optional)

Fig 5



Air starting system (Fig 6)

Different engine applications could call for an alternative starting system to the electrical starting system. The environment the machine is working in could be flammable and require a spark-proof machine or the cost of replacing batteries in extremely cold environments is seen to be excessive. One alternative is to use a dedicated air supply to spin an air-powered starter motor assembly.

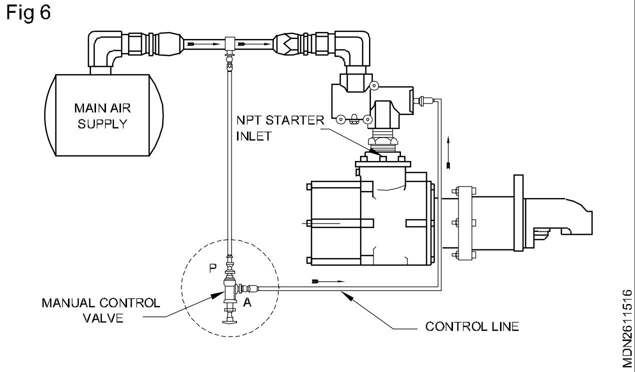
There are some advantages to having an air driven starter. They are much lighter and, therefore, have a higher power to weight ratio than a comparable output electric starter. There is no chance of an air starter overheating from over-cranking. Because of their simple design, there is very little that goes wrong with them. The most problematic area that can cause trouble with an air starter assembly is excessive moisture in the air system that can freeze in cold weather.

One disadvantage is how fast the air supply is depleted when the starter is engaged. Most starting tanks will empty within 20 seconds. If the air tank does deplete before the engine starts, this means charging the tank with an external air source from a shop air line, other machine, or service truck.

An air starter will generate high cranking speed and torque so that under normal conditions the engine should start before the starter air tank runs out.

There are two main types of air starter motors. One is a vane type that uses sliding vanes in a rotor to convert air flow into mechanical movement. The other type is called turbine, and its rotation is created by air flow pushing on the blades of one or more turbine wheels.

Fig 6



If you look back to the chart comparing air, hydraulic, and electrical starting systems, the main differences are the energy supply, type of motor, air lines, and system control.

The machine will most likely have an air compressor to provide air for other pneumatic systems and to keep the starter air tank charged up. Once the engine starts, it is then up to the machine's air compressor to recharge the starting tank and the machine's other supply tanks. The air starting tank will be charged to between 110 and 150 psi.

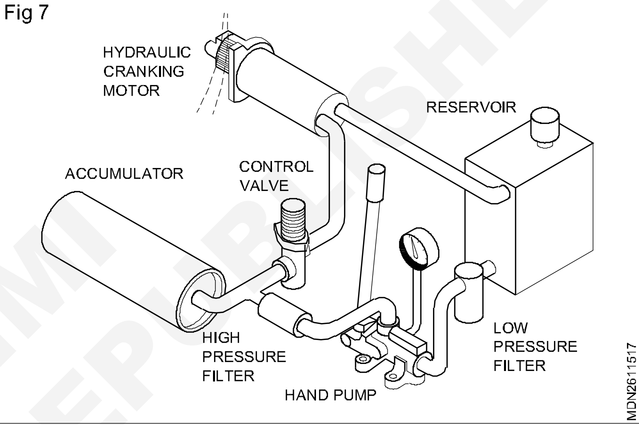
To send air to the starter, a relay valve will be controlled by an electric solenoid valve that is activated by the key switch or there could be a floor-mounted air relay valve to send air to the main relay valve. See Figure to see the arrangement of components for an air starting system. When the solenoid valve is energized, it will send air to the relay valve that will open to allow tank air into the starter motor. There are two main types of starter motors: vane and turbine. The motors create shaft rotation that usually has its speed reduced and torque increased through a gear reduction. The torque is then sent out through a drive pinion to engage with the flywheel. Vane-type motors will need lubrication and will usually have diesel fuel drawn into the motor inlet during starter engagement.

It is important to have clean dry air entering air starters and their control circuit. Problems with moist air are magnified in the winter with relay valves freezing and sticking. Air leaks and air restrictions are the only other concern with air starter systems. The motors will last a long time, and if they are found to be worn out, repair kits can be installed to renew the starter assembly.

Hydraulic starting system (Fig 7)

Another nonelectric starting system is one that uses hydraulic fluid to rotate a hydraulic starter motor. The motor will then rotate a drive gear in the same manner as typical electric starters. Hydraulic start systems have an accumulator that keep hydraulic fluid stored under pressure until needed. A control valve is actuated to send pressurized fluid to the motor to get the motor turning. The motor is a fixed displacement axial piston unit, and its shaft drives the pinion gear directly. See Figure for a hydraulic starting system. The control valve could be floor mounted, cable operated, or controlled electrically through an LCD screen touch pad called a human–machine interface (HMI).

Fig 7



The accumulator for this system has a pre-charge of 1500 psi of nitrogen, and when the oil is pumped into it, the pressure builds to 3000 psi.

This system will have a backup hand pump that could be used to charge the accumulator.

If the system doesn't operate, then just like an electric or air system, perform a good visual inspection. Then check the accumulator pre-charge pressure and the oil pressure after the accumulator has been charged. If these pressures are good, then look for restrictions or leaks past the accumulator toward the control valve. Make sure that the valve is moving as it should, and if there is still a problem, you may have to install pressure gauges throughout the system to see if there is oil pressure getting past the control valve.

As with any fluid power system, cleanliness is crucial so check for fluid contamination. For information on accumulator service and repair.

Air motor starting system for auxiliary engines on ships.

Auxiliary engine automation system

Objectives: At the end of this lesson you shall be able to
- **describe the function of auxiliary engine automation system**
- **describe the function of auxiliary engine stop system**
- **describe the function of marine engine cooling system**
- **describe the function of lubricating oil system.**

The sensors and indicators are installed on engine properly and connected to the power system panel for control and monitoring. The engine responds to the control signals via pneumatic and electronic mechanism of the engine.

The electrical power of DC24V and compressed air of about 30 bar should be supplied consistently during engine operation. The compressed air supplied from the air reservoir is lowered to a proper pressure through reducing valve around staring air motor, which is used for starting and stopping the engine.

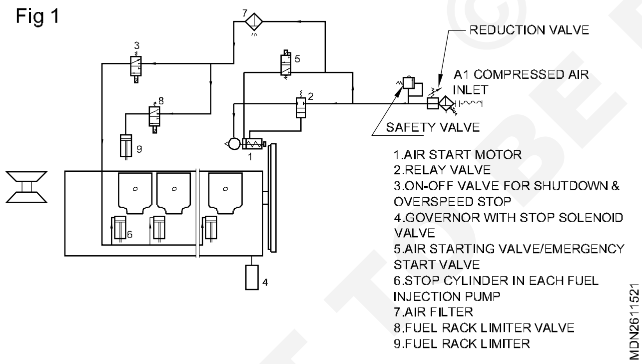
The basic functions of the engine automation system are as follows;

- Engine Starting System.
- Engine Stop System.
- Engine Speed control System.
- Engine Safety system

Auxiliary engine starting system (Fig 1)

In air motor starting system, the engine is started by a starting air motor which is operated by compressed air. Figure below shows the compressed air system for starting, stopping and fuel limiting for auxiliary engines on ships.

Fig 1



Compressed air reaches the auxiliary engine at 30 bar pressure. The air pressure is reduced to 6 bar with a reduction valve. A safety valve is also fitted in the line after reducing valve to protect the air starting system components. Air then enters air starting valve (5) and wait there. When 'START' button on the control panel is activated, starting solenoid valve (5) is opened to supply compressed air into the starting air motor (1). Then, the pinion of the air starting motor is engaged with the gear rim of the engine flywheel. As the pinion moves, relay valve (2) is supplied with air and it allows air to the starting air motor turbine wheel. Now air motor turns crankshaft of the engine. When the engine rotating speed reaches predetermined speed, fuel oil is injected into the combustion chamber. Then, starting is completed and the pinion of the air starting motor is disengaged from the gear rim at predetermined speed.

Purpose of fuel rack limiter

During starting period, the turbocharger is out of normal operation and therefore diesel engine is always in the incomplete combustion due to lack of air, which results in heavy smoke. The fuel rack limiter (9) is used to avoid excessive fuel injected into cylinder during starting period to avoid heavy smoke. During starting period, the engine automation system activate starting solenoid valve to supply compressed air to push the fuel rack limiter (9) piston. A fuel rack limiter valve (8) supplies air to a pneumatic cylinder or fuel rack limiter (9). The limiting position is set to about 50% load normally. The limiting position can be adjusted by guide when loosening locking screw.

On-off valve (3) is for stopping the engine when engine shut down is necessary or over speed trip is activated. This valve provides air to each stop cylinder (6), connected to each fuel pumps and pulls the rack to cut off fuel to the engine.

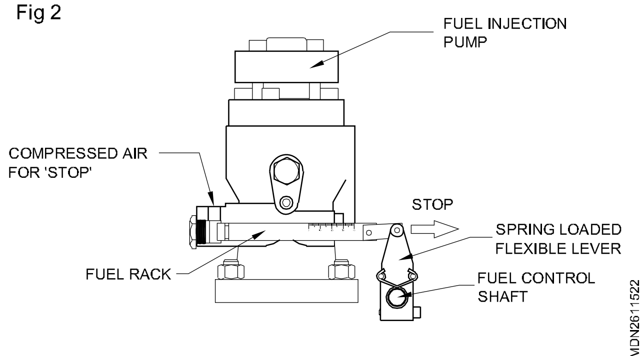
Auxiliary engine stop system (Fig 2)

The engine is stopped when pressing 'STOP' button or 'EMERGENCY STOP' button on control panel intentionally, or by 'AUTO STOP' signal. Engine automation system generate 'AUTO STOP' signal when abnormal condition of the engine is detected.

However, the engine is stopped fundamentally when the fuel injection into the combustion chamber is stopped. This means that the rack of each fuel injection pump is moved to stop position by stop signal. Every fuel rack is connected to common control shaft mechanically and also connected to common compressed air line pneumatically.

