MECHANIC MACHINE TOOL MAINTENANCE

NSQF LEVEL - 4

2nd Year

TRADE THEORY

Sector: C G & M

(As per revised syllabus July 2022 - 1200 Hrs)

Directorate General of Training

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

NATIONAL INSTRUCTIONAL MEDIA INSTITUTE, CHENNAI

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

Sector : C G & M

Duration : 2 Years

Trade : Mechanic Machine Tool Maintenance - 2nd Year - Trade Theory - NSQF Level - 4 (Revised 2022)

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Post Box No.3142
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INDIA
Email: chennai-nimi@nic.in
Website: www.nimi.gov.in

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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 2022 to help them secure jobs as part of the National Skills Development Policy. Industrial Training Institutes (ITIs) play a vital role in this process especially in terms of providing skilled manpower. Keeping this in mind, and for providing the current industry relevant skill training to Trainees, ITI syllabus has been recently updated with the help of comprising various stakeholders 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 Machine Tool Maintenance - 2nd Year - Trade Theory - NSQF Level - 4 (Revised 2022) in C G & M Sector** under **Annual pattern**. The NSQF Level - 4 (Revised 2022) Trade Theory will help the trainees to get an international equivalency standard where their skill proficiency and competency will be duly recognized across the globe and this will also increase the scope of recognition of prior learning. NSQF Level - 4 (Revised 2022) trainees will also get the opportunities to promote life long learning and skill development. I have no doubt that with NSQF Level - 4 (Revised 2022) the trainers and trainees of ITIs, and all stakeholders will derive maximum benefits from these Instructional Media Packages IMPs and that NIMI's effort will go a long way in improving the quality of Vocational training in the country.

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

Jai Hind

ATUL KUMAR TIWARI, ***I.A.S***
Secretary
Ministry of Skill Development & Entrepreneurship,
Government of India.

January 2024
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 Directorate General of Training, Ministry of Skill Development and Entrepreneurship) Government of India, with technical assistance from the Govt. of 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**

ACKNOWLEDGEMENT

National Instructional Media Institute (NIMI) sincerely acknowledges with thanks for the co-operation and contribution extended by the following Media Developers and their sponsoring organisation to bring out this IMP **(Trade Theory)** for the trade of **Mechanic Machine Tool Maintenance** under the **C G & M** Sector for ITIs.

MEDIA DEVELOPMENT COMMITTEE MEMBERS

Shri. D. Gunasekaran	-	Assistant Training Officer, Govt ITI, Coimbatore.
Shri. A. Vijayarahavan	-	ADT (Rtd) NSTI, MDC Member, NIMI.
Shri.T. Manoj Kumar	-	Training Officer (Rtd), RI Centre, Kozhikode.
Shri. A. Jayaraman	-	Training Officer (Rtd) NSTI, MDC Member, NIMI.
Shri. M. Gunasekaran	-	Training Officer (Rtd) NSTI, MDC Member, NIMI.
Shri. G. Mani	-	JWM (Rtd), MDC Member, NIMI.
Shri. V. Janarthanan	-	Assistant Professor (Rtd), MDC Member, NIMI.

NIMI COORDINATORS

Shri. Nirmalya Nath	-	Deputy Director, NIMI, Chennai - 32.
Shri. V. Gopalakrishnan	-	Manager, NIMI, Chennai - 32.

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

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

NIMI is grateful to all others who have directly or indirectly helped in developing this IMP.

INTRODUCTION

TRADE PRACTICAL

The trade practical manual is intented 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 Machine Tool Maintenance** trade supplemented and supported by instructions/ informations to assist in performing the exercises. These exercises are designed to ensure that all the skills in compliance with NSQF LEVEL - 4 (Revised 2022) syllabus are covered.

This manual is divided into Eleven modules.

Module 1 : Welding

Module 2 : Hydraulics & Pneumatic

Module 3 : Pipes & Valves

Module 4 : Milling

Module 5 : Grinding

Module 6 : Electrical & Electronics

Module 7 : PLC

Module 8 : CNC Turning

Module 9 : Pump and compressor

Module 10 : Material Handling Equipments

Module 11 : Maintenance & Testing

The skill training in the shop floor is planned through a series of practical exercises centred 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 Machine Tool Maintenance 2nd Year NSQF LEVEL - 4 (Revised 2022)** in **C G & M**. The contents are sequenced according to the practical exercise contained in NSQF LEVEL - 4 (Revised 2022) syllabus on TradeTheory 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 at least one class before performing the related skills in the shop floor. The trade theory is to be treated as an integrated part of each exercise.

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

CONTENTS

LEARNING / ASSESSABLE OUTCOME

On completion of this book you shall be able to

Sl.No.	Learning Outcome	Exercise No.
1	Make / Produce different joints by setting up of gas and arc welding machines and carry out the welding. (Mapped NOS: CSC/N0304)	**2.1.122 - 2.1.127**
2	Identify, dismantle, replace and assemble different pneumatics and hydraulics components. [Different components – Compressor, Pressure Gauge, Filter Regulator, Lubricator, Valves and Actuators.] (NOS:CSC/N9488)	**2.2.128 - 2.2.139**
3	Construct circuit of pneumatics and hydraulics observing standard operating procedure& safety aspect. (NOS:CSC/N9489)	**2.2.140 - 2.2.150**
4	Make pipe/tube fittings and valve connections for lubricants and coolants, test for leakages. (Mapped NOS: CSC/N0901)	**2.3.151 - 2.3.158**
5	Conduct preventive maintenance, perform dismantling and assembly of different components machine and test for accuracy of milling machine. (Mapped NOS: CSC/N0901)	**2.4.159 - 2.4.161**
6	Set the different grinding machine and produce component to appropriate accuracy. [Different machine:- Surface & cylindrical grinding; appropriate accuracy ±0.02mm] (Mapped NOS: CSC/N0304)	**2.5.162 - 2.5.167**
7	Conduct preventive maintenance, perform dismantling & assembly of different components of grinding machine and test for accuracy. [Different components grinding head, lead screw, table, hydraulic cylinders] (Mapped NOS: CSC/N0901)	**2.5.168 - 2.5.170**
8	Identify and explain basic functioning of different electrical equipment, sensors and apply such knowledge in industrial application including basic maintenance work. [Different electrical & electronics equipment- DC/ AC motors, passive & active electronic components, resistor, capacitor, inductors, rectifier, diode transistor, SCRS & ICS; Different sensors – proximity & ultrasonic] (Mapped NOS: CSC/N0305)	**2.6.171 - 2.6.189**
9	Programme PLC and interface with other devices to check its Applications. (NOS:CSC/N9490)	**2.7.192 - 2.7.198**
10	Prepare part programme, test on simulation software and interpret different errors. (NOS:CSC/N9491)	**2.8.199 - 2.8.212**
11	Troubleshoot & Overhaul of pumps, fans, blowers & compressors and perform preventive maintenance. (Mapped NOS: CSC/N0901)	**2.9.213 - 2.9.224**
12	Identify fault carryout maintenance work and break down of different machineries/ equipments viz., shaper, surface grinding, drilling, lathe, milling, in the shop floor, using appropriate tools &equipments to ensure its functionality. (Mapped NOS: CSC/N0901)	**2.10.225 - 2.11.236**

SYLLABUS

2nd Year **Duration: Two years**

Duration	Reference Learning Outcome	Professional Skill (Trade Practical) (With inidcative hour)	Professional Knowledge (Trade Theory)
Professional Skill 40 Hrs; Professional Knowledge 10Hrs;	Make / Produce different joints by setting up of gas and arc welding machines and carry out the welding. (Mapped NOS: CSC/N0304)	122. Setting up an Arc welding machine. (5hrs) 123. Edge preparation of material for Arc welding. (5hrs) 124. Perform square lap joint, butt joint, tee joint and Pipe Joint in Arc welding. (10hrs) 125. Making straight beads in gas welding. (4hrs) 126. Perform square lap joint, but joint & tee joint in Gas welding. (08hrs) 127. Perform gas cutting of MS plate. (08hrs)	**Arc Welding:**Introduction to arc welding and its safety. Welding types, Common tools used in welding. Basic Electricity as applied to Welding Arc Length & its effects Arc Welding Machines: - advantages & disadvantages of AC & DC Arc Welding Machine. Electrodes: - Sizes & Coding. Edge Preparation: Nomenclature of butt & fillet welding. Welding Symbols & Weld defects. **Gas Welding:**Introduction to gas welding process, its classifications, accessories and its safety. **Gas Cutting:** Principle of gas cutting. Systems of Oxy-Acetylene Welding- Flashback & backfire. Types of Oxy-Acetylene flames: - Gases used in welding & Gas flame combination. Safety in gas cutting process. (10 hrs)
Professional Skill 60Hrs; Professional Knowledge 18Hrs .	Identify, dismantle, replace and assemble different pneumatics and hydraulics components. [Different components – Compressor, Pressure Gauge, Filter Regulator Lubricator, Valves and Actuators.] (NOS:CSC/N9488)	128. Demonstrate knowledge of safety procedures in hydraulic systems (Demo by video). (4 hrs) 129. Identify hydraulic components – Pumps, Reservoir, Fluids, Pressure relief valve (PRV), Filters, different types of valves, actuators, and hoses. (07 hrs) 130. Inspect fluid levels, service reservoirs, clean/replace filters. (10hrs)	**Hydraulics & Pneumatics** Basic principles of Hydraulics - Advantages & limitation of hydraulic system, hydrostatic transmission, Pascal's law, Brahma's press, pressure Temperature & flow, speed of an actuator. Control valves: Different type of control valves used in hydraulic System. Function of pressure control valve, directional control valve, check valve, flow control valve. (06 hrs)
		131. Identify pneumatic components – Compressor, pressure gauge, Filter-Regulator-Lubricator (FRL) unit, and Different types of valves and actuators. (2 hrs)	Compressed air generation and conditioning, Air compressors, Pressure regulation, Dryers, Air receiver, Conductors and

Duration	Reference Learning Outcome	Professional Skill (Trade Practical) (With inidcative hour)	Professional Knowledge (Trade Theory)
		132. Dismantle, replace, and assemble FRL unit. (5 hrs) 133. Demonstrate knowledge of safety procedures in pneumatic systems and personal Protective Equipment (PPE). (2 hrs) 134. Identify the parts of a pneumatic cylinder.(1 hr) 135. Dismantle and assemble a pneumatic cylinder.(4 hrs) 136. Construct a circuit for the direction & speed control of a small-bore single-acting (s/a) pneumatic cylinder. (5 hrs) 137. Construct a control circuit for the control of a double acting pneumatic cylinder with momentary input signals. (5 hrs) 138. Construct a circuit for the direct & indirect control of a double acting pneumatic cylinder with a single & double solenoid valve. (08 hrs) 139. Dismantling &Assembling of solenoid valves. (07 hrs)	fittings, FRL unit, Applications of pneumatics, Hazards & safety precautions in pneumatic systems. Pneumatic actuators:- Types, Basic operation, Force, Stroke length, Single-acting and double-acting cylinders. Pneumatic valves:- Classification, Symbols of pneumatic components, 3/2-way valves (NO & NC types) (manually-actuated & pneumatically-actuated) & 5/2-way valves, Check valves, Flow control valves, One-way flow control valve Pneumatic valves: Roller valve, Shuttle valve, Two-pressure valve Electro-pneumatics: Introduction, 3/2-way single solenoid valve, 5/2-way single solenoid valve, 5/2-way double solenoid valve, Control components -Pushbuttons (NO & NC type) and Electromagnetic relay unit, Logic controls (12 hrs)
Professional Skill 110Hrs; Professional Knowledge 30Hrs .	Construct circuit of pneumatics and hydraulics observing standard operating procedure& safety aspect. (NOS:CSC/N9489)	140. Inspect hose for twist, kinks, and minimum bend radius, Inspect hose/tube fittings. (5 hrs) 141. Identify internal parts of hydraulic cylinders, pumps/motors. (10 hrs) 142. Construct a circuit for the control of a single acting hydraulic cylinder using a 3/2-way valve (Weight loaded double acting cylinder may be used as a single acting cylinder), 4/2 & 4/3 way valves. (10 hrs) 143. Perform overhauling of hydraulic pump. (10hrs) 144. Maintenance, troubleshooting, and safety aspects of pneumatic and hydraulic systems (The practical for this component may demonstrated by video). (13 hrs)	- Symbols of hydraulic components, Hydraulic oils – function, properties, and types, Contamination in oils and its control - Hydraulic Filters – types, constructional features, and their typical installation locations, cavitations, Hazards & safety precautions in hydraulic systems - Hydraulic reservoir & accessories, Pumps, Classification – Gear/ vane/ piston types, Pressure relief valves – Direct acting and pilot-operated types - Pipes, tubing, Hoses and fittings – Constructional details, Minimum bend radius, routing tips for hoses - Hydraulic cylinders –Types - Hydraulic motors –Types - Hydraulic valves: Classification, Directional Control valves – 2/2- and 3/2-way valves - Hydraulic valves: 4/2- and 4/3-way valves, Centre positions of 4/3-way valves

Duration	Reference Learning Outcome	Professional Skill (Trade Practical) (With inidcative hour)	Professional Knowledge (Trade Theory)
			- Hydraulic valves: Check valves and Pilot-operated check valves, Load holding function - Flow control valves: Types, Speed control methods – meter-in and meter-out - Preventive maintenance & troubleshooting of pneumatic & hydraulic systems, System malfunctions due to contamination, leakage, friction, improper mountings, cavitations, and proper sampling of hydraulic oils (13 hrs)
.		145. Construct Electro Hydraulic circuit –Speed and Pressure control of double acting cylinder.(10 hrs) 146. Perform overhauling of pneumatic cylinders. (12hrs) 147. Perform overhauling of hydraulic actuators. (10hrs) 148. Disassembly of power pack, hydraulic pipes, ferrules, hydraulic cylinders, pistons etc. (10hrs) 149. Replacing &refitting of hydraulic pipes, seals etc. (10hrs) 150. Assemble the parts and testing of the power press after air bleeding. (10hrs)	Electro hydraulic circuit, Electrical components - Switches - Solenoid - Relay Introduction to Pneumatic actuators Pneumatic Symbols Pneumatic circuit Electrical control components - Switches - Solenoid - Relay Study & working of a hydraulic press along with its components. Breakdown & preventive maintenance of a hydraulic press. Safety in use of and maintenance of hydraulic presses. Proximity Sensors Classification And Operation-Proximity Sensor-Types Of Proximity Sensor And Their Working-Industrial Application Sensors For Distance And Displacement -LVDT-Linear (17 hrs)
Professional Skill 80Hrs; Professional Knowledge 20Hrs	Make pipe/tube fittings and valve connections for lubricants and coolants, test for leakages. (Mapped NOS: CSC/N0901)	151. Flaring of pipes and pipe joints. (3 hrs) 152. Cutting & Threading of pipe length. (3 hrs)	Pipes and pipe fitting- commonly used pipes. Pipe schedule and standard sizes. Pipe bending methods. Use of bending fixture, pipe threads-Std. Pipe threads Die and Tap, pipe vices.

Duration	Reference Learning Outcome	Professional Skill (Trade Practical) (With inidcative hour)	Professional Knowledge (Trade Theory)
		153. Fitting of pipes as per sketch observing conditions used for pipe work. (09 hrs) 154. Bending of pipes- cold and hot. (7 hrs) 155. Fit & assemble pipes, valves and test for leakage & functionality of valves.(17 hrs) 156. Visual inspection for visual defects e.g. dents, surface finish.(3hrs)	Standard pipefitting- Methods of fitting or replacing the above fitting, repairs and erection on rainwater drainage pipes and house hold taps and pipe work. Inspection & Quality control -Visual Inspection - Basic 7 Quality tools (10 hrs)
		157. Dismantle & assembly of globe valve, gate valve, butterfly, diaphragm, direction control valve, pressure relief, non return& flow control valve. (30hrs) 158. Making & replacement of gaskets, washer. (08hrs)	Pipe colour code. Safety precautions to be observed while working at pipeline. Constructional detail of different type of valve & their uses like: Gate, Globe, butterfly, Diaphragm. (10 hrs)
Professional Skill 40Hrs; Professional Knowledge 10Hrs	Conduct preventive maintenance, perform dismantling and assembly of different components machine and test for accuracy of milling machine. (Mapped NOS: CSC/ N0901)	159. Dismantle and assemble of head stock, gear box lead screw, table of milling machine. (27hrs) 160. Check the accuracy of milling machine of after assembly. (08hrs) 161. Do the preventive maintenance of milling machine. (5hrs)	Breakdown maintenance and preventive maintenance of a milling machine. (10 hrs)
Professional Skill 60Hrs; Professional Knowledge 18Hrs	Set the different grinding machine and produce component to appropriate accuracy. [Different machine:- Surface & cylindrical grinding; appropriate accuracy ±0.02mm] (Mapped NOS: CSC/ N0304)	162. Demonstrate working of grinding machine. (05 hrs) 163. Set the machine, stroke length & do wheel balancing. (10 hrs) 164. Perform grinding of parallel and perpendicular surfaces (accuracy ±0.02mm). (15 hrs) 165. Perform grinding of angular surfaces grinding (accuracy ±0.02mm). (10hrs) 166. Setting the cylindrical grinding machine for grinding internal and external surfaces. (10hrs) 167. Setting the machine for grinding taper holes. (10hrs)	**Grinding:** Grinding machine – introduction, parts & constructional details, types – surface grinding and cylindrical grinding machines. Safety precaution followed while working on grinding machines. Grinding wheels – abrasives, bond and bonding process, grit, grade, and structure of grinding wheels and its marking system. Procedure for mounting of grinding wheels, balancing of grinding wheels, dressing and truing of grinding wheels, glazing and loading in grinding wheel. (18 hrs)

Duration	Reference Learning Outcome	Professional Skill (Trade Practical) (With inidcative hour)	Professional Knowledge (Trade Theory)
Professional Skill 40Hrs; Professional Knowledge 10Hrs	Conduct preventive maintenance, perform dismantling & assembly of different components of grinding machine and test for accuracy. [Different components grinding head, lead screw, table, hydraulic cylinders] (Mapped NOS: CSC/N0901)	168. Dismantle and assembly of grinding head, lead screw, table, hydraulic cylinders of grinding machine. (20hrs) 169. Check the accuracy of grinding machine after assembly. (10hrs) 170. Do the preventive maintenance of surface grinder and cylindrical grinding machine. (10hrs)	Preventive and breakdown maintenance of grinding machine. (10 hrs)
Professional Skill 110Hrs; Professional Knowledge 30Hrs	Identify and explain basic functioning of different electrical equipment, sensors and apply such knowledge in industrial application including basic maintenance work. [Different electrical & electronics equipment- DC/ AC motors, passive & active electronic components, resistor, capacitor, inductors, rectifier, diode transistor, SCRS & ICS; Different sensors – proximity & ultrasonic] (Mapped NOS: CSC/N0305)	171. Behaviour of Proximity Sensors. (5hrs) 172. Behaviour of ultrasonic sensors. (5hrs) 173. Logical Operation of Sensors. (5hrs) 174. Limit & Level Control using Sensors. (5hrs) 175. Interfacing of Sensors with Electrical Actuators. (5hrs) 176. Making simple wiring circuits and measurement of current and voltage. (5hrs) 177. Testing of power supply (AC & DC).(5 hrs) 178. Demonstration of use of test lamp and megger. (5 hrs) 179. Connections of DC/AC motors and its speed control - demonstration only. (5 hrs)	Switches, Fuse And Circuit Breakers. Introduction To Sensors--Fundamental Of Sensor. Potentiometer -Ultrasonic And Optical Sensors-Industrial Application. Basic principles of DC generators and motors, Alternators and AC motors and transformers. Various types of switches, circuit breakers, fuses, lamps, proximity switches, relays and contactor in electrical circuits. Passive circuit elements – resistors, capacitors and inductors. Its identification and testing. Colour code.(12 hrs)
		180. Identification of passive & active electronic components. (8hrs) 181. Use of oscilloscope. (05hrs) 182. Demonstrate of logic gate operations. (5hrs) 183. Testing and measurement of resistors, capacitors, inductors using multimeter. (8hrs) 184. Perform soldering and de-soldering of components on printed circuit board. (PCB). (10hrs) 185. Study of rectifiers and testing with multimeter. (5hrs) 186. Preparing and checking of rectifier circuits. (6hrs)	**BASIC ELECTRONICS** Introduction to electronics and its industrial applications. Introduction to digital electronics – numbers system and logic gates. Study of electronic circuit – macro level with block diagram. (18 hrs)