Therefore, there are two ways of moving fuel racks to stop position (Zero index) as shown in figure below.

Fig 2



The one is by the mechanical stop, which pull the racks to stop position by the governor or the manual control lever. 'STOP' button activates the governor to be 'STOP' position.

The other is by the pneumatic stop by compressed air (as discussed above with on-off valve 3), which pushes the rack to stop position regardless of the governor control. 'EMERGENCY STOP' button or 'AUTO STOP' signals activates the stop solenoid valve to supply the compressed air for all fuel injection pumps. This 'EMERGENCY STOP' signal also activates governor's stop simultaneously.

However, these two ways are mechanically independent each other and the spring-loaded levers provide mechanical flexibility between them.

Marine engine cooling system (Fig 3)

There are two types of cooling system used in marine engines.

1 Heat exchange cooling system

2 Keel cooling system

Heat exchange cooling system

Heat exchange cooling system consists of the following units.

Water cooled exhaust manifold.

Engine coolant pump.

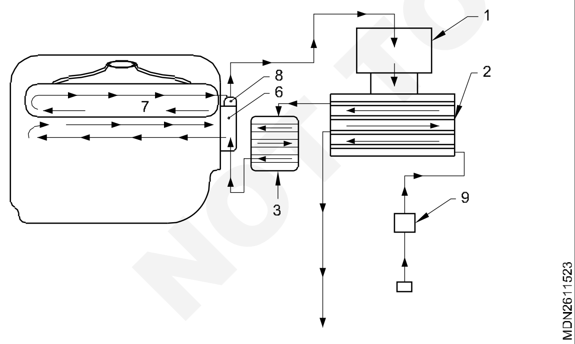
Heat exchanger

Expansion tank Operation

The coolant flows Fig 3 from the expansion tank (1) around core cells (2). These core cells contain sea water. The water is circulated through the core by the water pump (9). Hot engine coolant flows outside of the core (2) and it is cooled by the sea-water inside the core.

Coolant as fresh water is circulated through an expansion tank (1). From the expansion tank (1) it flows down around the cores (2). From the cores (2) to the oil cooler (3) and then through inlet of engine's coolant pump (6). It is then pumped to the engine and sent to the expansion tank (1) through the exhaust manifold (7) and thermostat (8).

Fig 3



A separate pump (9) is used to circulate sea water to cool cores (2) and back.

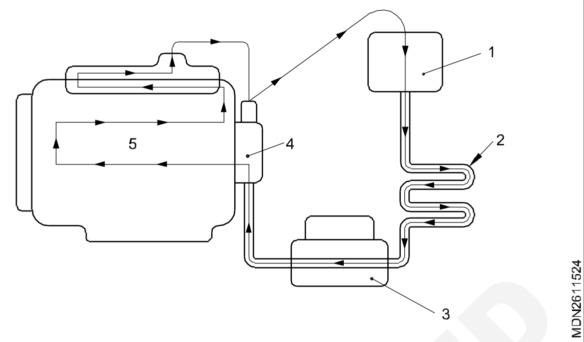
Keel cooling system

In this system coolant flows from the expansion tank (1) to the keeling coil (2) and goes to the engine (5) through an oil cooler (3). A pump (4) is used to circulate the coolant in system.

Open cooling system

In this system water is stored in a reservour and circulated in the engine by a water pump. Hot water from the engine is pumped to the reservoir where it flows from a height and gets cooled.

Fig 4

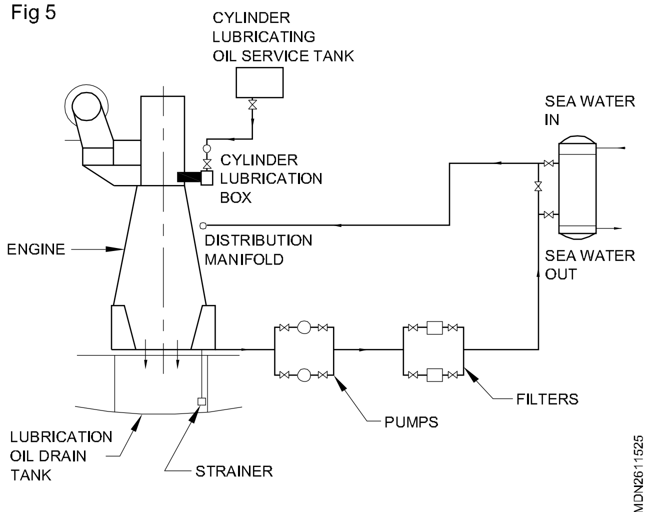


Marine diesel engine lubrication system

Function of lubrication: The lubrication system of an engine provides a supply of lubricating oil to the various moving parts in the engine. Its main function is to enable the formation of a film of oil between the moving parts, which reduces friction and wear. The lubricating oil is also used as a cleaner and in some engines as a coolant.

Main engine lubricating oil system (Fig 5) - This system supplies lubricating oil to the engine bearings, and cooling oil to the pistons. Lubricating oil is pumped from main engine lubricating oil. Circulating Tank, placed in the double bottom beneath the engine, by means of the ME LO Pump, to the main engine lubricating oil. Cooler, a thermostatic valve, and through a full-flow filter, to the engine, where it is distributed to the various branch pipes. Pumps and fine filters are arranged in duplicate, with one as a standby. From the engine, the oil collects in the oil pan, from where it is drained to the ME LO Circulating Tank for reuse. A centrifuge is arranged for cleaning the lubricating oil in the system and the clean oil can be provided from a storage tank.

Fig 5



Lubricating oil system: Lubricating oil for an engine is stored in the bottom of the crankcase, known as the sump, or in a drain tank located beneath the engine . The oil is drawn from this tank through a strainer, one of a pair of pumps, into one of a pair of fine filters. It is then passed through a cooler before entering the engine and being distributed to the various branch pipes.

The branch pipe for a particular cylinder may feed the main bearing, for instance. Some of this oil will pass along a drilled passage in the crankshaft to the bottom end bearing and then up a drilled passage in the connecting rod to the gudgeon pin or crosshead bearing.

An alarm at the end of the distribution pipe ensures that adequate pressure is maintained by the pump. Pumps and fine filters are arranged in duplicate with one as standby. The fine filters will be arranged so that one can be cleaned while the other is operating. After use in the engine the lubricating oil drains back to the sump or drain tank for re-use. A level gauge gives a local read-out of the drain tank contents. A centrifuge is arranged for cleaning the lubricating oil in the system and clean oil can be provided from a storage tank.

The oil cooler is circulated by sea water, which is at a lower pressure than the oil. As a result any leak in the cooler will mean a loss of oil and not contamination of the oil by sea water.

Where the engine has oil-cooled pistons they will be supplied from the lubricating oil system, possibly at a higher pressure produced by booster pumps, e.g. Sulzer RTA engine. An appropriate type of lubricating oil must be used for oil-lubricated pistons in order to avoid carbon deposits on the hotter parts of the system.

Cylinder lubrication

Cylinder oil is pumped from Cylinder Oil Storage Tank to the Cylinder Oil Service Tank, placed min. 3000mm above the cylinder lubricators. The cylinder lubricators are mounted on the roller guide housing, and are interconnected with drive shafts. Each cylinder liner has a number of lubricating orifices, through which the cylinder oil is introduced into the cylinders via non-return valves.

Large slow-speed diesel engines are provided with a separate lubrication system for the cylinder liners. Oil is injected between the liner and the piston by mechanical lubricators which supply their individual cylinder, A special type of oil is used which is not recovered. As well as lubricating, it assists in forming a gas seal and contains additives which clean the cylinder liner.

Lubricating oil sump level

The level of lubricating oil indicated in the sump when the main engine is running must be sufficient to prevent vortexing and ingress of air which can lead to bearing damage.

The sump level is to be according to manufacturers/ shipbuilders instructions . The 'Sump Quantity' is always maintained at the same safe operating level and is given in litres. It is essential that the figures are mathematically steady and correct from month-to-month, taking into account consumption, losses and refills and reported.

The 'Sump Quantity' is calculated with the engine stopped, but the lubricating oil pump in operation, thus keeping the system oil in circulation.

Sufficient reserve quantities of lubricating oil must always be held, i.e. to completely fill the main sump and sufficient quantities of other lubes must be held to cover the intended voyage plus 20%. Lubricating oils are a major expenditure item, therefore, all purchasing must be pre-planned with the aim of buying the maximum amounts from the cheapest supply sources which are primarily the US, Europe and Singapore.

Pre-lubrication sumps

They provide an essential part of the lubrication system on many types of engine in particular auxiliary engines with engine driven lubricating oil pumps.

They provide a supply of oil to the bearings prior to start up and limit the length of time that boundary lubrication exists, and shorten the time when hydrodynamic lubrication commences. They must be maintained and operated in accordance with the manufacturers' instructions.

Common rail system of marine engines

Objectives: At the end of this lesson you shall be able to
- **Describe the marine engine CRDI system**
- **Describe the hydraulic coupling system**
- **Describe the electromagnetic couplings system**
- **Describe the reduction gear drive**
- **Describe the marine electrical drive**
- **Describe the super charger**

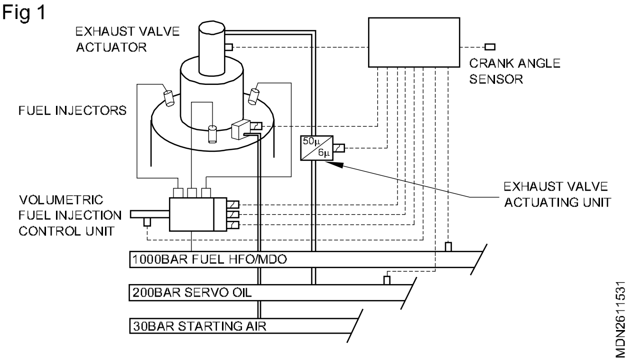
The common rail system (Fig 1) is a system which is common for every cylinder or unit of the marine engine. Marine engines of the early times had a fuel system, wherein each unit had its own jerk pump and the oil pressure was supplied through the jerk pumps.

However, in common rail system all the cylinders or units are connected to the rail and the fuel pressure is accumulated in the same. The supplied fuel pressure is thus provided through the rail.

The common rail fuel injection system was launched even before the jerk pumps, but was also not successful because of few drawbacks. However, latest advancement in technology and electronics, the common rail system has gained popularity.

The common rail engines are also known as smokeless engines as fuel pressure required for combustion is same for all loads or rpm of the engine.

Fig 1



The common rail is employed in the following marine engine operating system.

1 for heated fuel oil at a pressure of 1000 bars.

2 for servo oil for opening and closing of exhaust valves at a pressure of 200 bars.

3 control oil for opening and closing of valve blocks at a pressure of 200 bars.

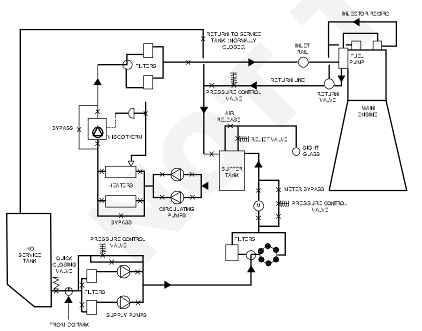
4 compressed air for starting main engine.

The common rail system consists of a high pressure pump which can be cam driven or electrical driven or both. Pressure requirement will be different for different system. For fuel oil the pressure are as high as 1000 bars, for servo and control oil the pressure is about 200 bars.

Valve block and electronic control system (Fig 2)

This is required for the control of the flow of the fuel oil, servo oil, control oil and starting air from the rail to the cylinder. The valve block is operated by the electronic control which operates when it gets a signal indicating that this cylinder is at top dead centre (TDC) and fuel has to be injected and decides when exhaust valve has to be opened. With the help of electronics the injection can be controlled remotely from the computer. For e.g. if we want to cut off fuel to one of the unit, then we need to cut off the signal given from the control system so that the valve will not open.

Fig 2



The fuel oil system this block is known as ICU(Injection control Unit) and for exhaust valve it is known as VCU (Valve Control Unit). The control system for opening and closing of ICU and VCU is done by electro hydraulic control with which when the signal for open is present the valve for control oil opens and control oil pushes the valve of ICU and VCU to open. The signal for electronic control is given by crank angle sensor which senses about each cylinder and sends signal to system which decides whether to open a valve or close the valve.

The timing of the opening of the valve can also be controlled by the electronics, which means that if the signal is given to open the valve early it will open early and vice versa.

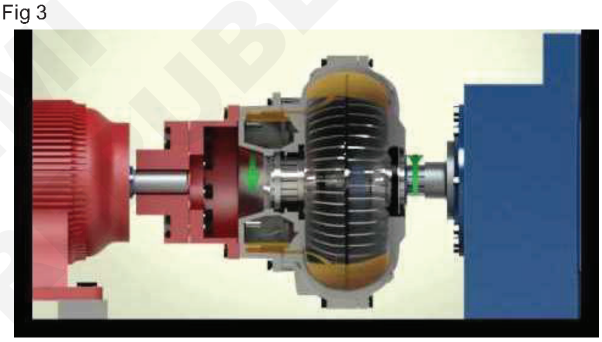
Marine diesel engines are designed to burn heavy resudues fuel. This is made up of the residues after the lighter and more costly fuels and gases been taken out of the crude oil at the refinery.

The Fig 2 shows a fuel oil supply system for a large 2 stroke engine. However the set up is typical of any fuel system for a marine diesel engine operating on heavy residual fuel.

Hydraulic coupling/fluid coupling (Fig 3 & 4)

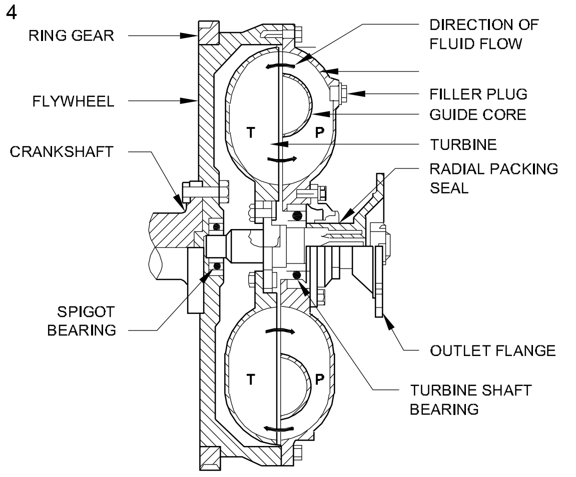
A fluid coupling (Fig 3 & Fig 4) or hydraulic coupling is a hydrodynamic device used to transmit rotating mechanical power. It has been used in automobile transmissions as an alternative to a mechanical clutch. It also has wide-spread application in marine and industrial machine drives, where variable speed operation and controlled start-up without shock loading of the power transmission system is essential.

Fig 3



HYDRAULIC COUPLING

Fig 4



FLUID COUPLING

Fluid couplings are used in many industrial application involving rotational power, especially in machine drives that involve high-inertia starts or constant cyclic loading. In some part of the globe it is also used in rail transport and marine engine application for the smooth operations.

Electromagnetic couplings (Fig 5)

Electromagnetic couplings & brakes from binder kendrion anterior entries technique GmbH

Fig 5

ELECTROMAGNETC COUPLINGS

MDN2611535

An electrically generated magnetic force ensures connection between armature and rotor in an electromagnetic coupling and thus making available. if the voltage dis appears, the magnetic field is removed and the pre-stressed spring will separate again the armature and rotor.

Application of elctro magnetic couplings

An electrical generated magnetic force ensures connection between armature and rotor in an electro magnetic coupling and thus making torque available. If the voltage disappears, the magnetic field is removed and the pre stressed spring will separate again the armature and rotor.

The electromagnetic couplings are usage in following systems.

Electromagnetic brake

Electromagnetic pull/ push

Electromagnetic clutch

Electromagnetic vibrations

Reduction gear drive

Reduction drives are used in engines of all kinds, to increase the amount of torque per revolution of a shaft, the gearbox, differential and steering boxes of any car is an example of a reduction drive.

Types of reduction gears

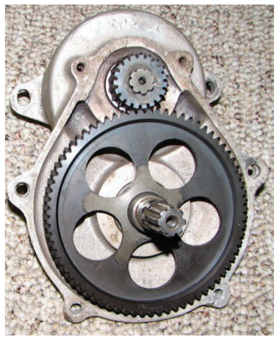
There are mainly two type of reduction gears:

- Single reduction gear
- Double reduction gear

Single reduction gear (Fig 6)

The arrangement consists of only one pair of gears. The reduction gear box consists of ports through which the propeller shaft and engine shaft enters the assembly. A small gear known as a pinion is driven by the incoming engine shaft. The pinion directly drives a large gear mounted on the propeller shaft. The speed is adjusted by making the ratio of the speed reduction to the diameter of pinion and gear proportional. Generally, a single gear assembly has a gear double the size of a pinion

Fig 6



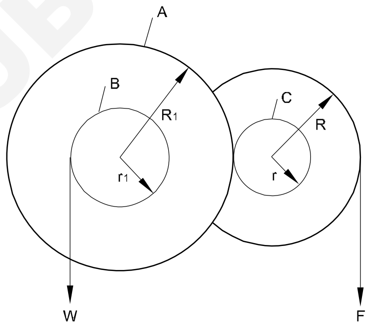
SINGLE REDUCTION GEAR

MDN2611536

Double reduction gear (Fig 7)

Double reduction gears are generally used in application involving very high speeds. In this arrangements the pinion is connected to the input shaft using a flexible coupling. The pinion is connected to an intermediate gear know as the first reduction gear. The first reduction gear is then connected to a low speed pinion with the help of one more shaft. This pinion is connected to the second reduction gear mounted directly on the propeller shaft. Such arrangement facilitates the reduction of speed to a ratio as high as 20:1.

Fig 7



DOUBLE REDUCTION GEAR
(A,B,C ARE PITCH CIRCLES OF GEARS)

MDN2611537

Reduction drives on marine vessels

Most of the word's ships are powered by diesel engines which can be split into three categories, low speed (<400 rpm), medium speed (400-1200 rpm), and high speed (1200 +rpm). Low speed diesels operate at speeds within the optimum range for propeller usage. THus it is acceptable to directly transmit power from the engine to the propeller. For medium and high speed diesels, the rotational speed of the crankshaft within the engine must be reduced in order to reach the optimum speed for use by a propeller.

Reduction drives operate by making the engine turn a high speed pinion against a gear, turning the high rotational speed from the engine to lower rotational speed for the propeller. The amount of reduction is based on the number of teeth on each gear. For example, a pinion with 25 teeth, turning a gear with 100 teeth, must turn 4 times in order for the larger gear to turn once. This reduces the speed by a factor of 4 while raising the torque 4 fold. This reduction factor changes depending on the needs and operating speeds of the machinery. For example the reduction gear ratio of a ship is 3.6714:1.

A large variety of reduction gear arrangements are used in the industry. The three arrangements most commonly used are: double reduction utilizing two pinion nested, double reduction utilizing two-pinion articulated, and double reduction utilizing two-pinion locked train.

The gears used in a ship's reduction gearbox are usually duke helical gears. This design helps lower the amount of required maintenance and increase the lifetime fo the gears. Helical gears are used because the load upon it is more distributed then in other types. The double helical gear set can also be called a herringbone gear and consists of two oppositely angled sets of teeth. A single set of helical teeth will produce a thrust parallel to the xie of the gear (known as axial thrust) due to created by both sets cancels each other out.

When installing reduction gears on ships the alignment of the gear is critical. Correct alignment helps ensure a uniform distribution of load upon each pinion and gear. When manufactured, the gears are assembled in such a way as to obtain uniform load distribution and too the contact. After completion of construction and delivery to shipyard it is required that these gears achieve proper alignment when first operated under load.