Duration	Reference Learning Outcome	Professional Skill (Trade Practical) (With inidcative hour)	Professional Knowledge (Trade Theory)
		187. Demonstrate of solid state devices –diode transistors. (5hrs) 188. SCRS & ICS –identification &testing. (5hrs) 189. Assembly of simple battery eliminator circuit using bright rectifier & fitter capacitor. (8hrs)	
Professional Skill 40Hrs; Professional Knowledge 10Hrs	Programme PLC and interface with other devices to check its Applications. (NOS:CSC/N9490)	192. Ascertain various modules, controls, and indicators of given PLC. (6 hrs) 193. Program and configure the PLC to perform a simple start/stop routine. (6 hrs) 194. Program the PLC using Timer and Counter instructions. (10 hrs) 195. Program the PLC to perform Move, Arithmetic, and Logical operations. (3 hrs) 196. Program the PLC for performing comparator operations. (3 hrs) 197. Practice on PLC wiring. (9 hrs) 198. Program PLC for controlling analog parameter(s). (3 hrs)	**PLC:** Overview of different control systems. Introduction about PLC. Block diagram of PLC. Different types of PLC, PLC Architectures (Fixed and Modular). Selection of PLC. Advantages of PLC. Applications of PLC. Various types of modules used in PLC. Familiarization of AND, OR and NOT logics with examples. Registers Basics. Timer Functions. Counter Functions. Introduction and importance of Sequential Control Systems. Communication protocols used in PLC: RS-232, RS-485, Ethernet, Profibus. Different programming languages of PLC: LDR, STL,FBD, CSF. Basic ladder programming of PLC. Configuration of PLC and its modules. Wiring of PLC. (10 hrs)
Professional Skill 60Hrs; Professional Knowledge 18Hrs	Prepare part programme, test on simulation software and interpret different errors. (NOS:CSC/N9491)	199. Knowledge rules of personal and CNC machine safety, safe handling of tools, safety switches and material handling equipment using CNC didactic/simulation software and equipment. (5hrs) 200. Identify CNC lathe machine elements and their functions. (5hrs) 201. Understand the working of parts of CNC lathe, using CNC didactic/ simulation software. (05hrs) 202. Identify common tool holder and insert shapes by ISO nomenclature. (5hrs) 203. Select cutting parameters from tool manufacturer's catalogue. (2hrs)	Concept of Co-ordinate geometry, concept of machine coordinate axis, axes convention on CNC lathes, work zero, machine zero. Converting part diameters and lengths into co-ordinate system points. Absolute and incremental programming. Programming – sequence, formats, different codes and words. ISO G codes and M codes for CNC turning. Describe CNC interpolation, open and close loop control systems. Co-ordinate systems and Points. Cutting tool materials, application of various materials.

Duration	Reference Learning Outcome	Professional Skill (Trade Practical) (With inidcative hour)	Professional Knowledge (Trade Theory)
		204. Write CNC programs for simple tool motions and parts using linear and circular interpolation; check on program verification/ simulation software. (04hrs) 205. Write CNC part programs using canned cycles for stock removal, grooving, threading operations, with drilling and finish turning. Use TNRC commands for finish turning. Check simulation on program verification/ simulation software. (06 hrs) 206. Avoiding collisions caused by program errors. Knowing causes and effects of collisions due to program errors, by making deliberate program errors and simulation on program verification/ simulation software. (6hrs) 207. Simple turning & Facing (step turning) without using canned cycles, on CNC simulator. (06 hrs) 208. Program checking in dry run, single block modes, on CNC simulator (2hrs) 209. Absolute and incremental programmingassignments and simulation. (6hrs) 210. Checking finish size by over sizing through tool offsets, on CNC simulator. (2hrs) 211. Recovering from axes over travel, on CNC simulator. (1 hr) 212. Interpret different messages generated against different errors. (05hrs)	Cutting tool geometry for internal and external turning, grooving, threading, face grooving, drilling. Insert holding methods for each. Writing part programs as per drawing & checking using CNC program verification/ simulation software. Process planning, work holding, tool and cutting parameters selection according to the part geometry and dimensions. Collisions due to program errors, effects of collisions. Costs associated with collisions – tool breakage, machine damage, injuries. Find out alarm codes and meaning of those codes. Program execution in different modes like MDI, single block and auto. Process planning & sequencing, tool layout & selection and cutting parameters selection. Work and tool offsets. Inputs value to the offset/ geometry page into machine. First part checking: Program checking in single block and dry run modes – necessity and method. (18 hrs)
Professional Skill 90Hrs; Professional Knowledge 20Hrs	Troubleshoot & Overhaul of pumps, fans, blowers & compressors and perform preventive maintenance. (Mapped NOS: CSC/ N0901)	213. Demonstrate various types of machine related centrifugal pump and their parts. (8hrs) 214. Overhauling of pumps with fitting of gland packing. (15hrs) 215. Priming of pump. (4hrs) 216. Testing of pump. (2hrs) 217. Perform preventive and schedule maintenance. (4hrs) 218. Trouble shooting in pump operation. (12hrs)	**Centrifugal Pump, Fan, Blower and Compressor:-** **Pump** Function of pump. Types and working principle of centrifugal pump (machine related). Constructional detail of pump Starting and stopping Pump performance and characteristics.

Duration	Reference Learning Outcome	Professional Skill (Trade Practical) (With inidcative hour)	Professional Knowledge (Trade Theory)
			Capitation & aeration Preventive & schedule maintenance of pumps. Gland packing changing procedure. Concept of Mechanical seal Trouble shooting in pump. (10 hrs)
		219. Identification of various types of fans, blowers and their parts. (5hrs) 220. Dismantle, inspect, repair/ replace work out part and assemble the same. (10hrs) 221. Demonstrate compressors and their parts. (8 hrs) 222. Cleaning and changing of filters of compressors. (8 hrs) 223. Perform schedule and preventive maintenance of blower & compressor. (6hrs) 224. Change compression ring & oil rings in a reciprocator compressor. (8 hrs)	**Fan & Blowers:** Types and working principle Constructional detail of Fans & Blowers. Starting and stopping of Fans and Blowers Different parts of Fans & Blowers Concept of surge. Preventive & scheduled maintenance. **Compressors:** Compression theory, Types of compressors Constructional detail of compressors, working mechanism Different parts and their function. Loading unloading system Concept of air dryer. Preventive & schedule maintenance. (10 hrs)
Professional Skill 110Hrs; Professional Knowledge 30Hrs	Identify fault carryout maintenance work and break down of different machineries/ equipments viz., shaper, surface grinding, drilling, lathe, milling, in the shop floor, using appropriate tools &equipments to ensure its functionality. (Mapped NOS: CSC/ N0901)	225. Demonstrate mechanical & hydraulic jack, rope puller, chain puller, chain block, and winch. (8 hrs) 226. Inspection of tools and tackles of material handling equipments. (6 hrs) 227. Shift a small machine from layout to loading centre/ different work place. (10 hrs)	Different type of jacks, chain block and pull lift. Knowledge of different types of scaffolding. Material movement by using different rigging tools and techniques. Safety appliances & precautions in rigging. Maintenance of tools and tackles. (09 hrs)
		228. Practice various belt & chain joining methods. (20 hrs) 229. Demonstrate belt conveyor system, vibratory screen & feeder. (Video demo)(6 hrs)	Bulk Material Handling (Conveyor belt, Vibratory screen, Feeders) Principle & mode of material handling.

Duration	Reference Learning Outcome	Professional Skill (Trade Practical) (With inidcative hour)	Professional Knowledge (Trade Theory)
			Various components used in belt conveyor system & their functions. (Pulleys, idlers, scrapers, skirts, belt, take up unit system and safety devices). Vibratory screen- working mechanism. Feeders- types, working mechanism. Maintenance practice-Pulley lagging, belt sway control belt joining methods. (06 hrs)
		230. Trouble shooting on machine tools such as drill, shaper, lathe & power saw machine. (15 hrs) 231. Perform overhauling of feed units of lathe milling & grinding. (15hrs) 232. Geometrical testing of machine tools. (10hrs)	Breakdown Maintenance, Preventive Maintenance, Predictive Maintenance & Concepts of TPM, OEE.(without calculations) Difference between breakdown and preventive maintenance – Its importance in productivity, types. Normal procedure followed for maintenance of machine tools on the shop floor. Accuracy testing of machine tools. Various maintenance practices. Concepts & Measurement of machine performance: MTBF, MTTR. (without calculations) (09 hrs)
		233. Preparation of check list for inspection of different machine tools. (5hrs) 234. Temperature measurement of machine tools. (5hrs) 235. Vibration measurement of machine tools. (5hrs) 236. Fault finding practice on machine tools. (05 hrs)	Inspection & Condition Monitoring. Maintenance strategy – Reactive, Preventive, Predictive and proactive. Corrective Maintenance & Plan Maintenance. Condition Base Maintenance (CBM), Reliability Centered Maintenance (RCM), Importance of inspection. Type / methods of equipment inspection. Commonly used gadgets for inspection. Concept of inspection check-list. Importance of condition monitoring and Various techniques used for condition monitoring. (vibration, temperature, sound and lubricant condition) Concept of Industry 4.0 and Digital Manufacturing. (09 hrs)

Welding (Fusion, Non-fusion and Pressure)

Objectives : At the end of this lesson you shall be able to
- **distinguish between fusion and non-fusion welding**
- **state the method of pressure welding.**

Welding is a method of joining metals permanently.

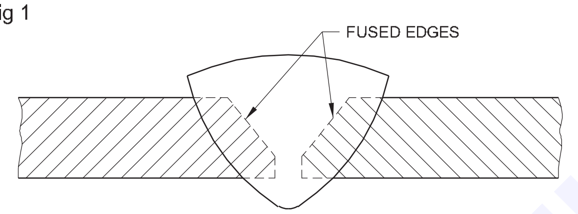
The method used in ancient days was forge welding.

Types of welding

Fusion welding (Fig 1)

A method of welding in which similar metals are joined together by melting and fusing their joining edges with or without the addition of filler metal but without the application of any kind of pressure is known as fusion welding. The joint made is permanent. The common heating sources in arc welding and gas welding.

Fig 1

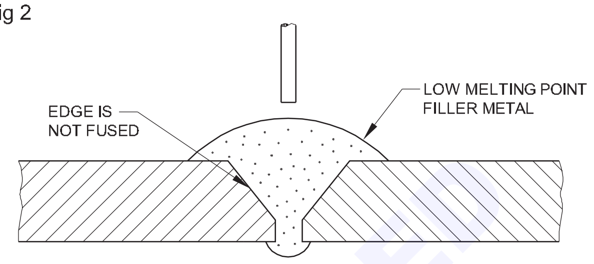


Non fusion welding

A method of welding in which similar or dissimilar metals are joined together without melting the edges is known as non-fusion welding. A low melting point filler rod is fused between the joints without the application of pressure. (Fig 2) The joint made is temporary.

The heat source may be arc or gas welding as in fusion welding.

Fig 2



Examples of non-fusion welding are silver soldering, brazing etc.

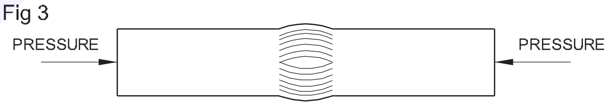
Pressure welding (Fig 3)

Pressure welding is a method of welding in which similar metals are joined together by heating them to a plastic or molten state and then joined by pressing or hammering without the use of the filler metal.

The joint made is permanent.

The heat source may be a blacksmith forge (forge welding) or electric resistance (resistance welding).

Fig 3



Safety precautions during arc welding

Objective : At the end of this lesson you shall be able to
- **state the precautions necessary in arc-welding.**

Safety precautions

- Never stand on a damp or wet place while arc-welding.
- Always wear all the safety apparels (gloves, apron, sleeves, shoes). (Fig 1)
- Use welding and a chipping screen during welding and chipping respectively, for the protection of the eyes and the face.
- Switch off the machine when not in use.
- Keep the clothes free from oil and grease.
- Use tongs while handling hot metals.
- Do not carry matches or petrol lighters in your pocket during arc-welding.
- Protect the outsiders from radiation and reflection of rays, by using portable screens or welding booths. (Fig 2)
- Keep the welding area free from moisture and flammable material.
- Do not try to rectify electrical faults yourself; call an electrician.

Fig 1

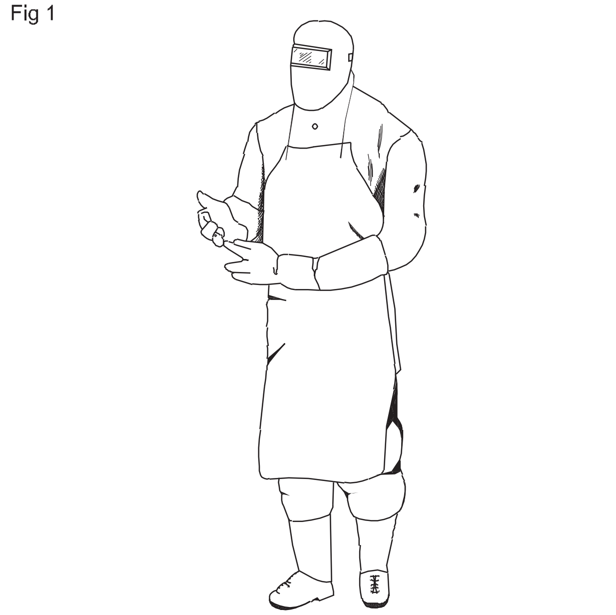
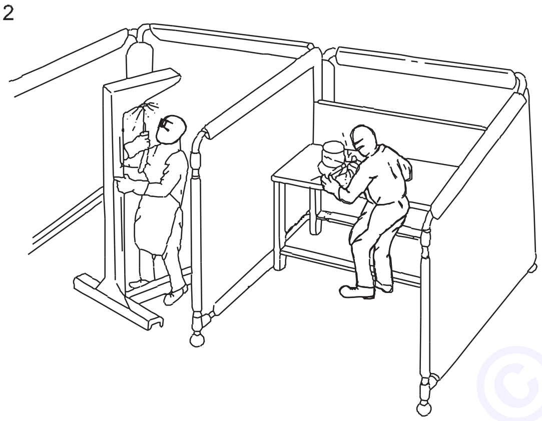
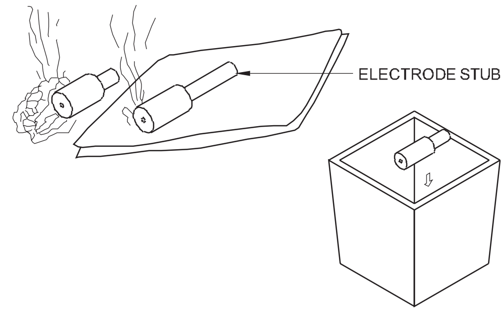


Fig 2



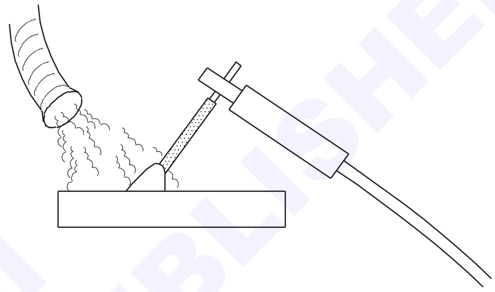
- Do not throw the electrode stubs on the floor. Put them in a container. (Fig 3)

Fig 3



- Use exhaust fans to remove the arc-welding smoke and fumes. (Fig 4)

Fig 4



Arc - Welding tools and accessories

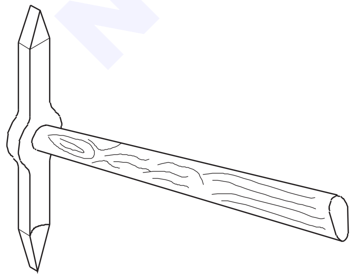
Objectives : At the end of this lesson you shall be able to
- **identify the different arc-welding tools and accessories**
- **explain the uses of each.**

Chipping hammer (Fig 1)

It is used to remove the slag from the weldment and is made of medium carbon steel.

One of its edges is pointed and the other is like that of a chisel.

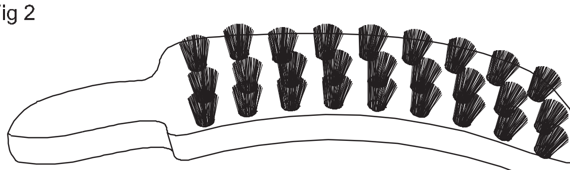
Fig 1



Wire brush (Fig 2)

It is used for cleaning the surface metal as well as the slag from the welds.

Fig 2



The wire brush is made of steel wires fitted on a wooden piece in three to five rows.

Welding hand screen (Fig 3)

A welding hand screen is used to shield and protect the face and the eyes from the arc radiation.

It is fitted with a filter lens and plain glass to protect the lens.

Welding helmet screen (Fig 4)

It is used as a hand screen but it can be worn on the head of the welder to enable him to use both his hands .

Fig 3

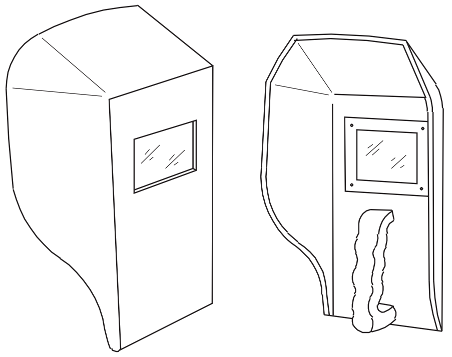
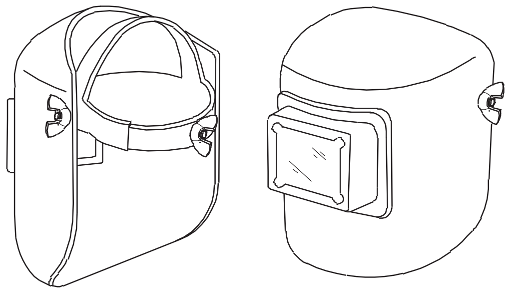


Fig 4

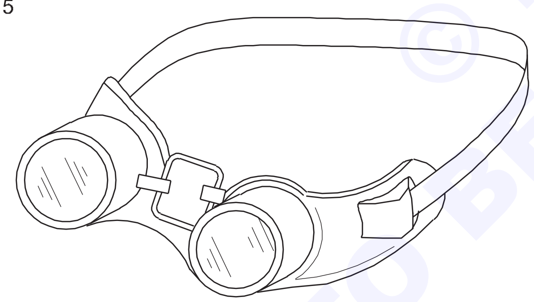


Chipping goggles (Fig 5)

Chipping goggles are used to protect the eyes while chipping the slag.