In order to ensure a reduction drive's smooth working and long lifetime, it is vital to have lubricating oil. A reduction drive that is ran with oil free of impurities like water, dirt, grit and flakes of metal, requires little care in comparison to other type of engine room machinery. In order to ensure that the lube oil in the reduction gears stay this way a lube oil purifier will be installed with the drive.

Marine electrical drive

Marine motor provides an excellent solution to running marine motor as it provides a low running cost, low maintenance and is almost silent and pollution free.

Benefits of electric drive/propulsion

- The power can be supplied by any number of generator which enables high redundancy.
- The motor drive combination consumes energy only when ship thrasher is actively turned.
- The environment benefits from lower fuel consumption and exhaust gas emission levels.
- Electric propulsion is a good platform for the next phase development - hydrodization.

Generally ship is designed with modern electric propulsion system as a diesel electric, LNG electric or even fully electric can be quite easily converted to a hybrid solution.

Generator and motors

Marine generator operating with diesel engines. The generator power is used for various purposes of the ship etc, lighting ,propulsion and communication system. The generator / motor is located between main engine and propulsion shaft, A C drive technology allows the optimum control of propulsion machinery at various speed, which saves energy.

Super charger

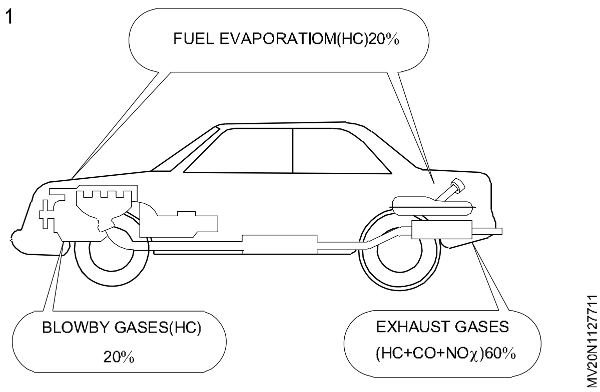
Super charging is a process, where a great mass of air is admitted in the cylinder, for combustion and consequently a greater amount of fuel is burnt efficiently. The power output of the engine is increased with higher thermal efficiency without increasing size of engine. The supercharger is driven through gears directly from the engine crankshaft. Supercharging system is commonly use in two stroke and four stroke marine engines, where higher compressed air is needed.

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 passenger vehicle, light vehicle and heavy vehicle**
- **follow the european emission standards for diesel passenger vehicle, light vehicle and heavy vehicle**
- **follow the bharat emission standards for gasoline passenger vehicle, light vehicle and heavy vehicle**
- **follow the bharat emission standards for diesel 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

the 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 commerical 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 1992, > 85 kW	ECE R-49	4.5 4.5	1.1 1.1	8.0 8.0	0.612 0.36	
Euro II	October 1996 October 1998		4.0 4.0	1.1 1.1	7.0 7.0	0.25 0.15	
Euro III	October 1999 EEVs only October 2000	ESC & ELR ESC & ELR	1.0 2.1	0.25 0.66	2.0 5.0	0.02 0.10 0.13*	0.15 0.8
Euro IV	October 2005		1.5	0.46	3.5	0.02	0.5
Euro V	October 2008		1.5	0.46	2.0	0.02	0.5
Euro VI	31 December 2013[15]		1.5	0.13	0.4	0.01	
* 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 2003.04 2005.04	NCR*, Mumbai, Kolkata, Chennai NCR*, 13 Cities† Nationwide
Bharat Stage III	Euro 3	2005.04 2010.04	NCR*, 13 Cities† 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	2.1	0.66	5.0	0.10
		ETC	5.45	0.78	5.0	0.16
2010‡	Euro IV	ESC	1.5	0.46	3.5	0.02
		ETC	4.0	0.55	3.5	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		0.56	0.50	0.05
		0.80	-	0.72	0.65	0.07
		0.95		0.86	0.78	0.10
2010‡	Euro 4	0.50		0.30	0.25	0.025
		0.63	-	0.39	0.33	0.04
		0.74		0.46	0.39	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 4.17 5.22	0.20 0.25 0.29	-	0.15 0.18 0.21
2010‡	Euro 4	1.0 1.81 2.27	-	0.1 0.13 0.16	0.08 0.10 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 2 g/test (effective 2000).

3- and 2-wheel vehicles

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

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 C.I 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

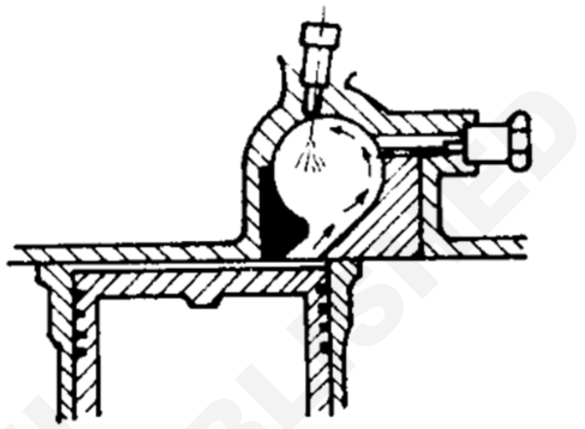
Reduced exhaust pollutants.

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

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 (CO_2) + 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

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.

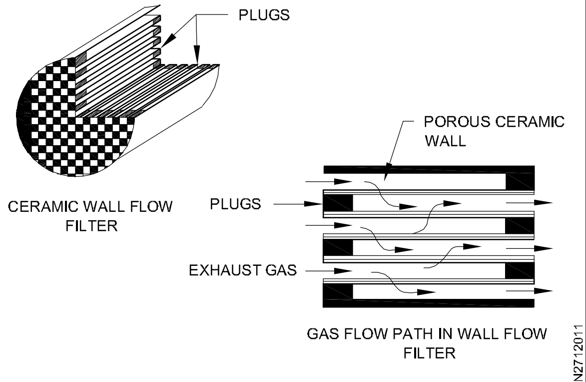
During combustion of the fuel and air mix,a variety of pollutant particles generically classified as diesel particulate matter is produced due to incomplete combustion.

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

Fig 1



CERAMIC WALL FLOW FILTER FOR DIESEL PARTICULATE

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.

Two types of regeneration systems have been investigated and a few developed for employment on production vehicles

Active regeneration

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.

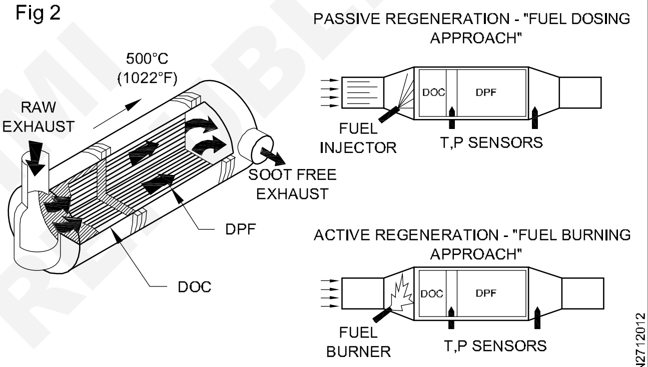
Use of electric heater upstream of filter - power to the electric heater is supplied by the engine alternator. A typical truck DPF regeneration system may require a 3 kw heater.

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

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 (co2)**
- **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.

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.

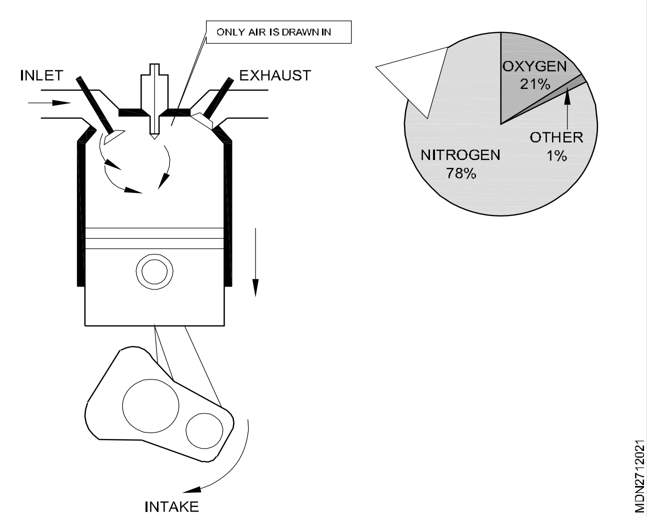
Particulates

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 lubicating oil inside combustor chamber leaves particulates in CI engine.

Fig 1



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 (co2)

Carbon dioxide is produced, with water, when complete combustion of air and fuel occurs.

Catalytic converters in gasoline-engine 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.

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 vhicles, crackcase 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.

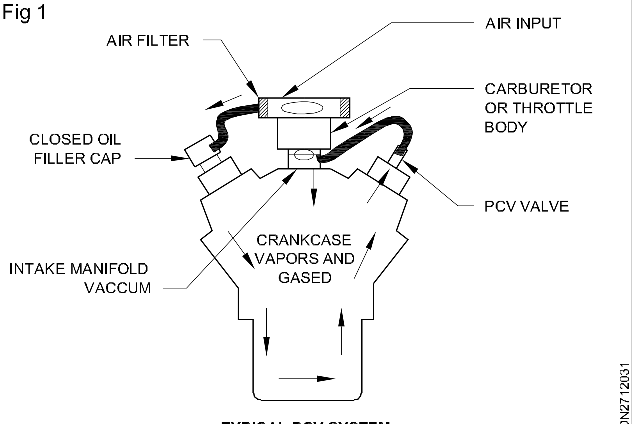
PCV working principle

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 manifold vaccum 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 manifold, it may upset the air-fuel ratio. The PVC valve helps to control the amount of vapors and gases going back into the intake manifold.