They are fitted with a plain glass to see the area to be cleaned.

Fig 5

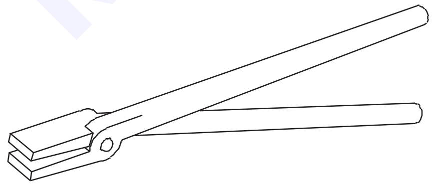


Tong (Fig 6)

Tongs are used to handle the hot metal-welding job while cleaning.

They are also used to hold the metal for hammering.

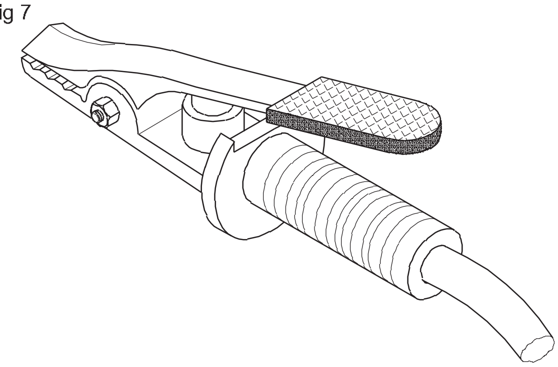
Fig 6



Electrode holder with cable (Fig 7)

An electrode holder is used to hold and manipulate the electrode.

Fig 7

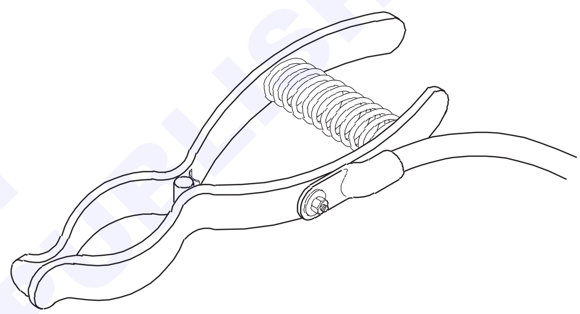


ELECTRODE HOLDER

The cable is insulated with a good quality flexible rubber and copper core wires, to carry the high current from the welding machines.

Earth clamp with cable (Fig 8)

Fig 8



An earth clamp is used to connect the return lead firmly to the job or to the welding table.

Welding table

The welding table is used to keep the jobs and assemble the pieces during welding. The top of the table is made of metal.

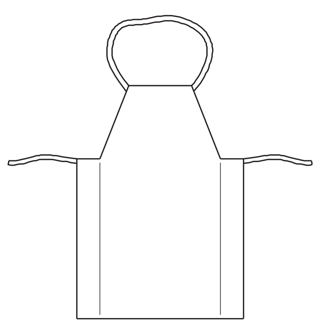
Apron (Fig 9)

An apron is used to protect the body.

It should be made of leather and worn.

It must be worn for protection from the radiation of the heat rays and hot spatters.

Fig 9

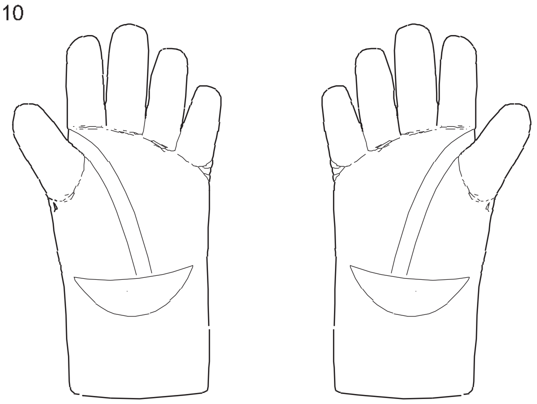


Hand gloves (Fig 10)

Hand gloves are used to protect the hands from electrical shock, arc radiation, heat and hot spatters.

The gloves are also made of leather.

Fig 10



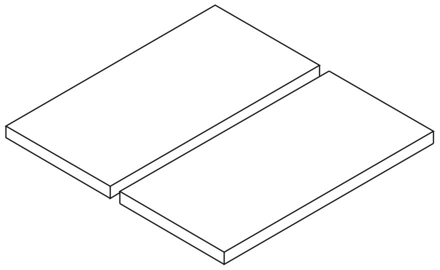
Types of edge preparation for butt joint

Objectives : At the end of this lesson you shall be able to
- **state the purpose of edge preparation in welding joints**
- **identify different edge preparations**
- **name the different methods of edge preparation.**

Butt joint (Fig 1)

A joint between two pieces lying in the same plane is called a butt joint.

Fig 1



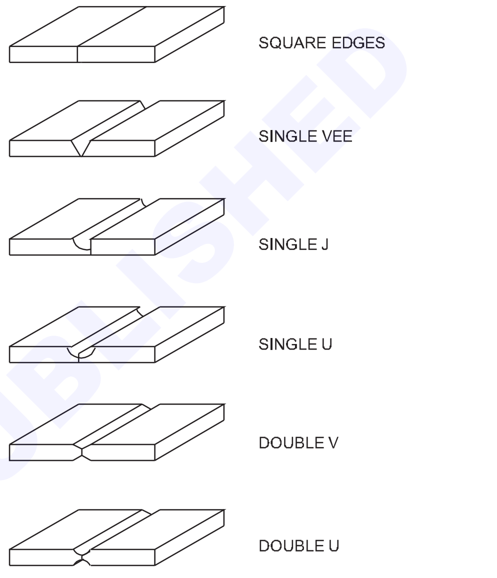
Preparing the joint edges before welding is essential to

- Ensure absolute fusion right through the joint, by cleaning the undesired elements i.e., oxide, rust, paint etc
- Weld successfully by setting the joint with a small gap.
- Make them straight/square for a correct fit up
- Ensure maximum penetration by preparing the edges to have vee or u shapes.

Types of edge preparation (Fig 2)

- Square edges
- Single Vee
- Single J
- Single U
- Double V
- Double U

Fig 2



Methods of edge preparation

The joining edges may be prepared for welding by

- Flame cutting
- Machine tool cutting
- Machine grinding or hand grinding
- Filing
- Chipping.

Basic Welding Joints and Nomenclature of butt and fillet weld

Objectives: At the end of this lesson you shall be able to
- **illustrate and name the basic welding joints.**
- **explain the nomenclature of butt and fillet welds.**

Basic welding joints (Fig 1)

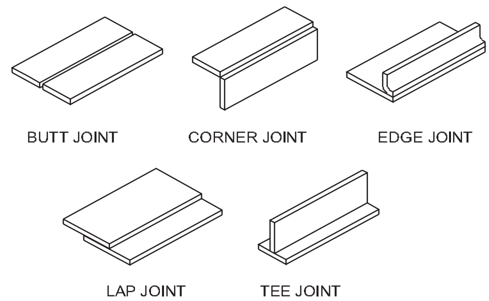
The various basic welding joints are shown in Fig 1.

The above types mean the shape of the joint, that is, how the joining edges of the parts are placed together.

Types of weld: There are two types of weld. (Fig 2)

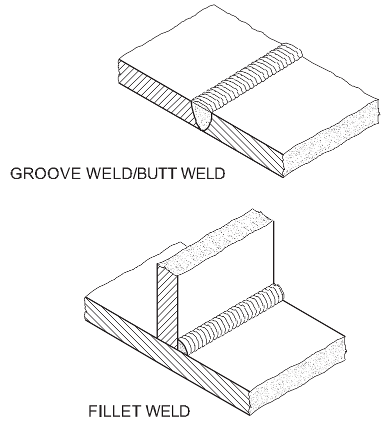
- Groove weld/butt weld
- Fillet weld

Fig 1



FUNDAMENTAL TYPE OF JOINTS

Fig 2



TYPE OF WELD

Nomenclature of butt and fillet weld (Figs 3 and 4)

Root gap: It is the distance between the parts to be joined. (Fig 3)

Heat affected zone: Metallurgical properties have been changed by the welding heat adjacent to weld.

Fig 3

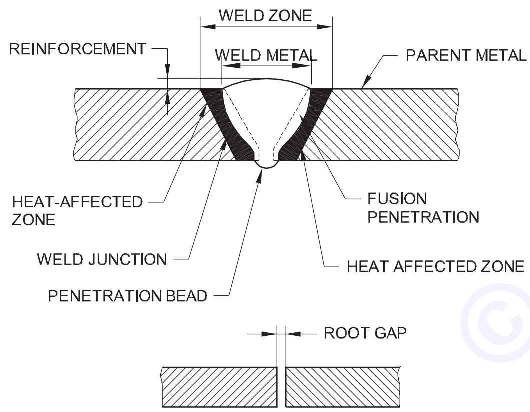
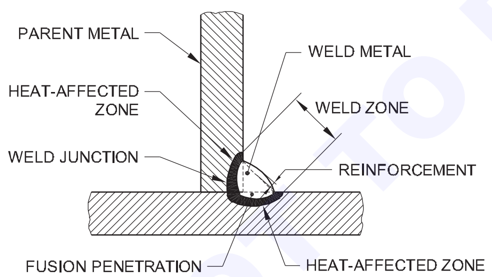


Fig 4



Leg length: The distance between the junction of the metals and the point where the weld metal touches the base metal 'toe' (Fig 5)

Parent metal: The material or the part to be welded.

Fusion penetration: The depth of fusion Zone in the parent metal. (Fig 3 and 4)

Reinforcement: Metal deposited on the surface of the parent metal of the excess metal over the line joining the two toes. (Fig 6)

Root Gap: The parts to be joined that are nearest together. (Fig 7)

Fig 5

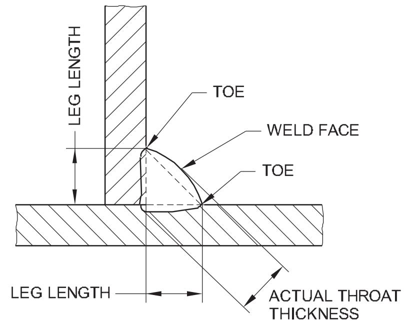


Fig 6

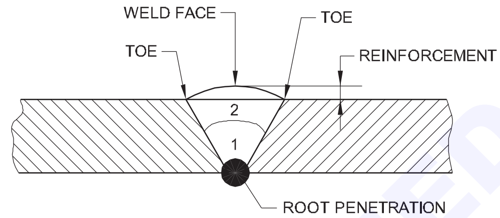
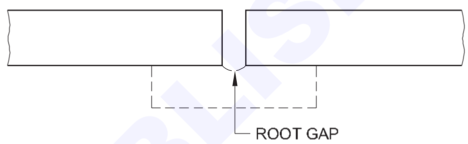
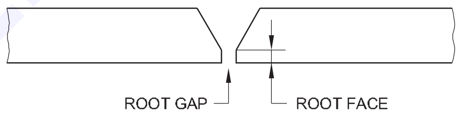


Fig 7



Root face: The surface formed by squaring off the root edge of the fusion face to avoid a sharp edge at the root. (Fig 8)

Fig 8

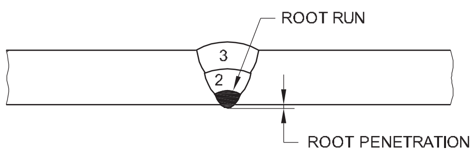


Root run: The first run deposited in the root of a joint (Fig 9)

Root penetration: It is the projection of the root run at the bottom of the joint (Fig 6 and 9)

Run: The metal deposited during one pass. Fig 9.

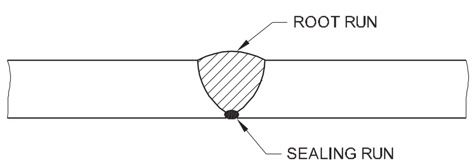
Fig 9



The second run is marked as 2 which is deposited over the root run. The third run is marked as 3 which is deposited over the second run.

Sealing run: A small weld deposited on the root side of a butt (after completion of the weld joint). (Fig 10)

Fig 10



Backing run: A small weld deposited on the root side of butt or corner joint (before welding the joint.) Fig 6

Throat thickness: The distance between the junction of metals and the midpoint on the line joining the two toes. (Fig 5)

Toe of weld: The point where the weld face joins the parent metal. (Fig 5&6.)

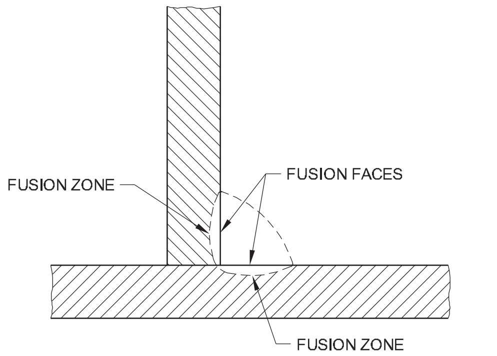
Weld face: The surface of a weld seen from the side from which the weld was made. (Fig 5&6.)

Weld Junction: The boundary between the fusion zone and the heat affected zone. (Fig 3&4)

Fusion face: The portion of a surface which is to be fused on making the weld. (Fig 11)

Fusion zone: The depth to which the parent metal has been fused. (Fig 11)

Fig 11



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Welding symbols

Objectives : At the end of this lesson you shall be able to
- **state the purpose of welding symbols**
- **interpret the common symbols used in welding.**

Welding symbols are used to convey the information required for welding from the designer to the operator. These symbols provide clearly necessary indications regarding the specific weld to be carried out.

Types of symbols

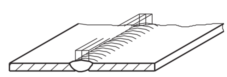
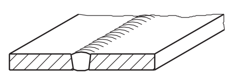
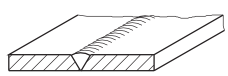
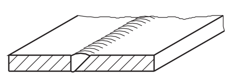
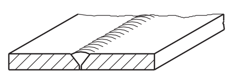
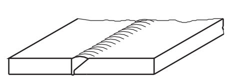
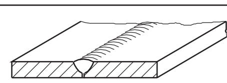
Standard symbols for arc and gas welds are given in Tables 1, 2 and 3.

Method of using symbols

See the Table 1 for applications

Table 1

(Elementary Symbols)

S.No.	Designation	Illustration	Symbol
1	Butt weld between plates with raised edges, (the raised edges being melted down completely)		
2	Square butt weld		
3	Single - V butt weld		
4	Single - bevel butt weld		
5	Single - V butt weld with broad root face		
6	Single - bevel butt weld with broad root face		
7	Single U butt weld (parallel or sloping sides)		

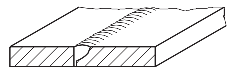
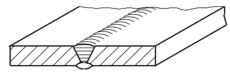
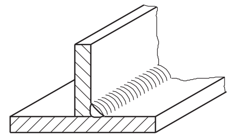
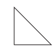
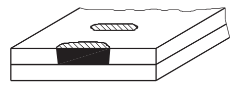
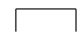
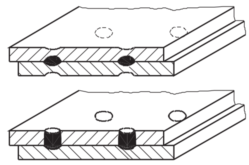
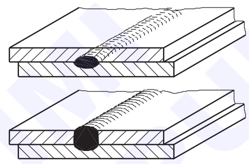
8	Single - J butt weld		
9	Backing run: back or backing weld		
10	Fillet weld		
11	Plug weld or slot weld		
12	Spot weld		
13	Seam weld		

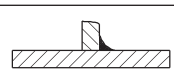
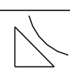
Table 2

(Supplementary Symbols)

	Shape of weld surface	Symbols
a	Flat (usually finished flush)	
b	Convex	
c	Concave	

Table 3

(Examples of Application of supplementary symbols)

Designation	Illustration	Symbol
Flat (flush) single - V butt weld		
Convex double - V butt weld		
Concave fillet weld		
Flat (flush) single V butt weld		

Methods of representation of welding symbol is shown in Fig 1

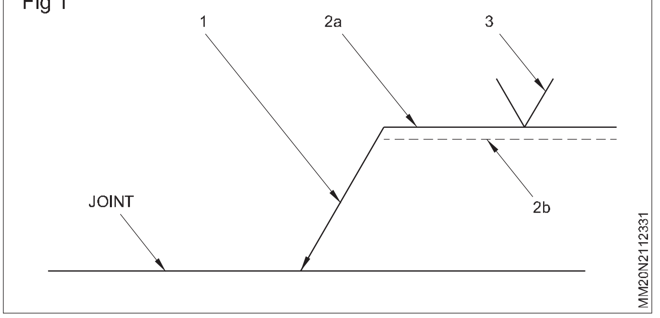
1 = Arrow line

2a = Reference line

2b = Identification line

3 = Welding symbol

Fig 1



Basic electricity as applied to welding

Objectives : At the end of this lesson you shall be able to
- **define simple electrical terms**
- **differentiate between electric current, pressure and resistance**
- **state AC and DC**
- **explain open circuit and arc voltage**
- **state OHM's law and its application**

Electricity is a kind of invisible energy which is capable of doing work such as:

- burning of lamps
- running of fans, motors, machines etc.
- producing heat.
- by creating an arc
- by electrical resistance of materials

It is dangerous to play with electricity.

Electric current: Electrons in motion is called current. The rate of flow of electrons is measured in amperes (A). The measuring instrument is called ampere meter, or ammeter.

Electric pressure/voltage: It is the pressure which makes the electric current to flow.

It is called voltage or electromotive force (emf). Its measuring unit is volt (V). The measuring instrument is called voltmeter.

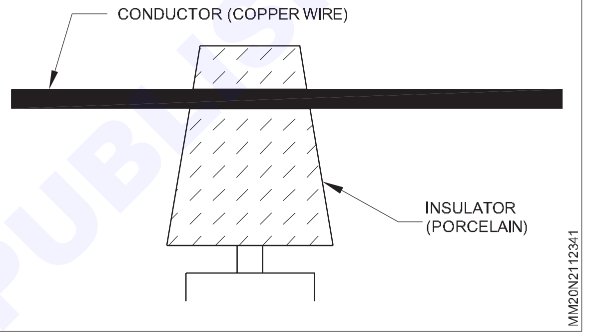
Electric resistance; It is the property of a substance to oppose the flow of electric current passing through it.

Its measuring unit is ohm and the measuring instrument is ohmmeter or megger.

- Resistance of a metal changes as given below:
- If the length is more the resistance will also be more.
- if the diameter is more the resistance will be less.
- the resistance will increase or decrease depending on the nature of the material.

Conductors: Those substances through which electricity passes are called conductors. (Fig 1)

Fig 1



Copper, aluminium, steel, carbon, etc, are examples of conductors. The resistance of these materials is low.

Insulators: Those substances through which electricity does not pass are called insulators.

Glass, mica, rubber. Bakelite, plastic dry wood, dry cotton, porcelain and varnish are examples of insulators. The resistance of these materials is high.

Electric circuits: It is the path taken by the electric current during its flow. Every electrical circuit comprises current, resistance and voltage.

The fundamental types of circuit are:

- series circuit
- parallel circuit.

Series circuit: The resistances of a circuit are connected in a series end-to-end making only one path in which the current flows.

Parallel circuit: The resistances are connected side by side to each other with the ends connected to power source.

Alternating current (AC): Electric current which changes its direction of flow and magnitude at a certain number of times per second is called alternating current. E.g. 50 cycles means it changes its direction 50 times per second. Its rate of change is called frequency i.e. hertz (Hz). (Fig 2)

Fig 2

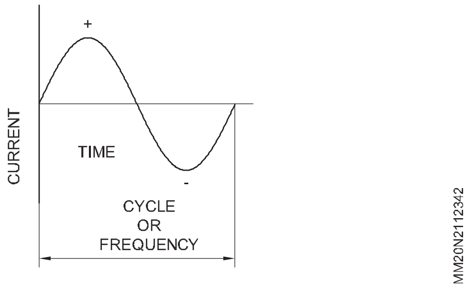
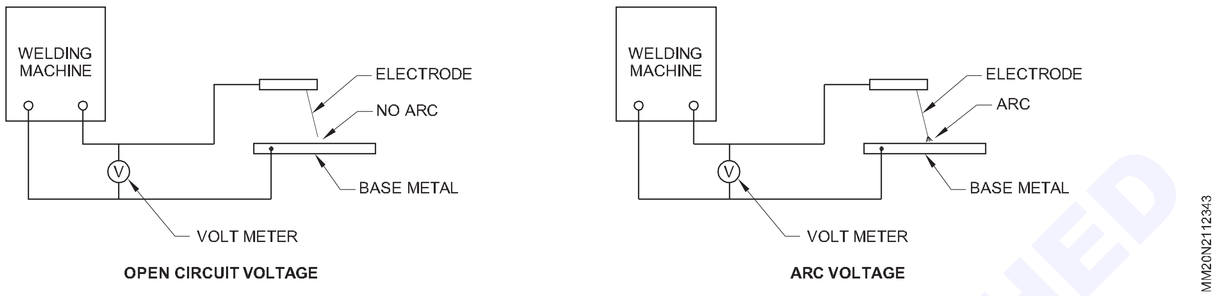


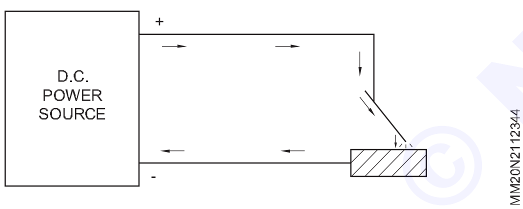
Fig 3



Direct current (DC) (Fig. 4): Electric current which always flows in a particular direction is known as direct current. (i.e) Negative to positive (electronic direction). Positive to negative (conventional direction).

Ohm's law: It is one of the most widely applied laws of electrical science.

Fig 4



It is the relationship of current, voltage and resistance, which was studied in 1827 by George. S. Ohm, a mathematician.

The law states:

In an electrical circuit, at constant temperature, the current varies directly as the voltage, and inversely as the resistance. i.e. current increases when voltage increases.

I=V/R

Where V = Voltage

I = Current

R = Resistance

Current decreases when resistance increases.

Application of Ohm's law: The importance of this law lies in its practical use for finding any one value when the other two values are known.

The three forms in which ohm's law may be written are shown below.

$I = \frac{V}{R}$ Where I = current in amps

$V = I \times R$ Where V = Voltage in volts

$R = \frac{V}{R}$ Where R = Resistance ohms

Open circuit voltage and arc voltage: Fig 3 shows an electric circuit used in arc welding. After switching on the welding machine, when there is no arc created/struck between the electrode tip and the base metal then the voltage "V" shown by the voltmeter in the circuit is called "Open circuit voltage".

The value of this open circuit voltage will very from 60V to 110V depending on the type of machine.

After switching on the welding machine, if the arc is struck/ created between the tip of the electrode and the base metal then the voltage "V' shown by the voltmeter in the circuit is called "Arc voltage".

The value of this arc voltage will vary from 18V to 55V depending on the type of machine.

Use of electricity as applied to welding: For fusion welding, the pieces to be joined are to be melted by:

- creating a high temperature (4500°C) arc between the electrode and the work using electric voltage and high current. (All types of arc welding)
- heating the work to red hot condition by using the resistance property of the metal and passing a very high current for a fraction of a second and then applying a very heavy pressure. (All types of resistance welding)
- using highly concentrated electron beam on the joint of the workpiece (Electron beam welding)
- Using the resistance of the slag and the current to flow through the molten slag (Electro slag welding)

In all the above welding processes, the electrical energy is converted to heat energy which is used to either melt the metal fully or heat them to red hot condition and then melted by applying heavy pressure. So electricity is used to a very large extent in many welding processes.

A.C. Arc welding machine

Objectives : At the end of this lesson you shall be able to
- **state the features of A.C. welding transformers**
- **state the advantages and disadvantages of A.C. welding machines.**

A.C. welding transformer

An A.C.welding transformer is a type of A.C. welding machine which converts the A.C. main supply into an A.C. welding supply. (Figs 1 and 2)

Fig 1

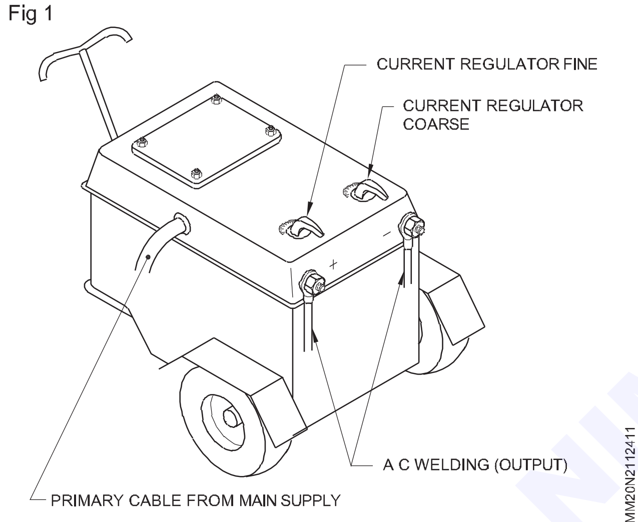
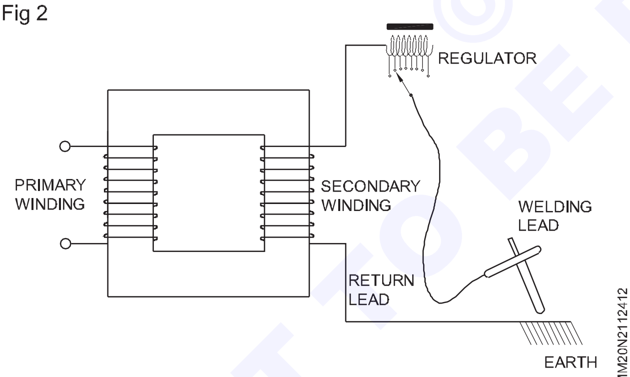


Fig 2



The A.C. main supply has high voltage - low ampere.

The A.C. welding supply has high ampere - low voltage.

It is a STEP-DOWN transformer which reduces the main supply voltage (220 or 440 volts) to the welding supply open circuit voltage (O.C.V.), between 40 and 100 volts.

It increases the main supply low current to the required output welding current in a hundred or thousand amperes.

The A.C. welding machine cannot be operated without the A.C. main supply.

Advantages

- Less initial cost
- Less maintenance cost
- Freedom from arc blow.

Magnetic effect which disturbs the arc is called the arc blow.

Disadvantages

- Not suitable for the welding of non-ferrous metals, light coated and special electrodes.
- The A.C. cannot be used without special safety precautions.

D.C. Arc-welding machines

Objectives : At the end of this lesson you shall be able to
- **state the features of a D.C. welding machine**
- **state its advantages and disadvantages.**

Motor generator set (Fig 1)

It is used to generate D.C. for arc-welding.

The generator is driven by an A.C. or D.C. motor.

Main supply is a must to run the machine.

Engine generator set (Fig 2)

Equipment is similar to the motor generator set except that the generator is driven by a petrol or diesel engine.

Its running and maintenance charges are higher.

It can be used anywhere in field work, away from electric lines.

Fig 1

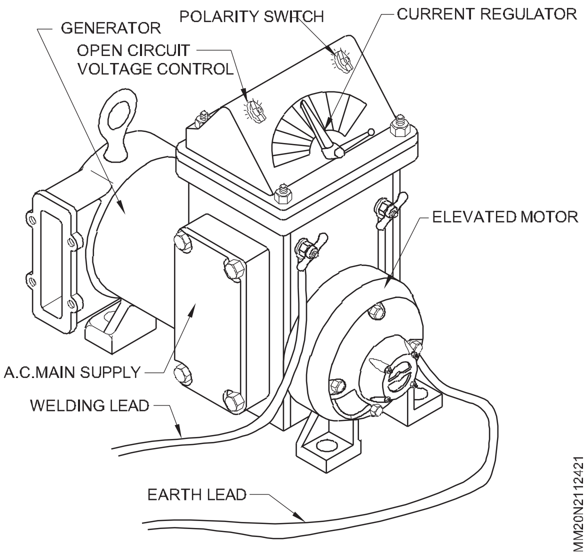
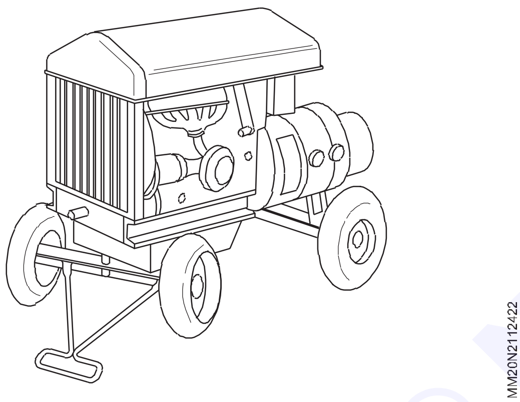


Fig 2



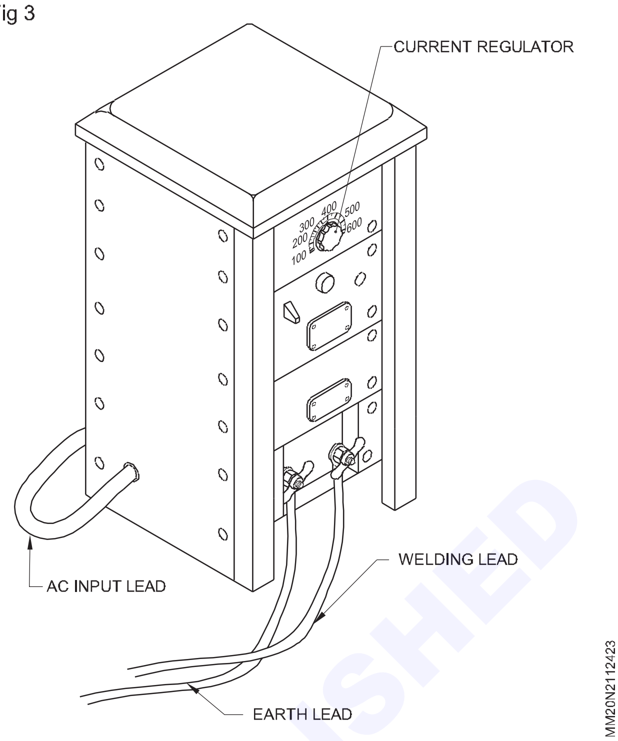
Rectifier set (Fig 3)

It is used to convert A.C. into D.C. welding supply.

Basically it is an A.C. welding transformer. The output of the transformer is connected with a rectifier to change the A.C. into D.C.

It may be designed to supply both A.C. and D.C. currents for welding (called A.C.-D.C. rectifier set).

Fig 3



Advantages

Suitable for welding all ferrous and non-ferrous metals using all types of electrodes

- Better heat distribution in the electrode and job due to polarity in the welding current supplies constant main load and accurate current setting.

It ensures safe working.

Disadvantages

- Initial cost is higher
- Maintenance cost is more
- Arc-blow trouble faced at certain times.

Arc length and its effects

Objectives : At the end of this lesson you shall be able to
- **state what is arc length**
- **differtiate normal arc, long arc and short arc**
- **explain the effects of different arc lengths.**

Arc length (Fig 1)

It is the straight distance between the electrode tip and the job surface when an arc is formed.

There are three types of arc length.

- Normal
- Long
- Short

Normal arc length (Fig 2)

The correct arc length or normal arc length is approximately equal to the diameter of the core wire of the electrode.

Long arc length (Fig 3)

If the distance between the tip of the electrode and the base metal is more than the diameter of the core wire, it is called 'long arc'.

Fig 1

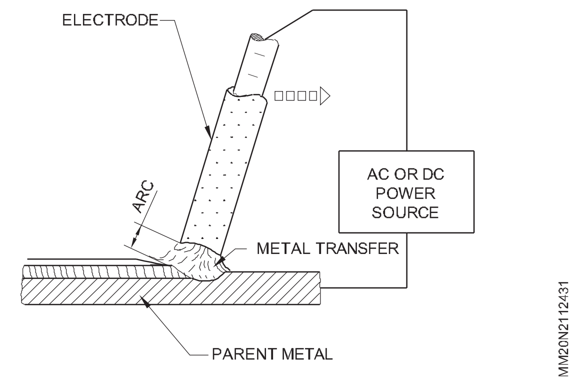


Fig 2

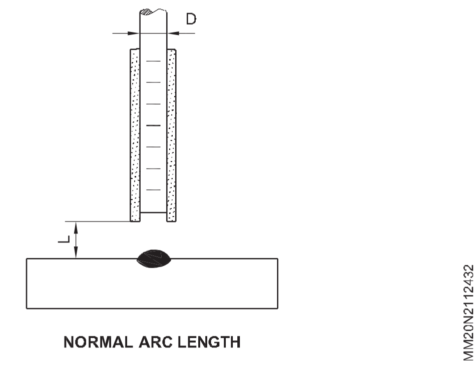
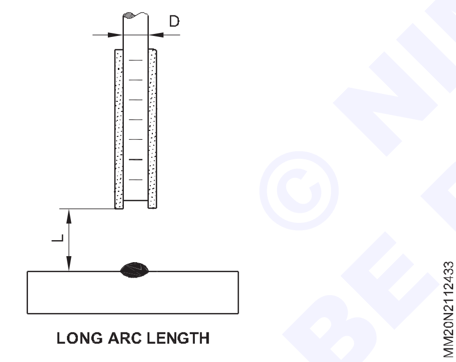


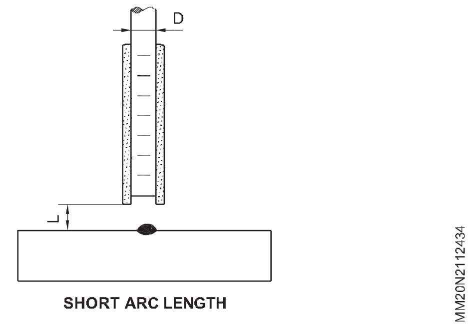
Fig 3



Short arc length (Fig 4)

If the distance between the tip of the electrode and the base metal is less than the dia. of the core wire, it is called a 'short arc'.

Fig 4



Effects of arc length

Long Arc

- A long arc makes a humming sound
- The arc is unstable
- Causes oxidation of the weld metal.
- Fusion and penetration are poor.
- Poor control of the molten metal.
- Creates more spatters resulting in wastage of the electrode metal.

Short arc

- It makes a popping sound.
- The electrode to melt slowly and try to freeze the job.
- Higher metal deposition with narrow width bead.
- Less spatters.
- Fusion and penetration is less.

Normal arc

- A stable arc produces a steady sharp crackling sound
- Electrode burns evenly.
- Less spatters.
- Correct fusion and penetration.
- The size of metal deposition is correct.

Metallic electrodes (Flux-coated)

Objectives : At the end of this lesson you shall be able to
- **name the types of metalic coated electrodes based on the thickness of coating**
- **state the functions of the coating on electrodes.**
- **select the current ranges for different diameters of electrodes.**

Metallic coated electrode (Fig 1)

This is in the shape of a rod or a wire coated with flux.

It is used to make an arc and also to deposit filler metal.

Electrodes are classified into bare electrodes (not much in use) and coated electrodes (commonly used).

The different types of electrodes based on the thickness of flux coating are (Fig 2)

- Lightly coated electrodes. (coating factor. 12 to 1.3)
- Medium coated electrodes. (coating factor 1.4 to 1.6)
- Heavily coated electrodes. (coating factor 1.6 to 22)

The relationship between the coating diameter and the core diameter is known as the coating factor.

$$\text{Coating factor} = \frac{\text{Coating dia}}{\text{Core dia}}$$

Fig 1

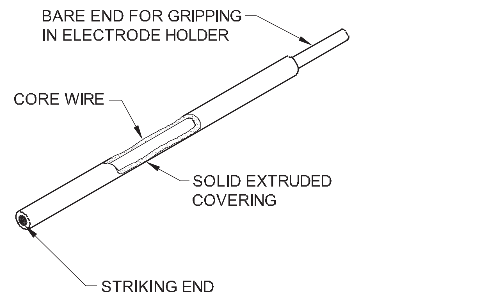
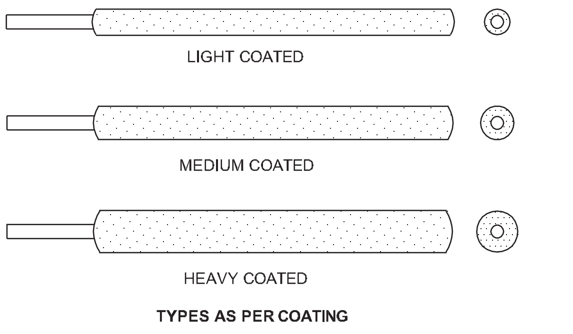


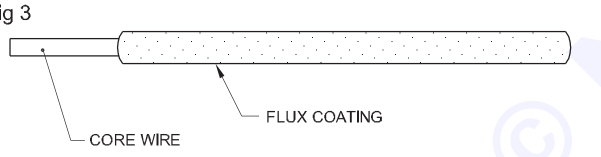
Fig 2



Common sizes of electrodes

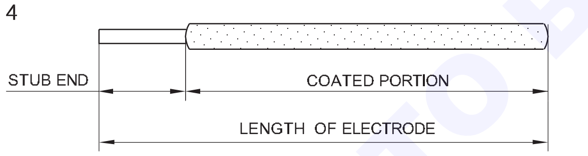
The size of the electrode is measured by the diameter of its core wire. (Fig 3)

Fig 3



Electrodes are generally produced in lengths of 450, 350, 300 and 250mm. (Fig 4)

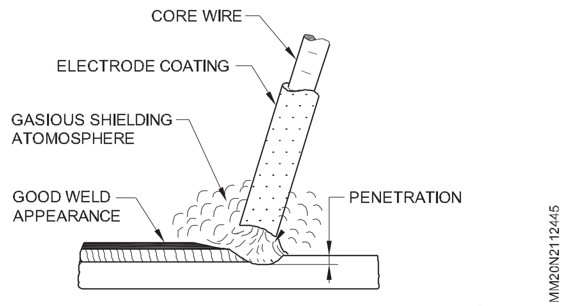
Fig 4



Functions of Flux Coating (Fig 5)

During welding, because of the heat of the arc the flux coating on the electrode melts and perform the following functions.

Fig 5



- It stabilizes the arc by ionising the air.
- It forms a gaseous shield which protects the molten metal from atmospheric contamination.
- It compensates the losses of certain elements which are burnt out during welding.
- It retards the rate of cooling of the deposited metal by covering with slag, and improves its mechanical properties.
- It helps to give a good appearance and penetration to the weld.

Current range for different sizes of electrodes. The current setting during welding depends on the diameter of the electrode. Table 1 gives the current range for diameters of electrodes.