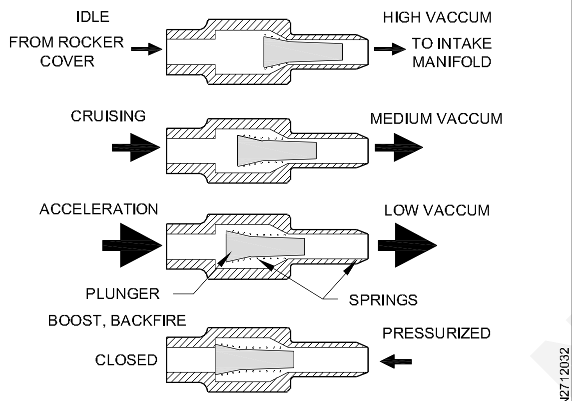
Fig 1



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 manifold 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 manifold allows the springs to keep the plunger " back" for maximum airflow through the PCV valve.

In the case when the intake manifold 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.

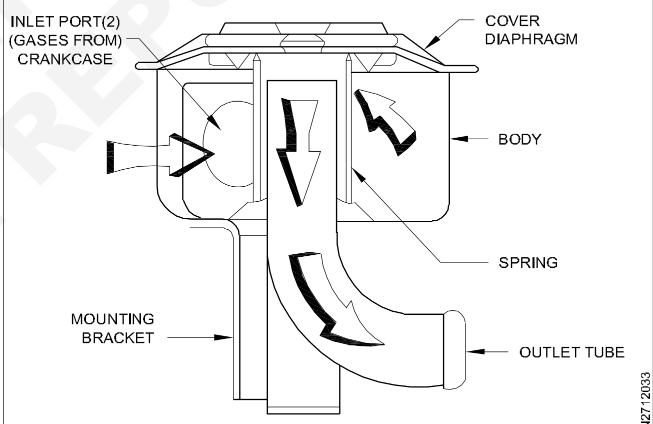
Crankcase depression regulator valve (CDRV) for diesel engine

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 manifold.

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 manifold 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 vaccum in tne crankcase. As intake vacuum decreases, the spring pushes the diaphragm away from the top of the outlet tube allowing more gases into the manifold. 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.**

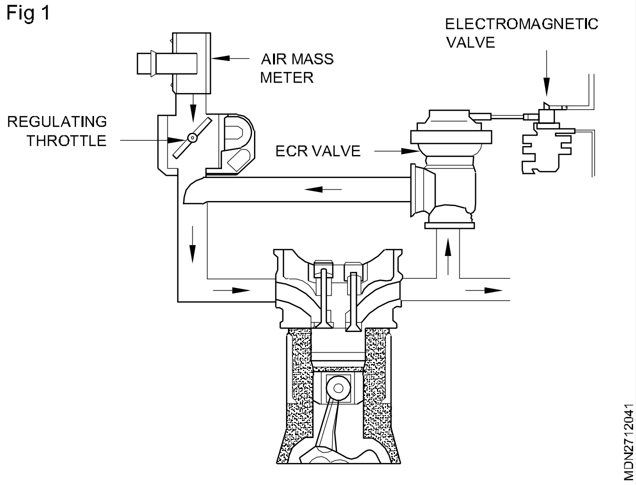
Purpose of exhaust gas recirculation (EGR) system

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.

EGR, valve, connected between the exhaust port or manifold, and the intake system.

Fig 1

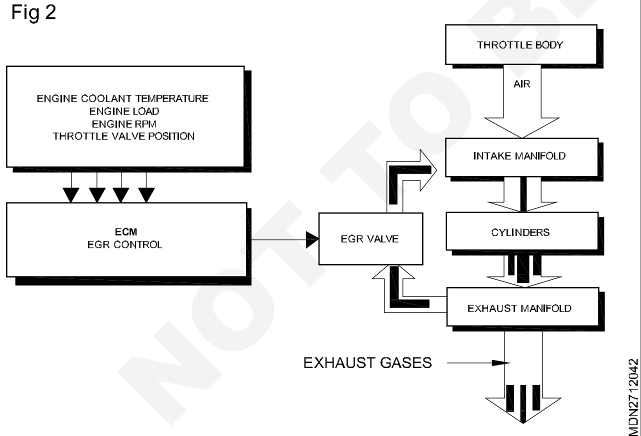


If engine conditions are likely to produce oxides of nitrogen, the EGR valve opens, letting some gases is (only about 6 to 10% of the total) pass from the exhaust, into the intake system. During combustion, these exhaust gases absorb heat from the burning air and fuel. This lowers peak combustion temperatures (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 mainfold (Fig 2) This has a quenching effect that lowers combustion temperatures and reduces the formation of NOx.

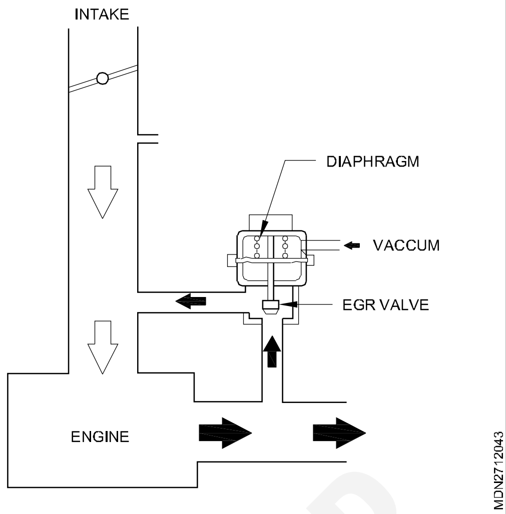
Fig 2



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, diaphragm and spring. When vacuum is applied to diaphragm lifts the valve off its seat allowing diaphragm gases into the intake air stream. When vacuum is removed the spring forces the diaphragm and valve downward closing the exhaust passage.

Fig 3

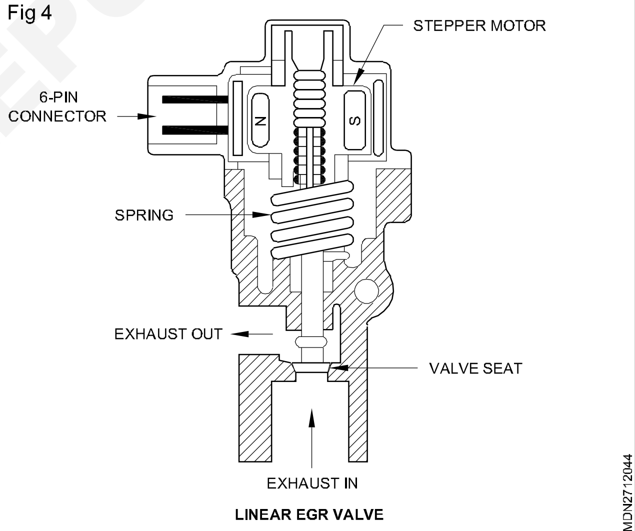


Current technology of EGR valve

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.

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.

Fig 4



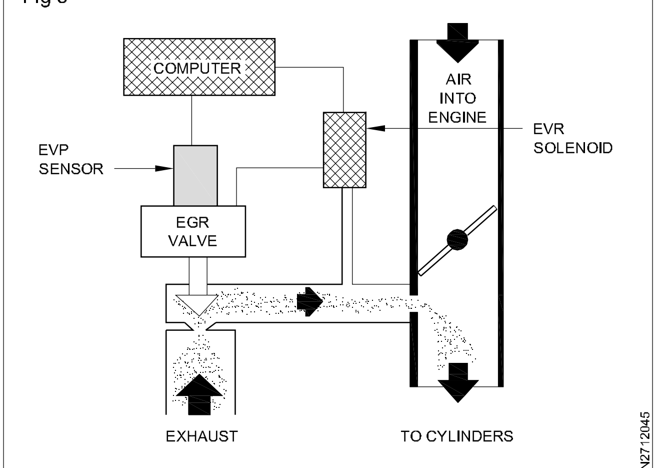
LINEAR EGR VALVE

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).

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.

Fig 5

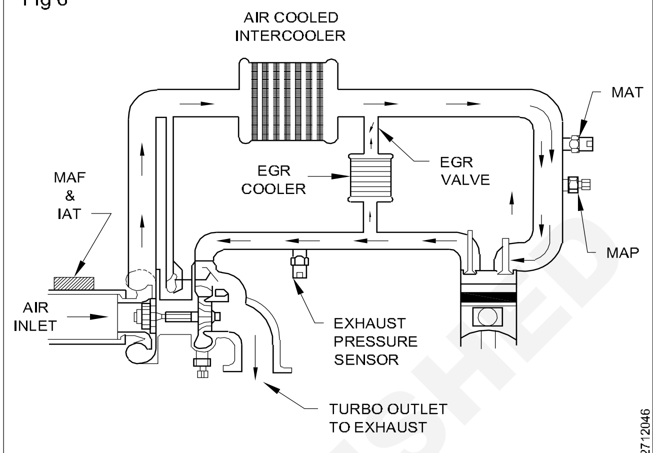


LINEAR EGR SYSTEM CIRCUIT

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.

Fig 6



INTAKE EGR SYSTEM IN DIESEL ENGINE

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.**

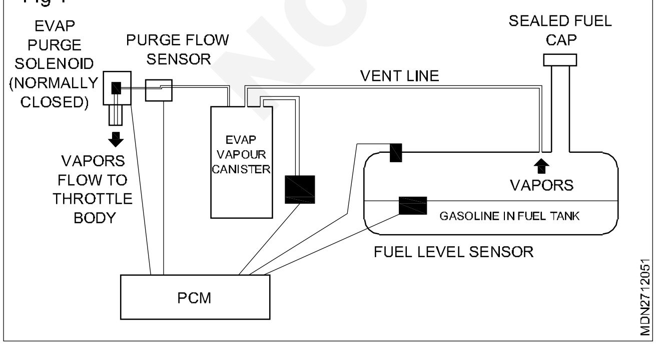
Purpose of Evaporation emission control (EVAP) systems

The Evaporation emission control (EVAP) systems totally eliminate fuel vapors 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



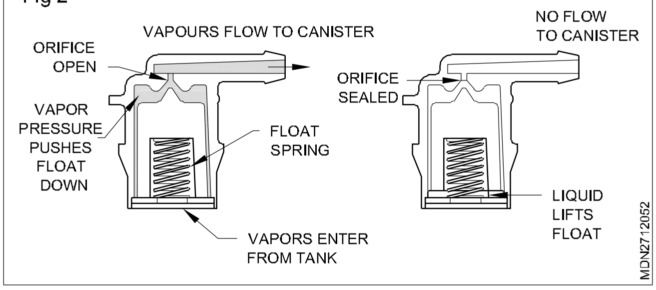
EVAP system components

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).