Table 1

Electrode size mm Ø	Current range amps.
1.6	40 - 60
3.5	50 - 80
32	90 - 130
4.0	120 - 170
5.0	130 - 270
6.0	300 - 400

Coding of Electrodes as per BIS, AWS and BS

Objectives: At the end of this lesson you shall be able to
- **explain the necessity of coding electrodes**
- **describe the electrode coding as per BIS, AWS and BS.**

Necessity of coding electrodes: Electrodes with different flux covering gives different properties to the weld metal. Also electrodes are manufactured suitable for welding with AC or DC machines and in different positions. These conditions and properties of the weld metal can be interpreted by the coding of electrodes as per Indian Standards.

The chart shown at the end of this lesson gives the specification of a particular electrode and also shows what each digit and letter in the code represents. By referring to this chart any one can know whether an electrode with a given specification can be used for welding a particular job or not.

Classification of electrodes shall be indicated by the IS: 814-1991 coding system of letters and numerals to indicate the specified properties or characteristics of the electrode.

Main coding: It consists of the following letters and numerals and shall be followed in the order stated:

a) a prefix letter 'E' shall indicate a covered electrode for manual metal arc welding, manufactured by extrusion process;

b) a letter indicating the type of covering;

c) first digit indicating the ultimate tensile strength in combination with the yield stress of the weld metal deposit;

d) second digit indicating the percentage elongation in combination with the impact values of the weld metal deposited;

e) third digit indicating welding position(s) in which the electrode may be used and

f) fourth digit indicating the current condition in which the electrode is to be used.

Additional coding: The following letters indicating the additional properties of the electrodes may be used, if required:

a) letters H_1, H_2, H_3 indicating hydrogen controlled electrodes.

b) letters J, K and L indicating increased metal recovery as 'Effective Electrode Efficiency' as per IS: 13043:91.

J = 110 - 129 percent;

K = 130 - 149 percent; and

L = 150 percent and above.

c) letter 'X' indicating the radiographic quality.

Different standards used in coding of electrodes

They are:

1 I.S. (814 - 1991)

2 A.W.S.

3 B.S.

INDIAN SYSTEM OF CODING OF ELECTRODES ACCORDING TO IS: 814-1991

Type of covering: The type of covering shall be indicated by the following letters.

A - Acid

B - Basic

C - Cellulosic

R - Rutile

RR - Rutile, heavy coated

S - Any other type not mentioned above

Strength characteristics: The combination of the ultimate tensile strength and the yield strength of the weld metal deposited shall be indicated by the digits 4 and 5. (See Table 1)

Table 1

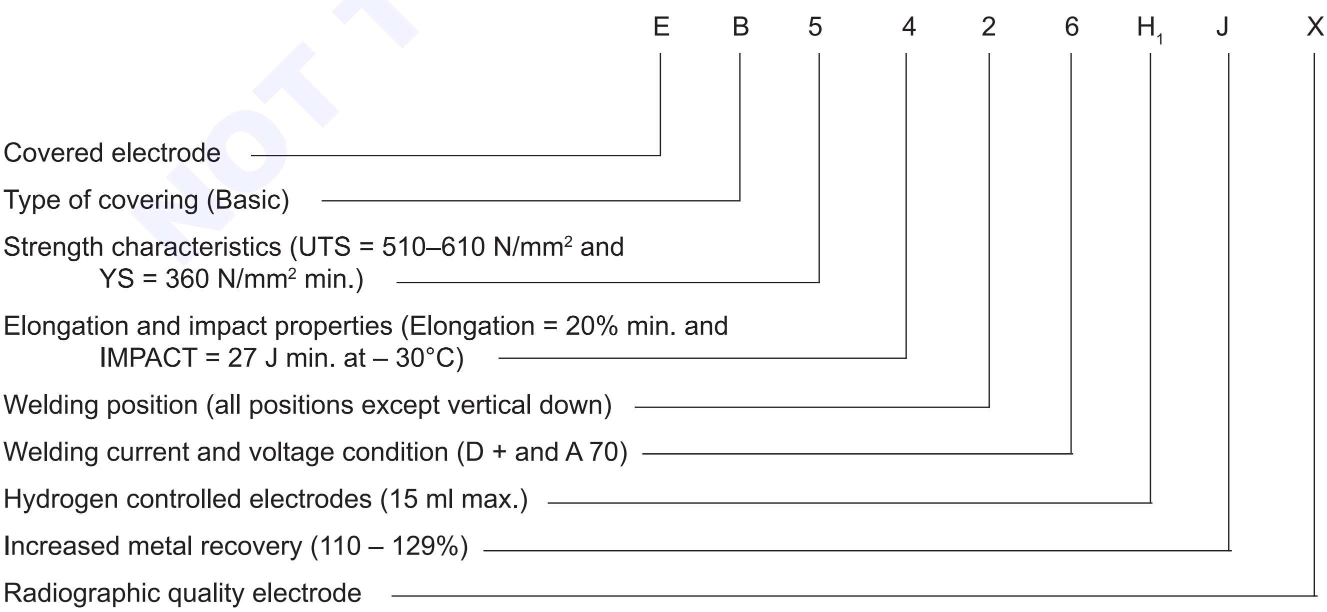
Designation of strength characteristics

(Clauses 52 and 5.3)

Designating digit	Ultimate tensile strength N/mm²	Yield strength Min N/mm²
4	410-510	330
5	510-610	360

Example 1

The classification for the electrode EB 5426H1JX



Example 2

The classification for the electrode ER 4211

E R 4 2 1 1

- E — Covered electrode
- R — Type of covering (Rutile)
- 4 — Strength characteristics (UTS = 410 – 510 N/mm^2 and YS = 330 N/mm^2 min.)
- 2 — Elongation and impact properties (Elongation = 22% min. and impact = 47 J min. at 0°C)
- 1 — Welding position (all positions)
- 1 — Welding current and voltage conditions (D ± and A 50)

Gas welding

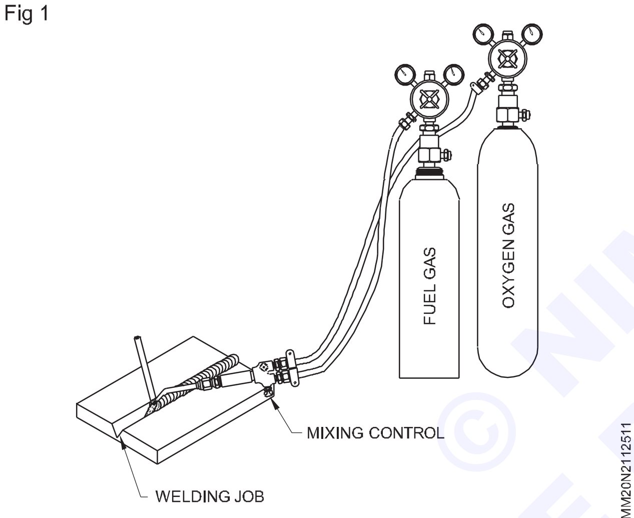
Objectives: At the end of this lesson you shall be able to
- **name the different types of gases used in gas welding**
- **state the different types of gas flame combinations**
- **state the temperatures and uses of the different gas flame combinations.**

In the different gas welding processes, the welding heat is obtained from the combustion of the fuel gases.

All the fuel gases require oxygen to support combustion.

As a result of the combustion of the fuel gases and oxygen, a flame is obtained. This is used to heat the metals for welding. (Fig 1)

Fig 1



Fuel gases used in welding

The following are the gases used as fuel for welding.

- Acetylene gas
- Hydrogen gas
- Coal gas
- Liquid petroleum gas (LPG)

Supporter of combustion gas

All gases burn with the help of oxygen. Hence it is known as the supporter of combustion.

Different gas flame combinations

Oxygen + Acetylene = Oxy - Acetylene gas flame

Oxygen + Hydrogen = Oxy - Hydrogen gas flame

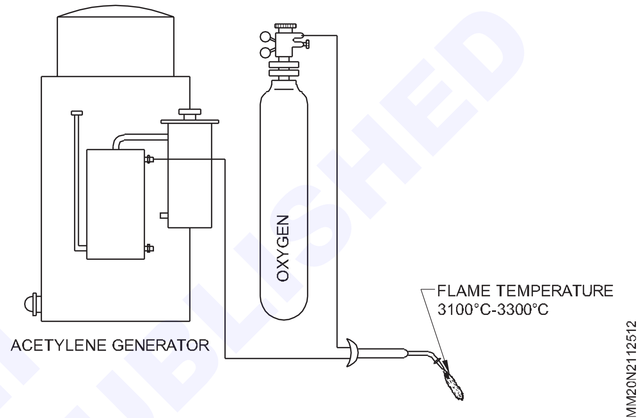
Oxygen + Coal = Oxy - coal gas flame

Oxygen + LPG = Oxy - LP gas flame

Temperature and uses of gas flame combinations

Oxy-acetylene gas flame (Fig 2)

Fig 2

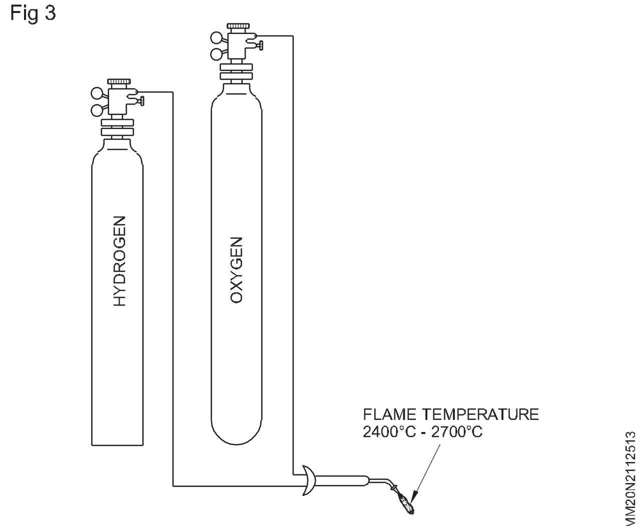


Flame temperature : 3100° C to 3300° C

The Oxy - Acetylene gas flame is used for welding all ferrous and non-ferrous metals and their alloys, gas cutting, gouging, steel brazing, bronze welding, metal spraying and powder spraying.

Oxy - Hydrogen gas flame (Fig 3)

Fig 3

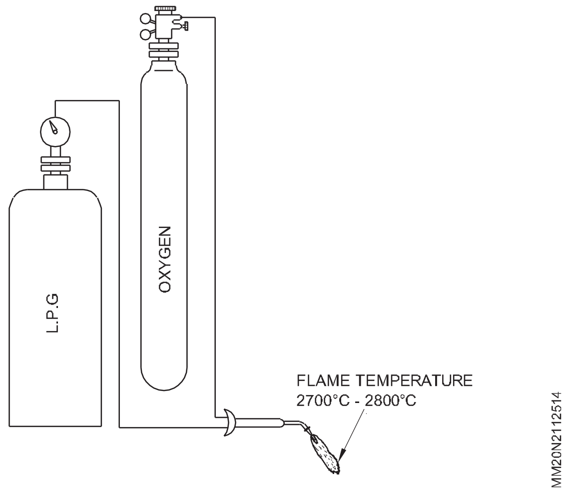


Flame temperature : 2400°C to 2700°C

It has carbon and moisture effect in the flame. It is used only for brazing, silver soldering and underwater gas cutting of steel.

Oxy-liquid petroleum gas flame (Fig 4)

Fig 4



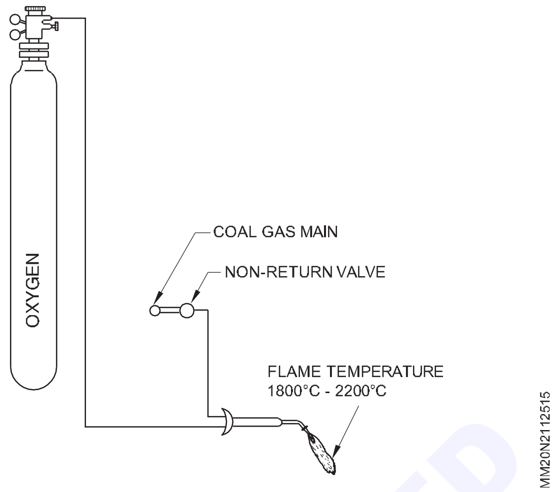
Flame temperature : 2700°C to 2800°C

This flame has carbon and moisture effect.

It is only used for gas cutting of steel, and for heating.

Oxy-coal gas flame (Fig 5)

Fig 5



Flame temperature : 1800°C to 2200°C

This flame has carbon effect in the flame and is used for silver soldering and brazing.

The most commonly used gas flame combination is OXY - ACETYLENE.

Types of oxy - acetylene flames

Objectives : At the end of this lesson you shall be able to
- **name the different types of oxy - acetylene flames**
- **state the characteristics of each type of oxy - acetylene flame**
- **explain the uses of each type of oxy-acetylene flame.**

The essential requirement for oxy - acetylene welding is a well controlled flame with sufficient heat, which can be easily manipulated to heat and melt metals without altering the chemical composition of the metal/weld.

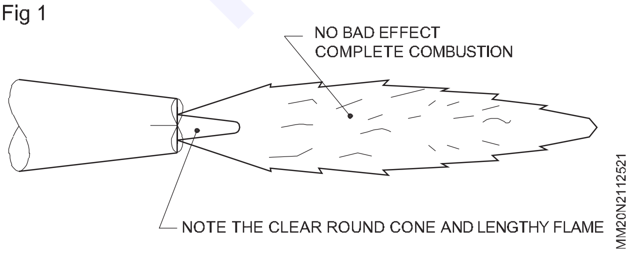
Flame types

The different flame types are

- Neutral flame
- Oxidising flame
- Carburising flame.

Neutral flame (Fig 1)

Fig 1



Characteristics

The neutral flame is formed with oxygen and acetylene in equal proportion.

Complete combustion takes place in this flame.

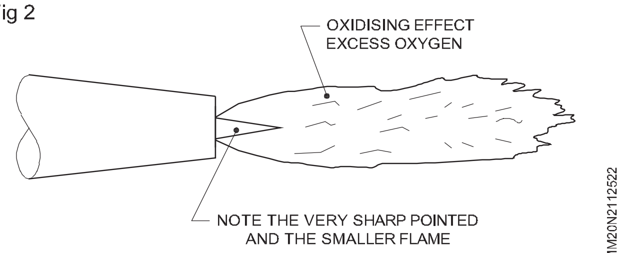
This flame does not have bad effect on metals/weld.

Uses

A neutral flame is used to weld most of the common metals, i.e. mild steel, cast iron, stainless steel, copper and aluminium.

Oxidising flame (Fig 2)

Fig 2



Characteristics

The oxidising flame is formed with excessive oxygen.

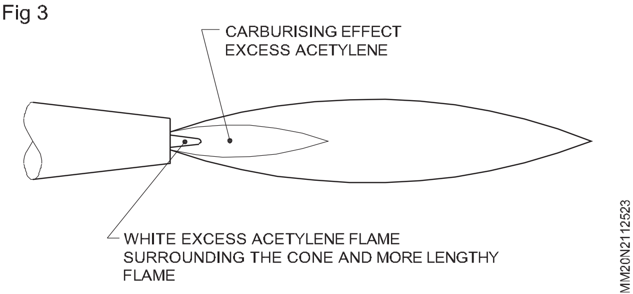
The flame has oxidising effect on metals.

Uses

The oxidising flame is useful only for the welding of brass and to control the burning of zinc.

Carburising flame (Fig 3)

Fig 3



This flame contains excess of acetylene .

The flame has a carburising effect on steel, causing hard, and brittle weld.

Uses

Useful for stelliting (hard facing), LINDE welding of steel pipes and flame cleaning.

> **The selection of the flame is based on the metal to be welded.**
>
> **Neutral flame is the most commonly used**

Tools and equipment used in oxy-acetylene gas welding

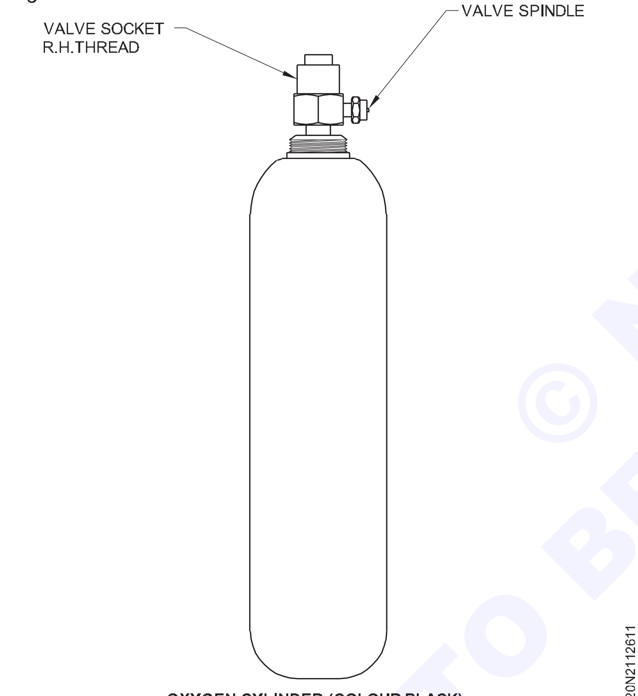
Objectives : At the end of this lesson you shall be able to
- **compare the features of oxygen and acetylene regulators**
- **state the features of hose-pipes used in gas welding**
- **identify the features of a blowpipe and state their functions**
- **state the features of a spark lighter**
- **state the use of a cylinder trolley.**

Oxy-acetylene gas welding

The essential requirement for a beginner dealing with oxy-acetylene gas welding is to identify the tools and equipment required and know their uses.

Oxygen gas cylinders (Fig 1)

Fig 1



OXYGEN CYLINDER (COLOUR BLACK)

The gas cylinder is a steel bottle, painted black with 7m^3 capacity for storing gas.

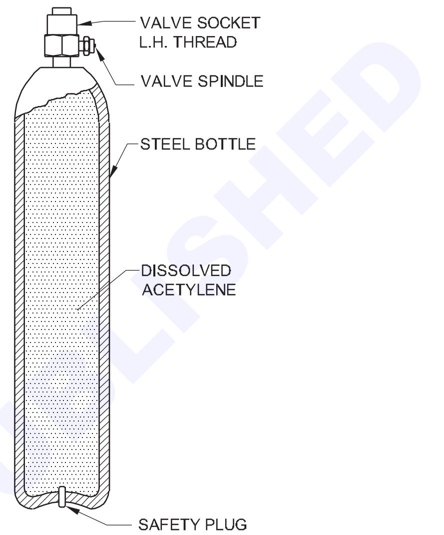
The valve socket has right hand threads.

The cylinder is used to store oxygen gas with a pressure of 120 to 150 kg/cm^3.

Dissolved acetylene cylinders (Fig 2)

This is painted maroon and has a storing capacity of 6m^3. The valve socket has left hand threads. It is used to store acetylene gas in a dossolved state with a pressure of 15-16 kg/cm^3.

Fig 2

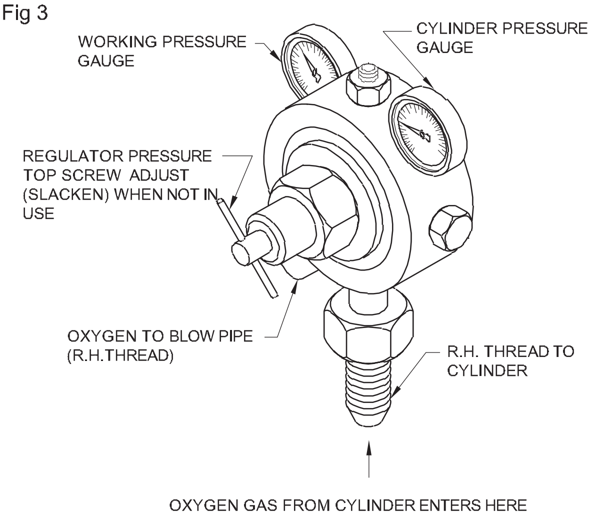


ACETYLENE CYLINDER (COLOUR MAROON)

Pressure regulators for oxygen

The regulator is meant to reduce and control the oxygen cylinder gas pressure to a suitable working pressure and maintain constant rate of flow for the blowpipe. This regulator has right hand threads. (Fig 3)

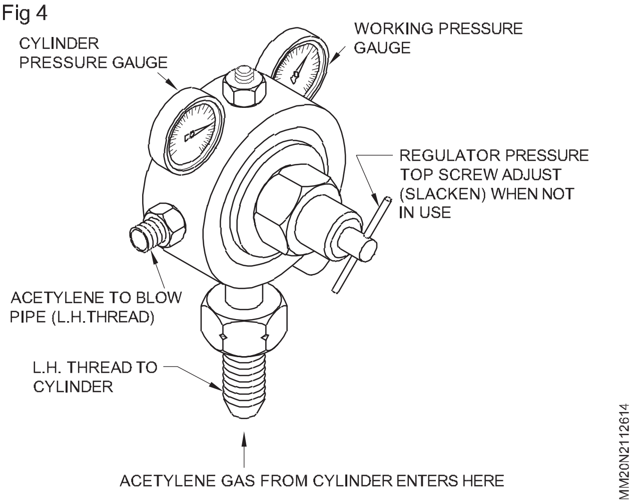
Fig 3



Pressure regulators for acetylene

This is to reduce and control the acetylene cylinder gas pressure to a suitable working pressure at a constant rate of flow for the blowpipe. This regulator has left hand screw threads. (Fig 4)

Fig 4

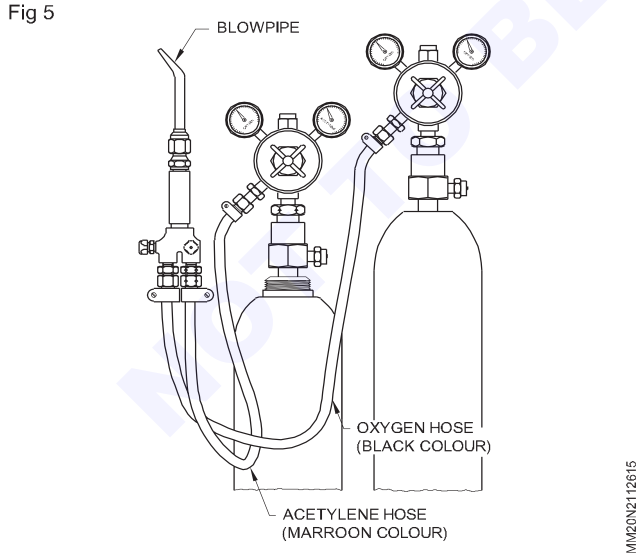


Both oxygen and acetylene regulators have a cylinder pressure gauge to indicate the cylinder gas pressure and a working pressure gauge to indicate the working pressure required for the blowpipe. (Figs 3 & 4)

Rubber hoses

The hose carries the gases from the gas regulators to the blowpipe. The hoses are made of strong canvass rubber having good flexibility. The hose pipe for the oxygen line is black in colour while that for the acetylene line is of maroon colour. (Fig 5)

Fig 5

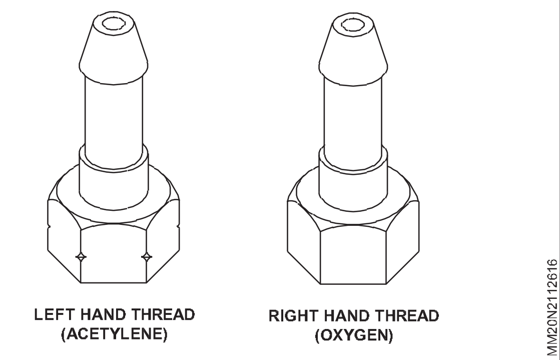


Hose pipe connections for regulators

This is a connecting union used to connect rubber hose pipes with the regulators.

Oxygen connection has right hand threads while the acetylene connection has left hand threads. (Fig 6) The nut used for the acetylene rubber hose connections will have a notch at its corners.

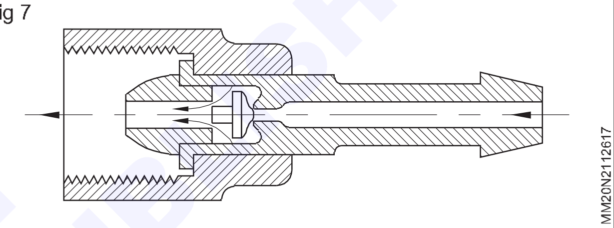
Fig 6



Hose pipe connections for blowpipes

This has the shape of a connecting union and is fitted with a non-return disc to prevent flash-back and backfire during welding. (Fig 7)

Fig 7

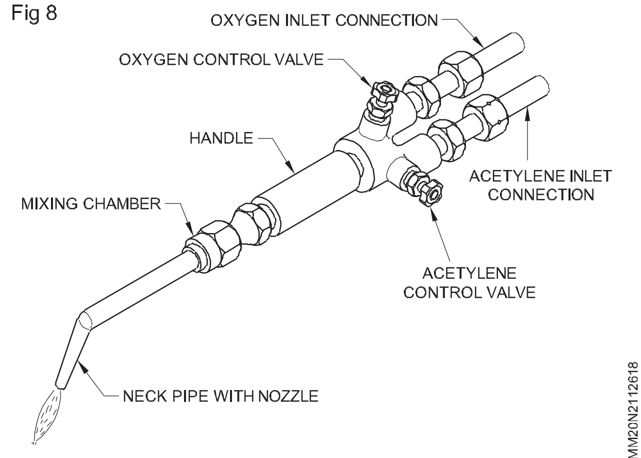


It is used to connect the rubber hose pipe with the blowpipe.

The oxygen connection has right hand threads while the acetylene one has left hand threads.

Blowpipe set with nozzle (Fig 8)

Fig 8



This is a device with a handle and inlet connection for acetylene (left hand threads) and oxygen (right hand threads). It has control valves for acetylene and oxygen gas flow, a gas mixing chamber, and a neck-pipe with a nozzle.

This is used to control and mix the acetylene and oxygen gases in the required proportion to make a perfect oxy-acetylene gas flame.

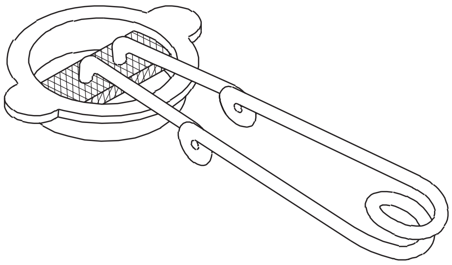
A set of interchangeable nozzles of different sizes are used to produce smaller or bigger flames.

Spark lighter (Fig 9)

This is used to ignite the flame.

The spark is produced by rubbing the flint over a metal surface with cuts like those in a file.

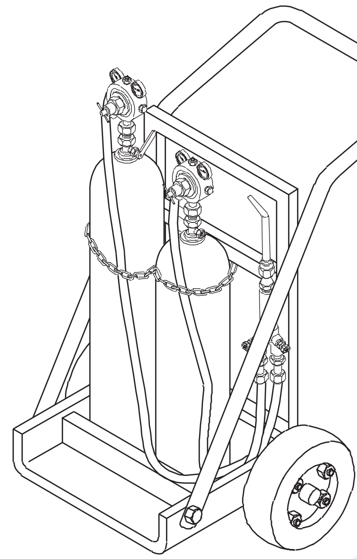
Fig 9



Trolley for cylinder (Fig 10)

The trolley is used to keep both oxygen and acetylene cylinders in an upright position. The trolley helps to transport the cylinders - safely and easily.

Fig 10



Safety precautions in handling gas welding plant

Objectives : At the end of this lesson you shall be able to
- **state the general safety precautions in oxy-acetylene plants.**
- **state the safety rules for handling gas cylinders**
- **state the safety precautions for handling gas regulators and hose-pipes.**
- **state the safety precautions related to blowpipe operations.**

To be accident-free, one must know the safety rules first and then practise them as well. As we know accident starts when safety ends'.

Ignorance of rules is no excuse!

In gas welding, the welder must follow the safety precautions in handling gas welding plants and flame-setting to keep himself and others safe.

Safety precautions are always based on good common sense.

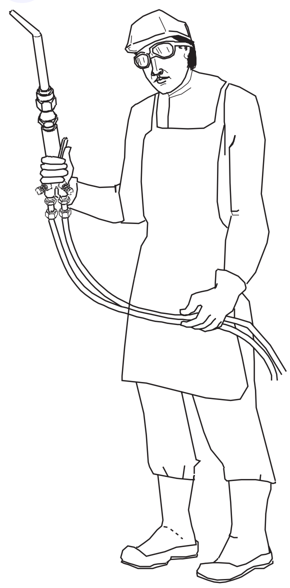
The following precautions are to be observed, to keep a gas welder accident-free.

General safety

Do not use lubricants (oil or grease) in any part or assembly of a gas welding plant. It may cause explosion.

Keep all flammable material away from the welding area. Always wear goggles with filter lens during gas welding. (Fig 1)

Fig 1

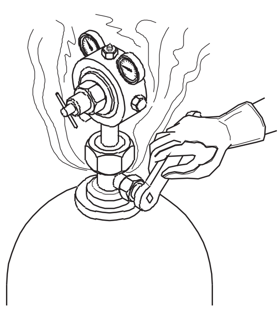


Always wear fire resistant clothes, asbestos gloves and apron.

Never wear nylon, greasy and torn clothes while welding.

Whenever a leakage is noticed rectify it immediately to avoid fire hazards. (Fig 2)

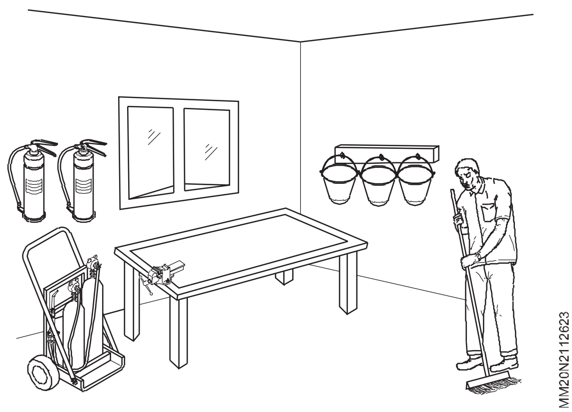
Fig 2



Even a small leakage can cause serious accidents.

Always keep fire-fighting equipment handy and in working order to put out fires. (Fig 3)

Fig 3



Keep the work area free from any form of fire.

Safety for gas cylinders

Do not roll gas cylinders or use them as rollers.

Use a trolley to carry the cylinders.

Close the cylinder valves when not in use or empty.

Keep full and empty cylinders separately.

Always open the cylinder valves slowly, not more than one and a half turn.

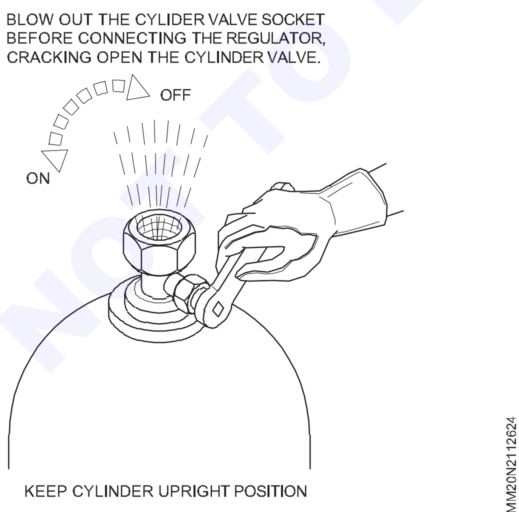
Use the correct cylinder keys to open the cylinders.

Do not remove the cylinder keys from the cylinders while welding. It will help to close the cylinders QUICKLY in the case of a back-fire or flash-back.

Always use the cylinders in an upright position for easy handling and safety.

Always crack the cylinder valves to clean the valve sockets before attaching regulators. (Fig 4)

Fig 4



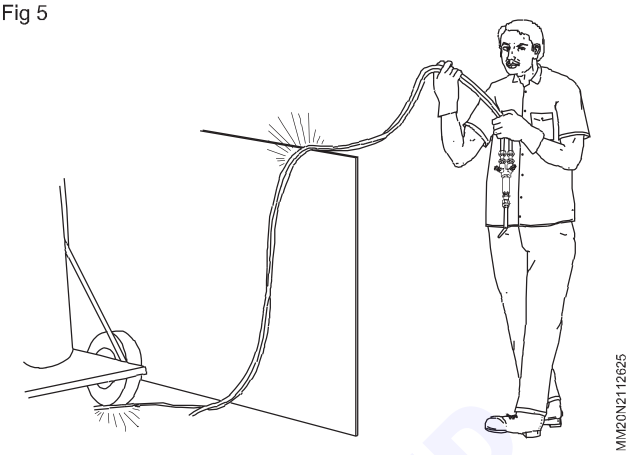
Safety for rubber hose pipes (Fig 5)

Inspect the rubber hose pipes periodically and replace the damaged ones.

Do not use odd bits of hose pipes / tubes.

Do not replace the hose pipes for acetylene with the ones used for oxygen.

Fig 5



Always use a black hose pipes for oxygen and maroon hose pipes for acetylene.

Safety for regulators

Prevent hammer blows to the gas cylinders and ensure that water, dust and oil do not settle on the cylinders.

One right hand threaded connection for oxygen and left hand threaded connection for acetylene.

Safety for blowpipes

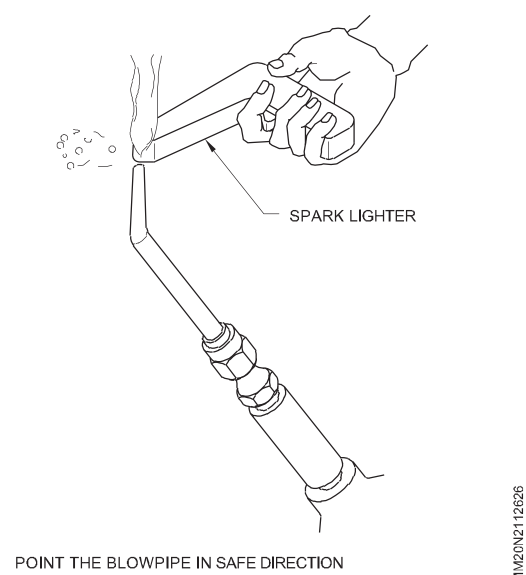
When a blowpipe is not in use put out the flame and place the blowpipe in a safe place.

When flame snaps out and backfires, quickly shut both the blowpipe valves (oxygen first) and dip in water.

While igniting the flame, point the blowpipe nozzle in a safe direction. (Fig 6)

While extinguishing the flame, shut off the acetylene valve first and then the oxygen valve to avoid a backfire.

Fig 6

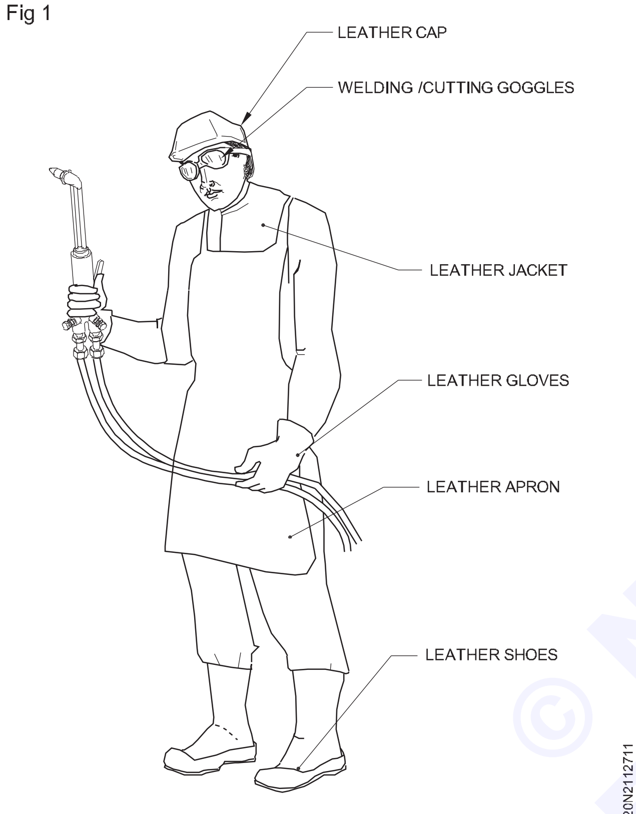


Safety in gas cutting process

Objective : At the end of this lesson you shall be able to
- **state the safety precautions to be observed while gas cutting.**

Safety of the operator (Fig 1)

Fig 1



WEAR PROTECTIVE CLOTHING

Always use safety apparels for the

- Protection of the eyes
- Protection from burns
- Protection of clothing
- Prevention of inhaling burnt gases.

Goggles, gloves and other protective clothing must be worn.

Safety during operation

Keep the work area free from flammable materials.

Protect yourself and others from the flying sparks.

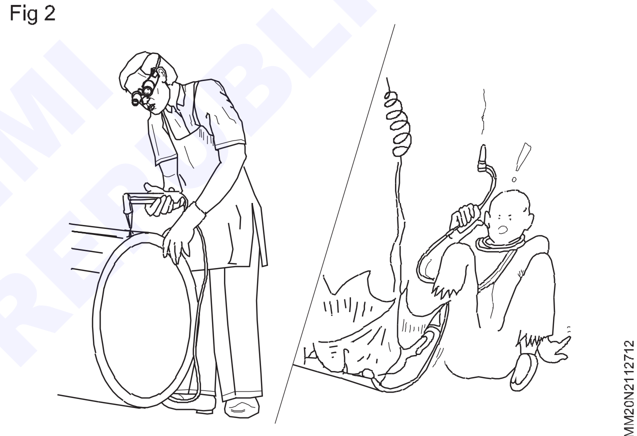
Ensure that the metal being cut is properly supported and balanced so that it will not fall on the feet or hoses.

Keep the space underneath the cut clear to allow the slag to run freely and fall.

Be careful of the blown-back hot metal and flying sparks while starting a cut.

Containers which hold combustible material should not be taken directly for cutting or welding. (Fig 2)

Fig 2



Wash the containers with carbon tetrachloride and caustic soda before welding or cutting or fill them with argon gas or water before undertaking repair work.

Keep fire-fighting equipment handy and ready always.

Oxy - acetylene cutting equipment

Objectives : At the end of this lesson you shall be able to
- **name the different equipment and accessories used for hand cutting**
- **differentiate between cutting and welding blowpipes.**

Cutting equipment

Basic equipment for cutting is similar to that of welding and consists of :

- Acetylene gas cylinder
- Oxygen gas cylinder.
- Acetylene gas regulator
- Oxygen gas regulator
- Rubber hose pipes, for acetylene and oxygen.
- Cutting blowpipe.

The cutting process requires more oxygen.

Heavy cutting requires a higher pressure oxygen regulator and an oxygen hose pipe of larger bore.

Cutting and welding blowpipes (Fig 1)

The function of a cutting blow pipe is to supply :

- Flame to preheat the metal before cutting
- A steady stream of pure oxygen for cutting.