Fig 2



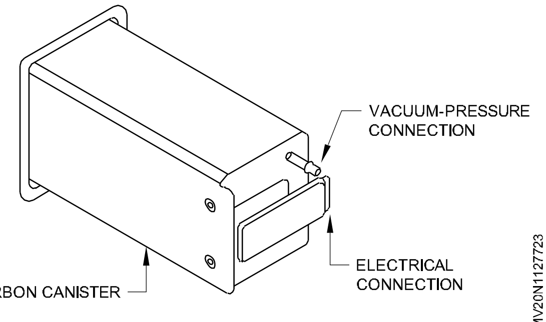
Liquid-Vapor Separator - This is located on top of the fuel tank or part of the expansion overflow tank. This device prevents liquid gasoline from entering the vent line to the EVAP canister.

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)

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)

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.

Fig 3



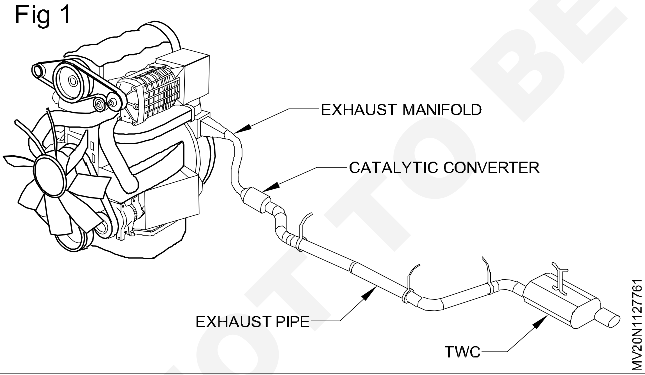
Catalytic converter

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: H2O (Water), CO2(Carbon Dioxide), and N2 (Nitrogen)

Block Diagram of three-way catalytic converters (TWC) 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:

Fig 1

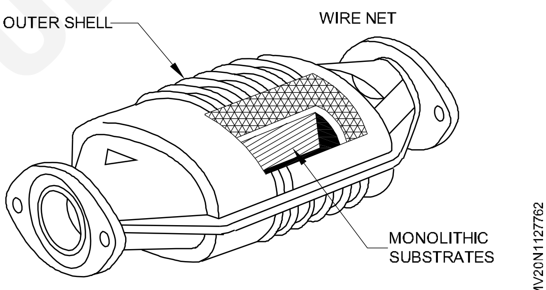


- Unburnt Hydrocarbons are oxidized into water/steam.
- Carbon monoxide is oxidized into carbon Dioxide
- Oxides are converted into Nitrogen and Oxygen

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.

Fig 2



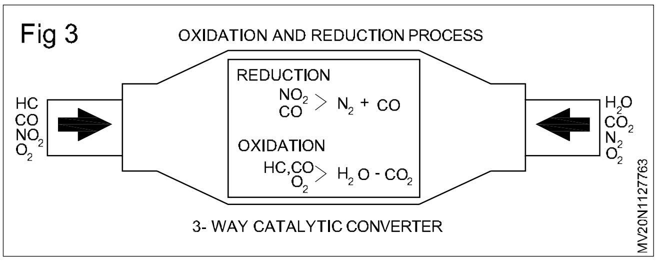
The exhaust gases first pass over the reduction catalyst in the converter. The platinum and rhodium coating helps to reduce the oxides of nitrogen, together known as 'NOX' emissions

The three-way catalyst (Fig 3), which is responsible for performing the actual feed gas conversion, formed by coating the internal substrate with the following type materials.

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 diagram (Fig 3) below shows the chemical reaction that takes place inside the converter.

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.

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)

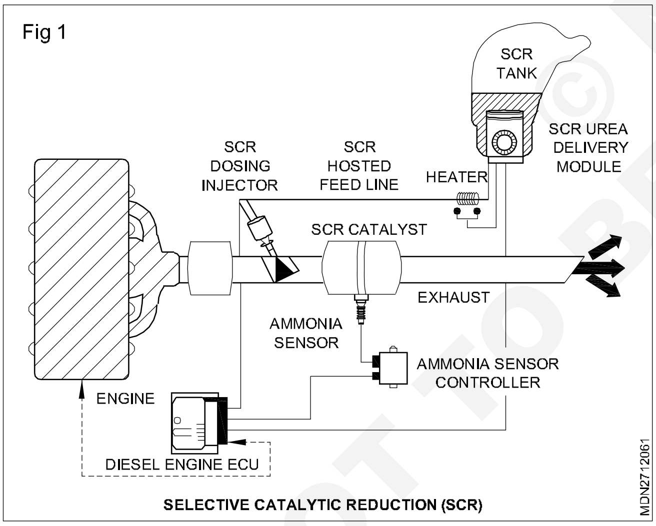
selective catalytic reduction (SCR) is the process by which oxides of nitrogen (Nox) contained in diesel exhaust are reduced to nitrogen (N2) and water (H2O)

selective catalytic reduction

Selective : targets NOx in diesel exhaust

Catalytic : requires a catalyst

Reduction : NOx is reduced to nitrogen (N2) (Fig 1)



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 water 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(CO2)

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 different 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 sulfer 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.

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

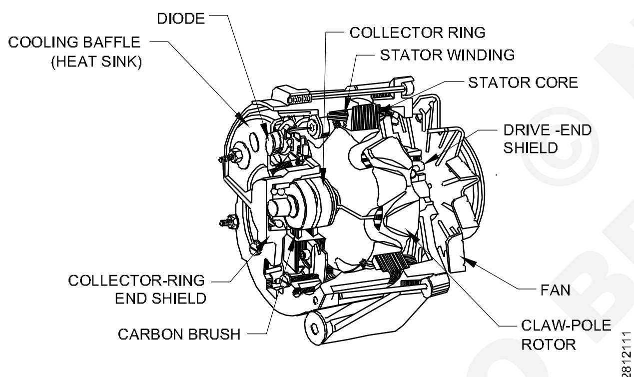
Objectives : At the end of this lesson you shall be able to
- **explain the purpose of an alternator**
- **describe the circuit of the alternator**
- **list out the different parts of the alternator**
- **explain the functions of the various parts of an alternator**
- **explain the working of an alternator.**

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)

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).

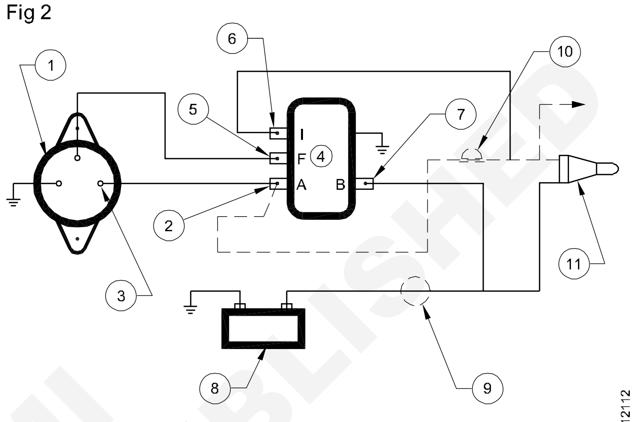
Description of parts of an alternator

Drive end frame (Fig 3)

The drive end frame supports a pre-lubricated sealed bearing in which the drive end of rotor shaft rotates.

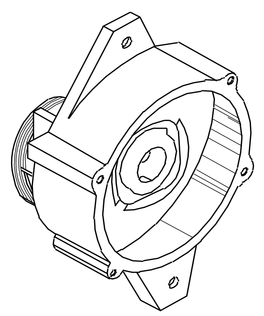
The rotor and its shaft is mounted and encased between drive end frame and slip ring end frame.

Fig 2



ALTERNATOR WIRING CIRCUIT IN A VEHICLE

Fig 3

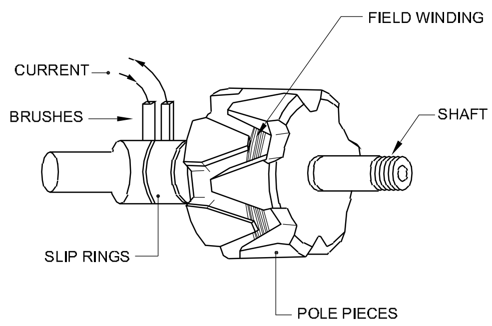


DRIVE END FRAME

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.

Fig 4



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.

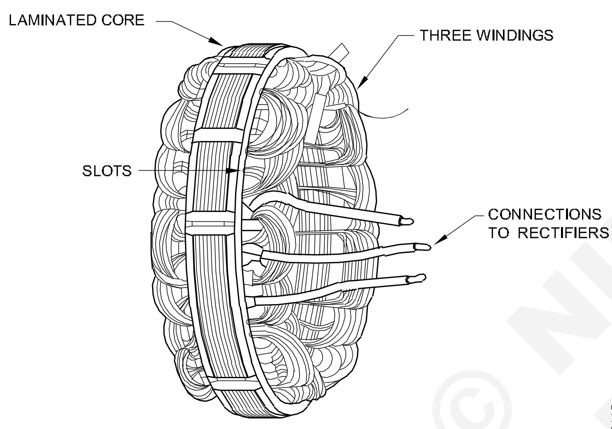
Stator assembly (Fig 5)

It is a stationary part which is held between two end covers. (Figs 1 & 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.

Fig 5



STATOR ASSEMBLY

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.

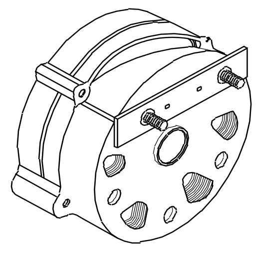
Slip ring end frame (Fig 6)

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.

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.