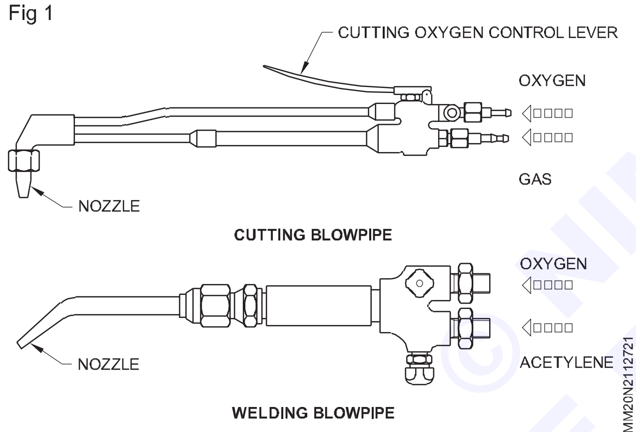
The purpose of a welding blowpipe is to provide the required type of flame to heat and fuse the metal for welding.

Cutting blowpipe

A cutting blowpipe has two control valves (oxygen and acetylene) at the rear to control the preheating flame, and one high pressure lever type control valve to control the pure oxygen for making cutting.

A welding blowpipe has only two control valves to control the heating flame. (Fig 1)

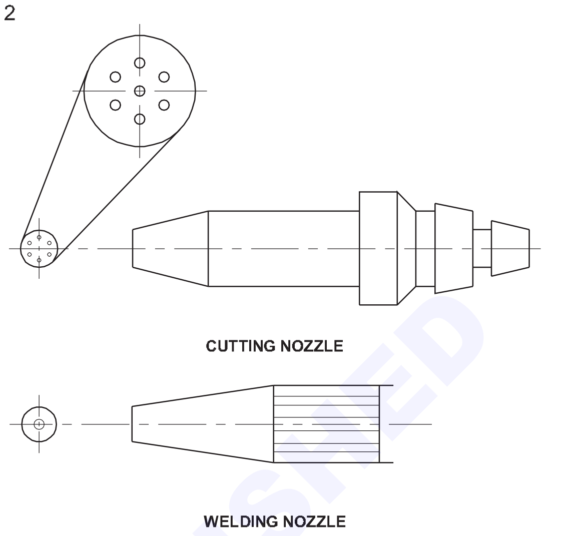
Fig 1



The nozzle of a cutting blowpipe has one hole in the centre for the cutting oxygen and a number of holes around the circle for the preheating flame.

The nozzle of a welding blowpipe has only one hole in the centre for the heating flame. (Fig 2)

Fig 2



Principle of gas cutting

Objectives : At the end of this lesson you shall be able to
- **state the principal of gas cutting**
- **state the cutting operation and cutting action.**

When a ferrous metal is heated to a red hot condition and then exposed to pure oxygen, a chemical reaction takes place between the heated metal and oxygen (oxidation reaction) producing a great amount of heat.

Cutting operations

There are two operations in oxy-acetylene gas cutting.

A heating flame is directed on the metal to be cut, and raises it to bright red heat or IGNITION POINT. (Fig 1)

Then a stream of high pressure oxygen is directed on to the hot metal. (Fig 2)

Fig 1

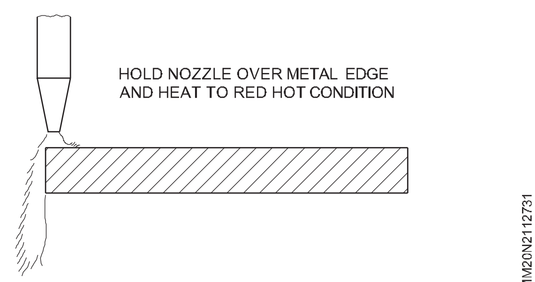
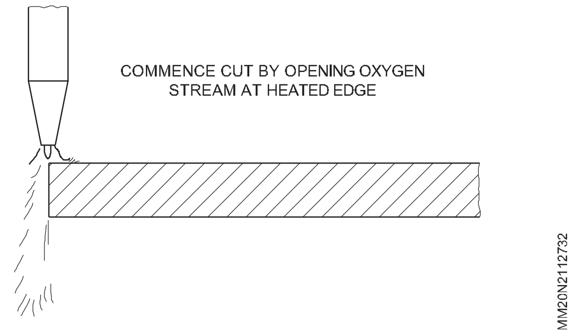


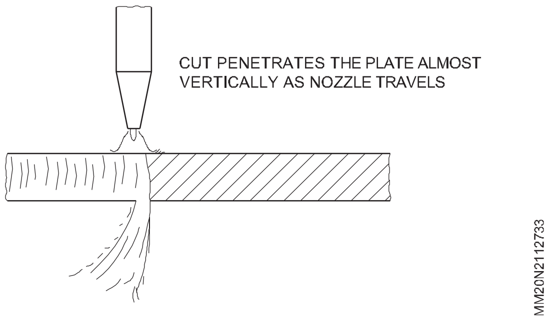
Fig 2



Cutting action

The iron is immediately oxidized to iron oxide and since its melting point is well below that of iron, it melts immediately and gets blown away by the oxygen stream. (Fig 3)

Fig 3



300 litres of oxygen are required to oxidize completely one kg of iron.

The ignition temperature of steel for gas cutting is 875°C to 900°C.

Back fire

At certain times, during flame lighting or gas welding a small explosion of the flame occurs at the tip of the torch.

The flame may or may not go off. This explosion is called backfire.

The causes for backfire are

- The pressure setting is low
- The nozzle is overheated
- The nozzle orifice has carbon or spark deposits
- The nozzle touches the molten pool
- There is leakage near the nozzle.

Eliminate the causes before proceeding further to avoid backfire

Flash back

Sometimes, during backfire, the flame goes off and the burning gases travel backward in the blowpipe, towards the regulator or cylinders. This is known as 'flashback'.

Indications of flashback

- A sharp squealing sound inside the blowpipe.
- Heavy black smoke and spark may come out of the nozzle. (Fig 4)

The blowpipe handle starts heating.

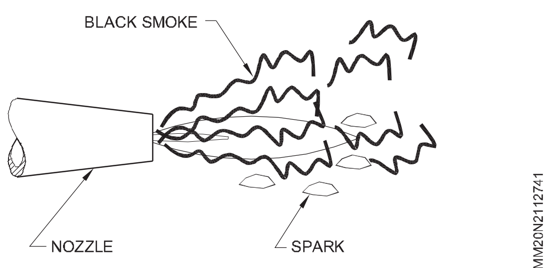
Precautions

Close the blowpipe valves (Oxygen first).

Immerse the blowpipe in water and close the cylinder valves.

If the backfire of flashback is not checked in time, it may cause serious accidents to men and equipment.

Fig 4



Introduction of Hydraulic system

Objectives: At the end of this lesson you shall be able to
- **define hydraulic system**
- **define Pascal's law**
- **state the Bernoulli's principle.**

Any working or control system that uses liquid as the transmitting fluid is known as hydraulic system.

The word hydraulic is derived from Greek words "hydra" meaning water and "aulic" meaning pipe.

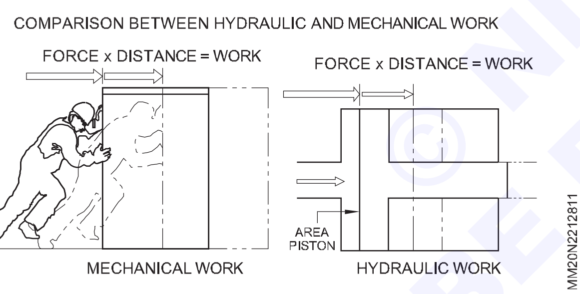
Some common examples of hydraulic system include automobile braking, power steering, elevators, earth moving equipments, jacks, presses, riveting machines, tool feeding mechanisms etc. The liquid used in hydraulics is generally viscous petroleum oils.

The following paragraphs gives basic physical properties and laws that govern liquids, relevant to hydraulic systems.

"Work" is defined as the product of force and the distance in which the object has moved in the direction of force.

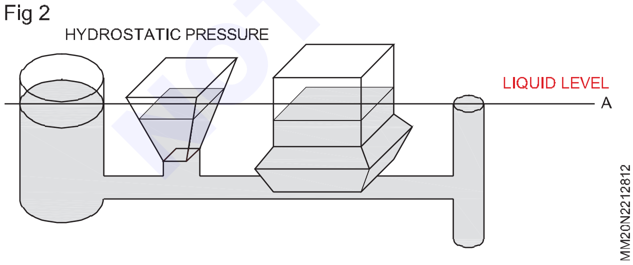
Fig 1 shows the comparison between the work done in a mechanical and hydraulic system.

Fig 1



The Fig 2 shows that different shaped and sized containers inter-connected by a pipe, the level of the liquid remains same. This is because of the internal pressure of the liquid. At any point the liquid attains certain pressure proportional to the height of the liquid above.

Fig 2



Therefore the higher pressure in any of the container will force the liquid to flow to the next container until the pressure on both the sides are equalised.

Through the line 'A' the pressure in all the open containers remain the same, since height of liquid columns are same.

Pascal's Law

It states that the pressure exerted on a liquid is transmitted equally in all the directions. Fig 3 clearly explains this law followed by Fig 4.

Fig 3

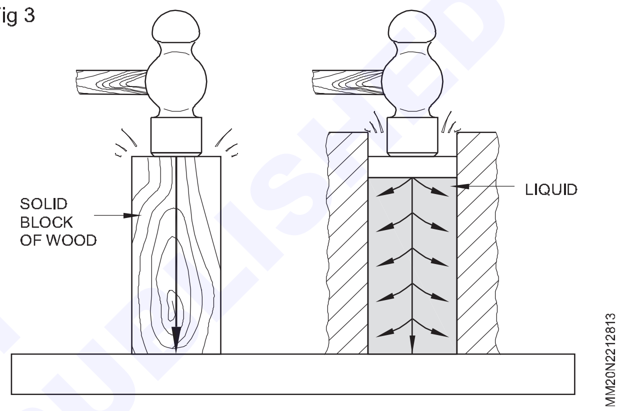
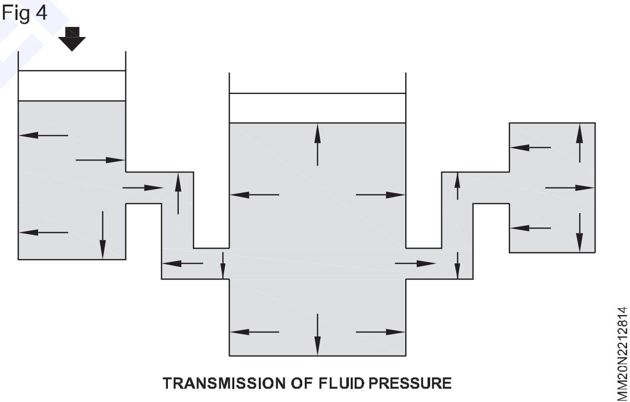
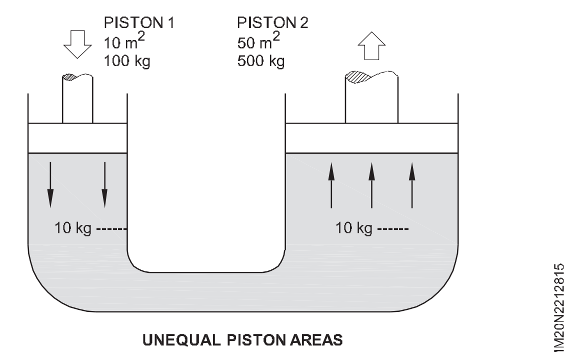


Fig 4



Thus if small amount of pressure is exerted on a smaller piston as shown in Fig 5, the higher force can be attained at the larger piston, since the pressure is equally applied on larger area.

Fig 5



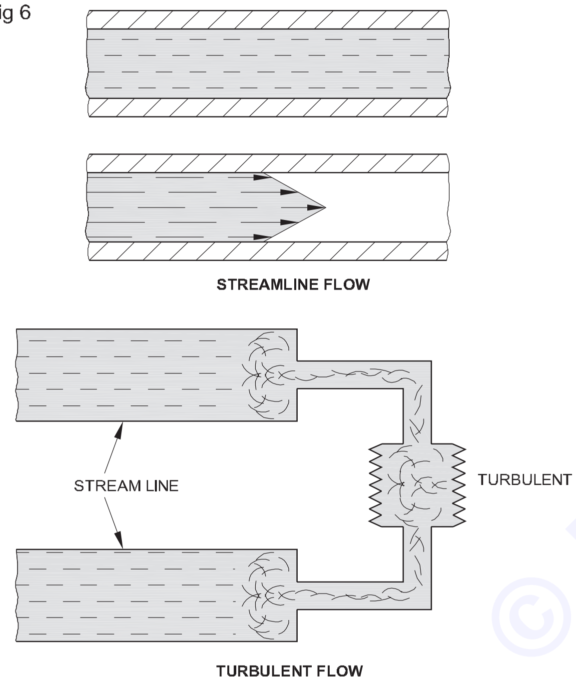
Stream line flow (Laminar flow): The flow in which the fluids flow in parallel layers.

Turbulent flow: The flow fluid in which the fluids travels in irregular parts

Cavitation

The inter-locked air bubbles and pockets in the hydraulic pipe lines and components is called cavitation. In cavitation the static pressure falls below vapour pressure. The vapour formation condenses resulting in pressure jerks and noise, and heating-up the oil resulting in a turbulent flow. Therefore resulting flow of oil should be a stream line or laminar in the pipe lines (Fig 6).

Fig 6

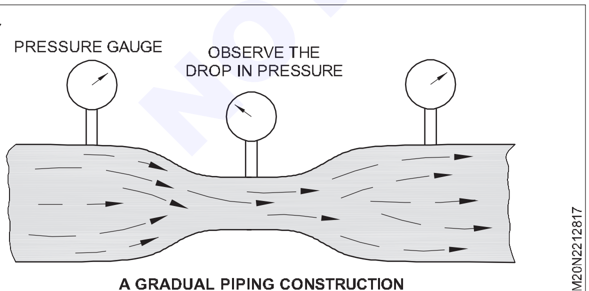


Bernoulli's principle

Gravitational potential energy of elevation, fluid pressure energy and kinetic energy of fluid motion remains constant.

The Bernoulli's principle states that the total energy of fluid always remains constant. During the course of flow of liquid, the flow increases and pressure decreases when a restriction is encountered. If the flow decreases, liquid pressure increases. Fig 7 Depicts this principle clearly.

Fig 7



Effect of heat

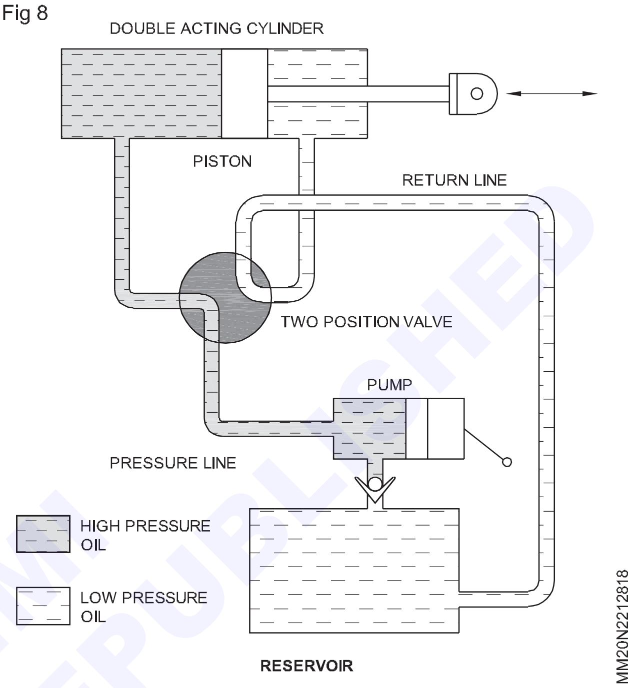
Since the liquids (oil) full in containers cannot expand or be compressed on heat, it exerts pressure on the container thus developing unwanted stresses.

Heat also thins out the oil. The low viscous oil may leak through seals and packings. Heat also causes the deterioration of oil. Hence a suitable cooling system must be provided.

The basic hydraulic system consists of the following elements

The following components make up actual hydraulic power system (Fig 8) for a safe and greater range of work.

Fig 8



- A reservoir to store the hydraulic fluid
- A pump to provide fluid pressure to the system
- A filter to remove dust, chips and other foreign particles from the fluid
- A pressure-regulating valve, which keeps the fluid pressure in the main part of the system at the proper level
- An accumulator, which acts as a cushion and prevents large variations in fluid pressure that occurring in the system
- Check valves, which permit fluid flow only in the desired directions.
- A hand pump for operating the system manually if necessary
- A pressure gauge, which indicates the amount of fluid pressure in the system
- A relief valve, which prevents the system pressure from rising too high, if the pressure-regulating valve fails
- Piping or tubing to circulate the fluid through the system

Pneumatics	Hydraulics
Confined pressureized system that use moving/air or other gases	confinded pressurized systems that use moving liquids
Because gases can be compressed, there is a delay in the movement, the force.	Liquids are not very compressible, there is no delay in the movement
Need for air compressor	Hydraulic Fluid-liquid inside system
Examples	Cylinder-container holding liquid
Pneumatic brakes (air brakes) used by buses, trucks, trains	piston-plunger moving inside cylinder
tampers used to pack down dirt and gravel	pumps-moves liquid in specific direction (usually against gravity)
lungs	Valves-controls the flow of direction (allows flow in one direction)
nail gun	Examples
dentist chair	Dump truck lift
most industrial pneumtic application uses pressure of 550 to 690 kpa	Hydralic lift to lift cars
	Jaws of lift
	blood in body used in cars
	Hydraulic application commonly use from 6.9 to 34.5 mpa. Special high pressure application may exceed 69 mpa.

Bramah press

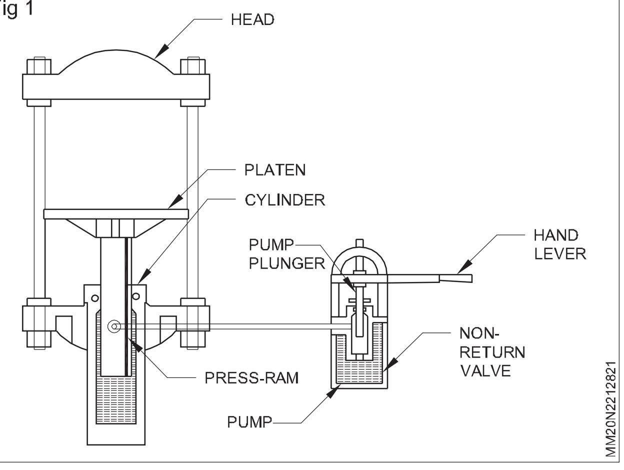
Objectives: At the end of this lesson you shall be able to
- **define bramah (hydraulic) press**
- **describe the principle and working of bramah press.**

A hydraulic press is a device using a hydraulic cylinder to generate a compressive force. It uses the hydraulic equivalent of a mechanical lever and was also known as a bramah press after the inventor Joseph bramah of England.

Principle and working (Fig 1)

The hydraulic press depends on the pascal's law a fluid such as oil is displaced when either piston is pushed inward. Since the fluid is incompressible the volume that the small piston displaces is equal to the volume displaced by the large piston. This causes difference in the length of displacement which is proportional to the ratio of areas of the heads of the pistons given that volume = Area X length. Therefore the small piston must be moved a large distance to get the large piston to move significantly. Water is drawn in to the pump through the valve then forced under pressure through the pipe to the cylinder. Here with its increased area and consequent increased pressure it to actuate the press ram.