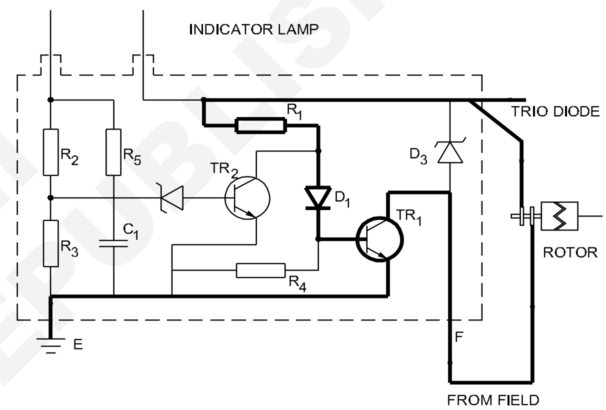
Fig 6



SPRING END FRAME

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 7



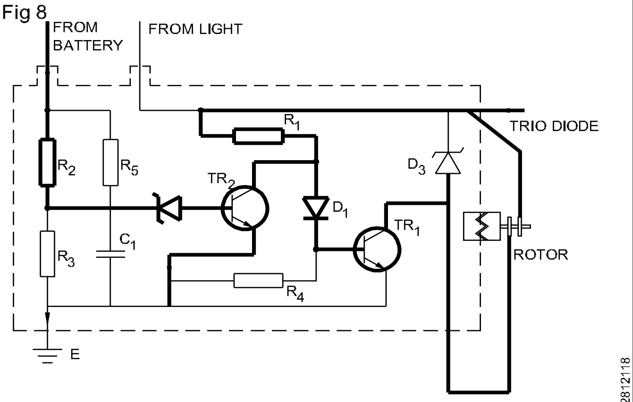
FIELD TURNED ON

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 zener 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 zener 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.

Fig 8



FIELD TURNED OFF

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.

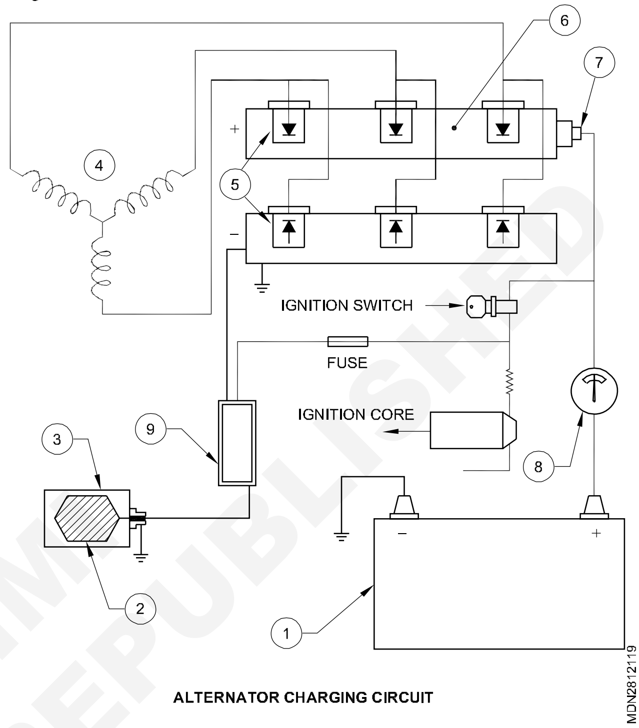
If more rotor magnets pass through each stator coil (4) in a given time, the generation of current will be more, since they form the ends of metal fingers, each finger acting like a magnet. These fingers interlock but do not touch each other.

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.**

Differences between Alternator and DC Generator/Dynamo

	Alternator	DC Generator/Dynamo
1	The alternator develops DC current	The generator also 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.

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.

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 loose.	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.
2 Over charging	Defective gauge	Replace.
3 Low output	Worn or dirty slip rings.	Replace.
	Loose connections.	Tighten.
4 Alternator noise	End bearing worn out	Replace
	Rotor touch with stator	Rectify

Starting motor

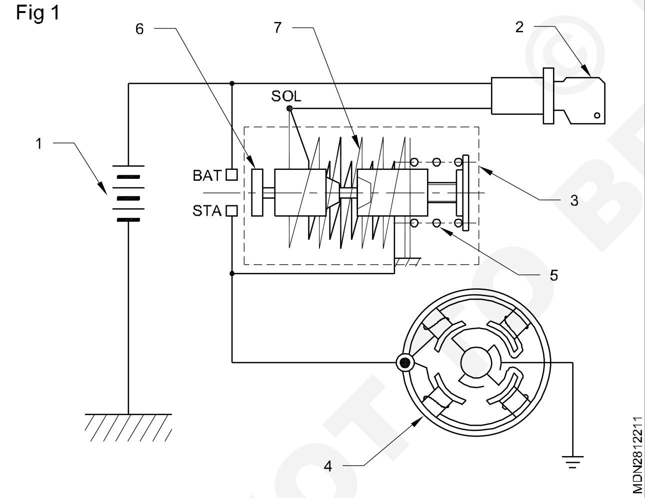
Objectives : At the end of this lesson you shall be able to
- **explain starting circuit**
- **explain the construction of a starter motor**
- **explain the functions of a starter motor**
- **explain the functions of a starter drive unit**
- **explain the need of a solenoid switch**
- **explain the construction 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 a 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.

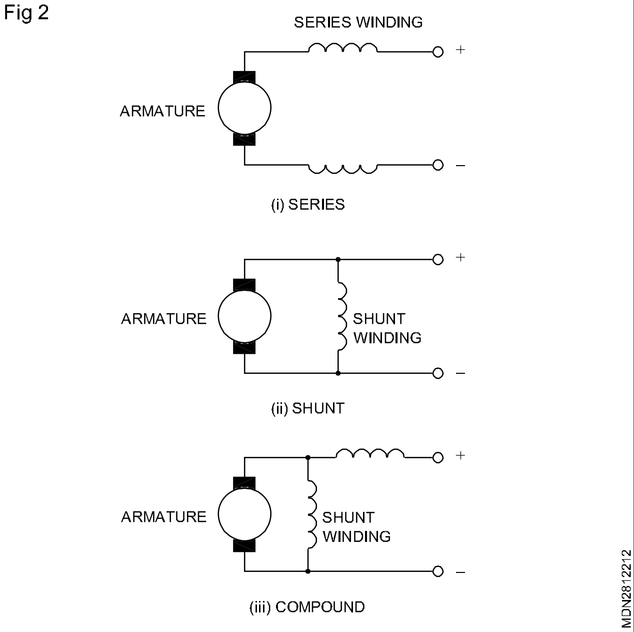
- Series (Fig 2)
- Shunt
- Compound

In Automotive 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.

Fig 2

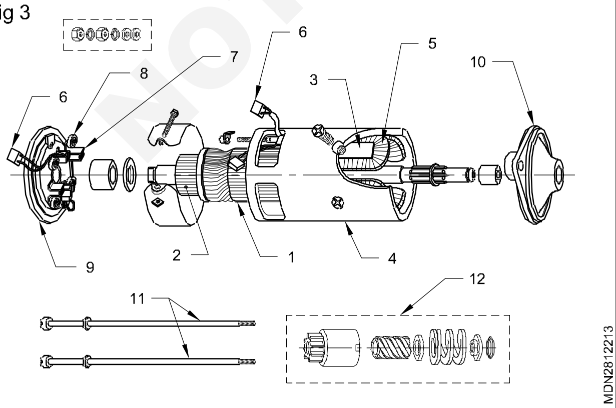


Operation of starter motor

Current from the battery is supplied to the armature's (1) (Fig 3) coil by two or four stationary brushes (6). These brushes (6) are in contact with the commutator's (2) segments. The same current is also supplied to the field coils (5). Both the field coil (5) and the armature's (1) magnetic field attract and refuse each other and cause the armature to rotate. Each coil of armature (1) is connected to one pair of copper segments of the commutator (2). The brushes come in contact with each coil of the armature (1) by turn, and in the process the armature's speed increases further.

Once the engine starts running under its own power it attains a speed up to 4000 r.p.m. (depending upon the design). Since the flywheel ring to starter pinion ratio is very high, the starter pinion will rotate at a much higher speed than the engine. This speed will damage the starting motor by throwing the windings out of the armature slots and also the commutator segments due to centrifugal force. In order to prevent this it is necessary to disengage the starter pinion from the flywheel ring gear once the engine has started. To achieve this three types of drive mechanisms are used.

Fig 3



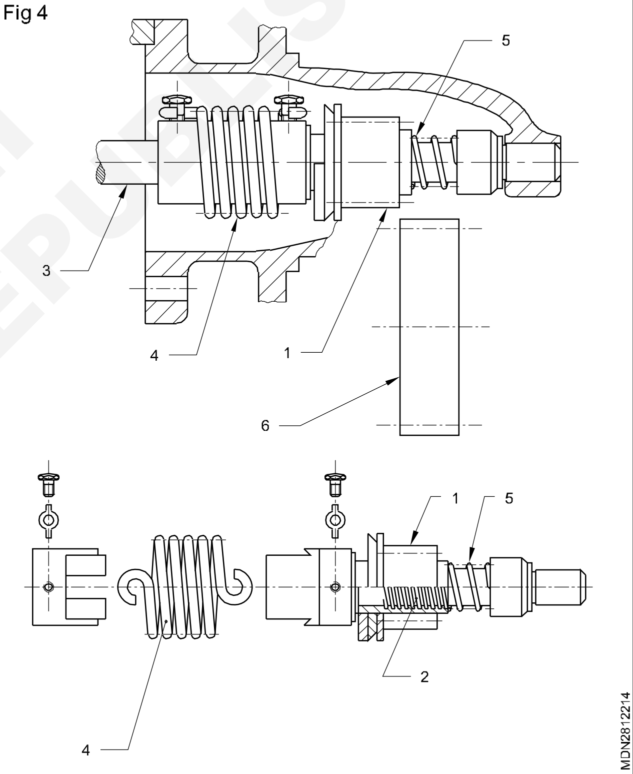
- Bendix drive
- Over-running clutch drive
- Axial or sliding armature type and non-coaxial type

Bendix drive

This is a most commonly used mechanism. It consists of a pinion (1) (Fig 4) which is mounted on a hollow sleeve. The pinion (1) has internal screw threads and is loose fitted on the sleeve (2). The armature shaft (3) is supported by bearings at both the ends. A bendix drive spring (4) is provided to limit the turning of the sleeve on the armature shaft. An anti-drift spring (5) is provided to prevent the pinion from striking the flywheel (6).

When the motor is switched on, the drive head rotates with the armature shaft (3). This motion is transmitted to the sleeve. The pinion (1) rotates along with the sleeve and travels forward to come in mesh with the flywheel ring gear (6). Now the engine's crankshaft rotates and the engine is started. When the engine speed increases the pinion (1) is thrown back to its original position due to inertia.

Fig 4



Over running clutch drive

The shift lever (2) is used by the over-running clutch to slide the pinion along the armature shaft (3) for meshing into or out of the flywheel teeth (4). The shift lever (2) is operated either by a solenoid (5) or by manual linkage. The over-running clutch permits the drive pinion (1) to run faster than the armature for a brief period during which the pinion (1) remains in mesh with the ring gear (4) once the engine has started. This protects the armature from damage due to over-speeding. (Fig 5 & Fig 6)

The over-running clutch, (Fig 7) which consists of a shell and a sleeve (1) assembly, is splined to the armature shaft (8), so that the shell is driven by the shaft.

Fig 5

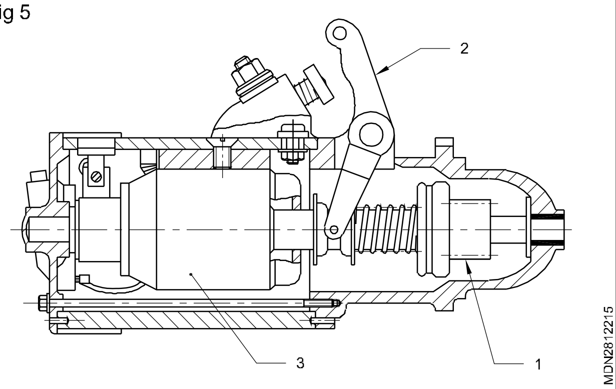
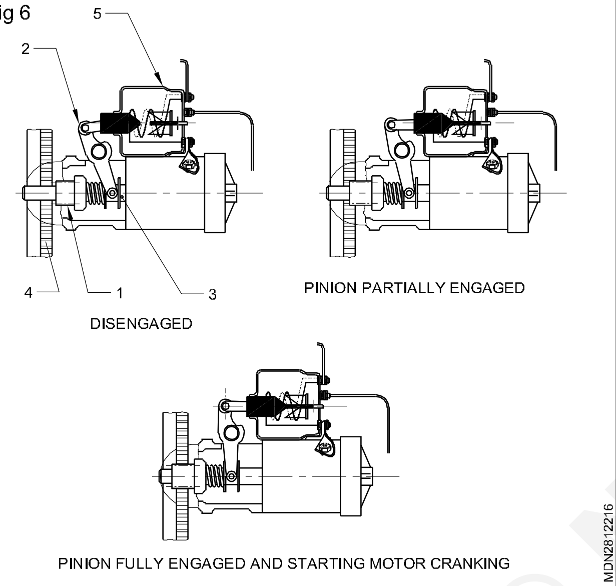


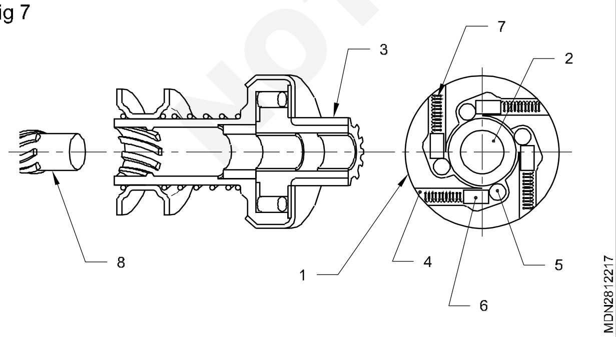
Fig 6



The pinion gear (3) is fastened to a collar (9) which is fitted inside the clutch shell. Four tapered notches (4) cut in the shell contain steel rollers (5). These are held in the small ends of the notches by spring (7) and plunger assemblies so that the rollers contact the collar.

The pinion (3) is forced to rotate with the armature shaft and cranks the engine. When the engine starts its attempts to drive the armature shaft (8) cause the rollers (5) to rotate out of the small ends of the notches. This will release the collar (3) from the shaft. This allows the pinion (3) to rotate at high speed without driving the armature.

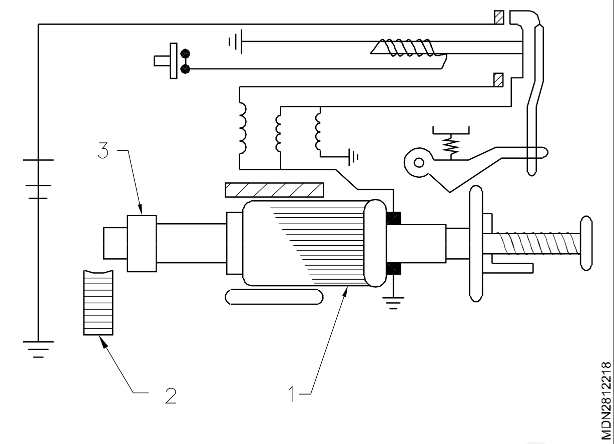
Fig 7



Axial or sliding armature drive

This type of drive allows its armature (1) (Fig 8) to slide in order to enable its pinion to come in mesh with the flywheel ring gear (2).

Fig 8



When the starter switch is operated, the solenoid coil is energised. This completes the circuit of the shunt winding and also of an axillary series field winding. The armature is pulled due to the magnetic field and the pinion (3) engages with the flywheel ring gear (2). A clutch is provided between the armature (1) and pinion (1). When the starter switch is released, the armature returns to its original position by the return spring. Since the pinion (1) is still in mesh with the flywheel (2).

It rotates at very high speed but the clutch prevents the rotation of the armature at the pinion's speed and prevents damage to the armature. The pinion is held in mesh until the starter switch is released by the auxiliary shunt winding. When the engine starts, the current falls down and the magnetic field is reduced. Now the pinion is pulled back to its position by the spring.

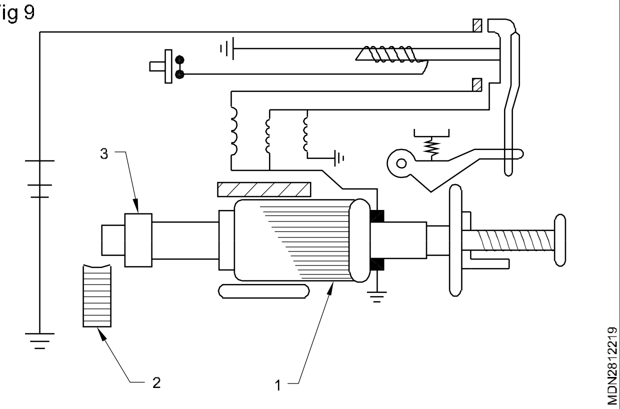
Need of solenoid switch

The solenoid switch is a strong electromagnetic switch. It is used to operate the over-running clutch drive pinion to engage with the flywheel ring gear. It also acts as a relay to close the contacts between the battery and the starting motor.

Construction of solenoid switch (Fig 9)

In a solenoid there are two windings, a pull-in winding (1) and a hold-in winding (2). The pull-in winding (1) is wound with thick wires (series winding) and the hold-in winding (2) is of thin wires (shunt winding). The pull-in winding (1) is connected to the starter switch (3) in the solenoid.

Fig 9



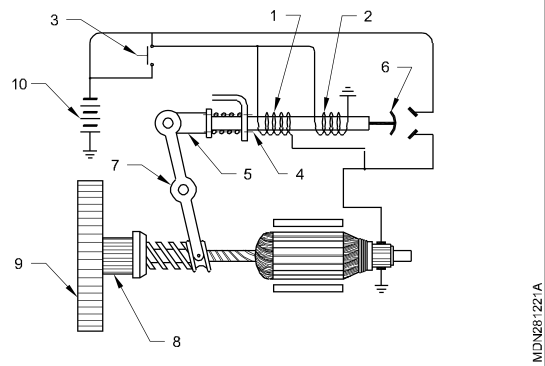
The hold in winding (2) is connected across the switch terminal and ground. The two windings are wound around a hollow core (4). An iron plunger (5) is placed inside the core (4).

The other end of the plunger moves a shift lever (7) to engage the pinion (8) with the flywheel ring gear (9).

Function of solenoid switch (Fig 10)

When the starter switch (3) is turned, current flows from 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 starting motor.

Fig 10



Common troubles and remedy in starter circit

Troubles	Remedies
Heavy starter cable terminal worm unit solenoid coil defective sleeve operating lever bend Replace/Replace	Replace Replace the solenoid
Pinion gear teeth worn-out	Replace the pinion
Armature short circuit	Rewinding/Replace
Commutator worn-out	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

Troubleshooting (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
Raptured 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 head	Retighten or replace head gasket
Valve in proper seating	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 / top-up coolant
Lack of lubrication	Top up engine oil
Erratically working thermostat	Replace
Radiator core tubes clogged	Repair or Replace
water pump performance poor	Repair or Replace
Wrong injection timing	Set proper timing

Engine overheating Contd.....

Causes	Remedies
Leaky radiator core tube	Repair
blocked silencer	Clean
Closed radiator shutter	Open
Closed radiator fins	Straighten the fins
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 reborn
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 worn-out	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
Worn out oil pump gear	Replace gears
Strainer pipe mounting loose	Tighten
Defective oil pressure gauge	Replace
Defective pressure relief valve	Replace
Crank/camshaft bearing worn out	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
High oil level in the sump	Maintain the correct oil level

Engine noise

Causes	Remedies
Worn-out gudgeon pins	Replace
Worn-out 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 worn-out	Replace