Fig 1



Air compressor parts and function

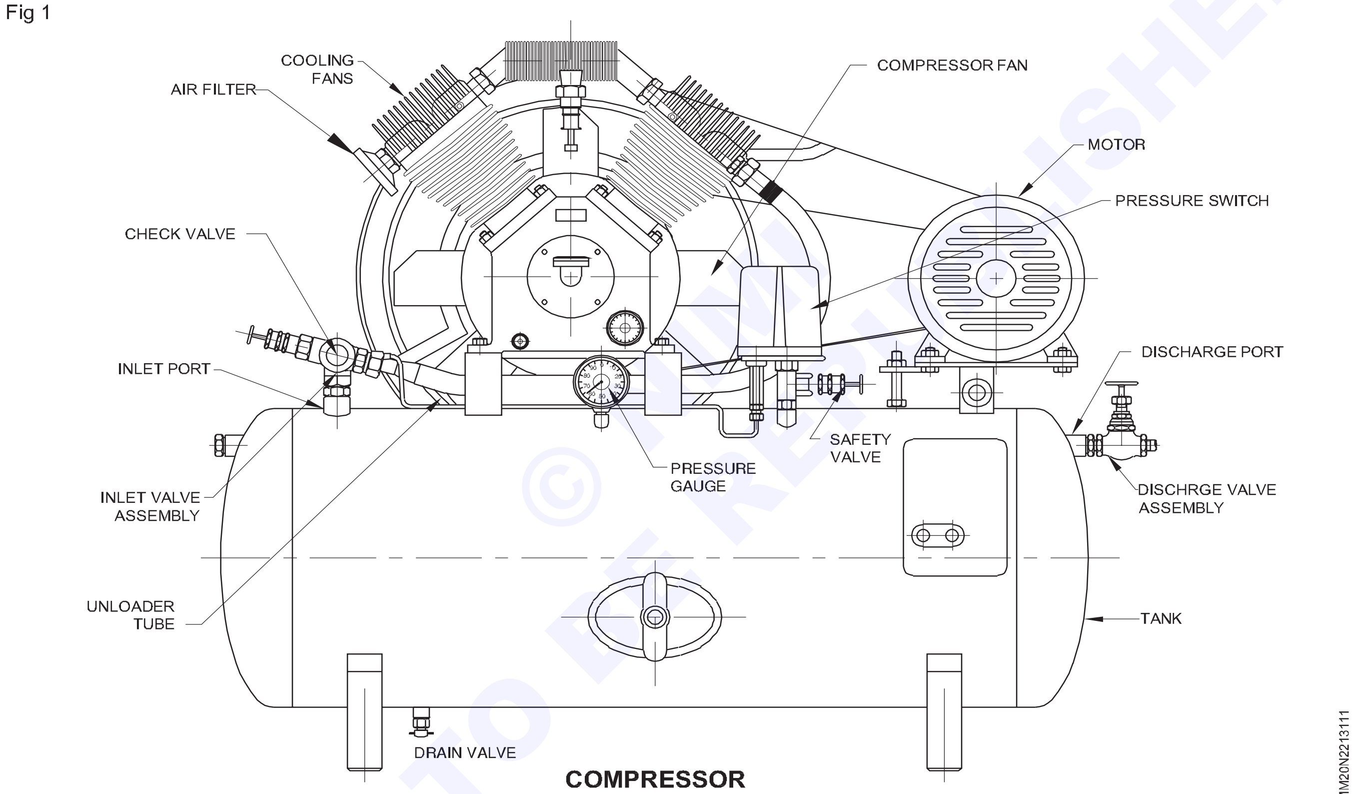
Objectives: At the end of this lesson you shall be able to
- **state construction of compressor**
- **explain parts of compressor**
- **describe the working principle of air compressor.**

Air compressor parts and functions

Air compressors are a type of machine tool and they work great with other power tools too. It basically provides other tools the ability to function and the power to do household as well as industrial improvement projects and installations. In order for tools to function at their best, air compressor must be working in its optimum power and efficiency and that means that the parts of an air compressor must be working 100% of the time to make sure the work is done.

Parts of an air compressor (Fig 1)

Fig 1



COMPRESSOR

The following are the main parts of an air compressor.

Motor

An air compressor needs an electric motor to power up the machine. The motor basically drives two belts a pulley which allows the transfer of power from the motor to the pump pistons and this is done through a flywheel and a crankshaft. One important thing need to install will be a magnetic starter to prevent the motor form overload.

Tank

This is the compressor part that stores the air being compressed. It is biggest part of the air compressor and it can range from 1-10 gallons or even more for bigger construction needs. The tank generally made of steel.

Pressure switch

The pressure switch automatically shuts down the motor when the receiver reaches the factory-set limit. Once the pressure level drops to a pre-set level then the pressure switch restarts the motor therefore resuming the pumping of air by the compressor. We can also call this as an emergency switch that regulates how much pressure in the tank can take.

Drain valve

The main purpose of the drain valve is exactly what its name implies. It drains the oil,dirt, moisture, and other debris that might be trapped inside the tank. Simple maintenance of air compressors entails draining a tank from impurities and debris from use. Moisture and oil are the most common reasons for rust to develop inside the tank when not drained.

Pressure gauge

This gauge measures compressed air pressure in the tank of the air compressor. It lets the user know that there is a problem if the measurement is higher than the regulated normal limit and serves as a warning to inspect the air compressor or stop the compression before the gauge reaches even higher pressure. On the contrary if the reading is very low from the normal allowed measurement, it also indicates a problem with the compressor such as a leak in the tank. This should also be checked right away to avoid any more complications and accidents.

Inlet port

This port is used to guide the inlet air towards the compressor inlet valve.

Inlet valve assembly

Inlet valve assembly compromises valve plate, and valve spring. Inlet valve controls the flow of air towards the cylinder of compressor. It is opening downwards to allow the air inside when the piston moves downwards. Valve plate is used to hold the inlet valve in proper position.

Cooling fins

Cooling fins are the extended part provided from the cylinder body to assure heat transfer from cylinder to surrounding. Generally these are made of aluminium.

Discharge Port

It is the opening provided at the top of compressor cylinder to guide discharge air towards the discharge line.

Discharge valve assembly

It comprises discharge valve plate, valve plate and valve spring. Valve plate helps to hold the discharge valve in proper position. Valve is aimed for discharge the high pressure air when the piston reaches its top.

Air filter

Air filter is very important part in an air compressor. It helps to prevent the dirt and dust to enter inside the compressor cylinder. Filter is provided in the suction end of the compressor.

Safety valve

A safety valve is provided on the air storage tank or air outlet line row prevent the danger occurred when the air pressure reaches beyond the capability of storage tank capacity.

Regulator

Generally an air regulator is provided in the discharge tube to regulate the high pressure air flow.

Check valve/Non return valve (NRV) and unloader tube

An one way check valve is provided in the bypass line in between air receiver tank and compressor head. It will open and admit the high pressure air towards the receiver tank while unloading is going on during the starting time. An unloader tube is connected at the inlet port of the check valve and the valve only opens in one direction (ie from compressor top to receiver air flow). During this time the high pressure air is unloaded towards tank through unloader tube.

Compressor fan

A compressor fan is connected at one end of the crank shaft to provide sufficient cooling air to compressor. It will prevent overheating of compressor.

Air compressor working principle

Working principle (Fig 1)

Air compressors collect and store air in a pressurized tank, and use pistons and valves to achieve the appropriate pressure levels within and air storages tank that is attached to the motorized unit. There are a few different types of piston compressors that can deliver even air pressures to the user.

Automotive compressors are combustion engine compressors that use the up-and-down stroke of the piston to allow air in and pressurize the air with in the storage tank. Other piston compressors utilize a diaphragm, oil-free piston. These pull air in, and pressurize it by not allowing air to escape during the collection period.

Now the air compressor is capable of building extreme pressure in storage tanks capable of storing enormous amounts of pressurized gases for industrial use.

Air dryer

A compressed air dryer is used for removing water vapor from compressed air.

Compressed air dryers commonly found in a wide range of industrial commercial facilities.

Usage

Drying air for use in commercial or industrial processes that demand dry air:

Telecom industry (pressurizes its underground cables to repel moisture and avoid shorts).

Painting.

Pneumatic tools.

Textile manufacturing.

Pneumatic control systems.

Feed air for zeolite type oxygen and nitrogen generators.

Dental office air.

Truck and train air brake systems.

The process of air compression concentrates atmospheric contaminants, including water vapor. This raises the dew point of the compressed air relative to free atmospheric air and leads to condensation within pipes as the compressed air cools downstream of the compressor.

Excessive water in compressed air, in either the liquid or vapour phase, can cause a variety of operational problems for users of compressed air. These include freezing of outdoor air lines, corrosion in piping and equipment , malfunctioning of pneumatic process control instrument, fouling of processes and products and more.

There are various types of compressed air dryers. Their performance characteristics are typically defined by the dew point.

- Refrigerated dryers
- Deliquescent dryers
- Desiccant dryer
- Memberane dryers

Refrigerated dryer

Refrigeration dryers employ two heat exchangers, one for air-to-air one for air-to-refrigeration. These dryers are used in refrigeration compressors.

Deliquescent dryer

A deliquescent dryer typically consists of a pressure vessel filled with a hygroscopic medium that absorbs water vapor. The medium gradually dissolves-or deliquesces-to form a solution at the base of the pressure vessel. The liquid must be regularly drained from the vessel and new medium must be added.

Deliquescent dryers are used for removing water vapour from compressed air, natural gas, and waste gases.

Desiccant dryer

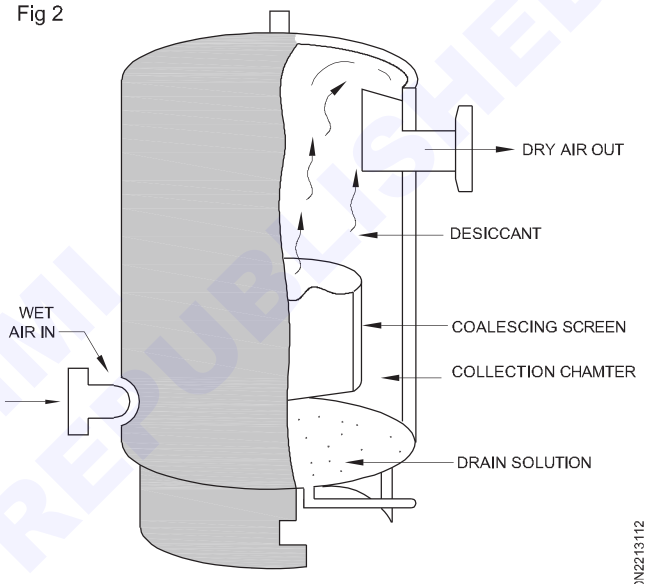
The term “desiccant dryer” refers to a abroad class of dryers. Other terms commonly used are regenerative dryer and twin tower dryer,and to a lesser extent absorption dryer.

The compressed air is passed through a pressure vessel with two “towers” filed with a media such as activated alumina, silica gel, molecular sieve or other desiccant material. This desiccant material attracts the water from the compressed air via adsorption.

Membrane dryer (Fig 2)

Membrane dryer refers to a dehumidification membrane that removes water vapor from compressed air. Typically, the compressed air is first filtered with a high-quality coalescing filter. This filter removes liquid water, oil and particulate from the the compressed air. The water vapor-laden air then passes through the center bore of hollow fibers in the membrance bundle. At the same time, a small portion of the dry air product is redirected along the outside surface of the fibers to seep out the water vapor which has permeated the membrane. The moisture-laden sweep gas is then vented to the atmosphere, and clean, dry air is supplied to the application. The membrane air dryers are designed to operate continuously, 24 hours per day, 7 day per week. Membrane air dryers are quiet, reliable and require no electricity to operate.

Fig 2



MEMBRANE DRYER

FRL unit (Filter, regulator, lubricator)

Objectives: At the end of this lesson you shall be able to
- **define FRL unit**
- **state the types of FRL**
- **state the specifications of FRL.**

Fitter,regulator,lubricator (FRL) assemblies are pre-packaged or modular assemblies of air filters,pressure regulators,and gauges. Air leaving a compressor is hot,dirty,and wet and can cause damage to equipment and tools if it is not filtered.

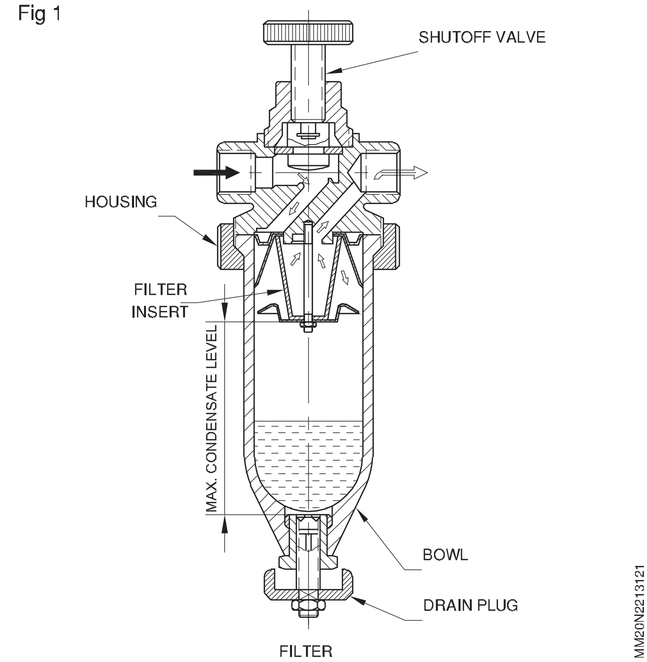
The filter cleans compressed air by trapping solid particles and separating liquids,such as oil and water,that are trapped in the compressed air. Filters are installed in the air line upstream of regulators,lubricators,and all pneumatically-powered tools and equipment. They remove contaminants from pneumatic systems,preventing damage to equipment and reducing production losses due to contaminant-related downtime. (Fig 1)

Pressure regulators control fluid pressure in compressed air systems. Regulators are also known as pressure reducing valves(PRVS). Pressure regulators maintain a constant output pressure regardless of input pressure variations and demands made on the system by downstream components.

Lubricators add controlled quantities of oil into the compressed air system to reduce the friction between moving components within air tools and other equipment that are powered by the system. Adding lubrication oil to the system also clears compressor oils that travel through the system in vapor form. To prevent build-up of oil within system components,mineral oils are added to the system to flush away the deposits.

Downstream equipment flow and pressure requirements determine the correct regulator and lubricator for the application. Manufactures offer flow characteristics charts on their products to help chose the correct combination of regulators and lubricators.

Fig 1



FILTER

Types

There are several choices for regulator type.

- **General-purpose regulators** are designed for typical industrial use;they generally operate only above atmospheric pressure.
- **High- pressure regulators** are rated for inlet pressures higher than general purpose,typically over 1,000 psi.
- **Low- pressure regulators** have special design characteristics for precise control of pressures typically below 15-20 psi.
- **Differential or bias regulators** maintain a pressure differential between two locations in the system.
- **Pressure- reducing valves** provide a sub-circuit with a supply of fluid at a pressure that is less than the pressure in the main circuit.

Specifications

Performance specifications:

- **Regulating (adjustment) range** - Dictates the limits of adjustment control
- **Maximum flow (gas or air)** - Unnecessary to specify if primary application is liquid
- **Maximum pressure rating**- Refers to the pressure rating for the valve or inlet pressure for the regulator
- **Filter minimum particle size rating** - Applies to filter,regulator,and lubricator (FRL) assemblies. It is the smallest size particle that will be entrapped by the filter. This rating is an indication of the largest opening in the filter element.

Other important specifications include:

- Regulator type
- Medium
- Adjustement control
- Connectors or pipe size
- Body material
- Environmental parameters

Applications of pneumatics

Objectives : At the end of this lesson you shall be able to
- **state the application of pneumatic cylinders**
- **state various areas of automation**
- **describe the hazards and safety precautions in pneumatic system.**

Application

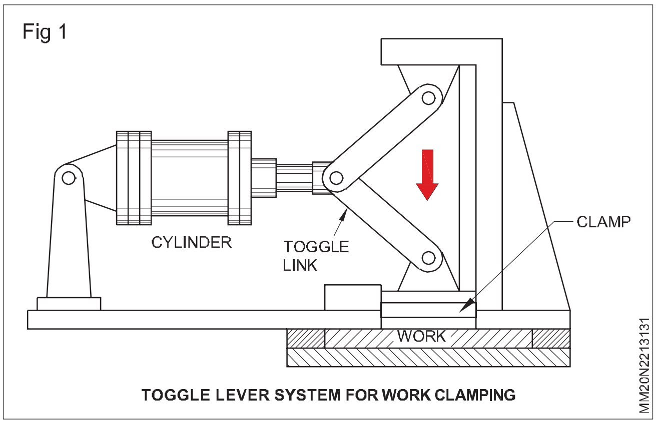
In any control system or automation,penumatics can be economically applied. Besides,in other inaccessible areas like furnaces Pharmaceutical industry Food Processing and nuclear/reactors,compressed air is the only choice to operate the control system.

Air cylinders are widely used in pneumatic systems,since the liner motion is the most common requirement of the sytem. But rotating actuators (motors)find their application in hand tools like portable drilling machine. As a general practice pneumatics is efficiently used in speed control rather than power requirements.

In the Fig 1 the piston moves the toggle link. The free ends of the toggle link moves down to clamp the work.

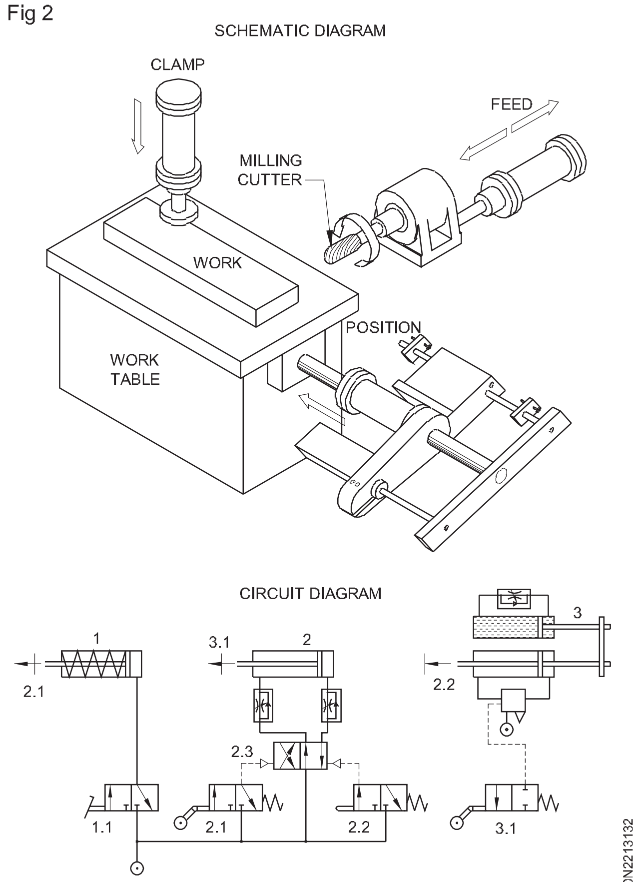
The Fig 2 Shows feed unit. For a slot milling machine. The pedal operates valve 1. 1 clamps the jobs on the table. The piston rod at the end of its travel operated the valve 2. 1 and make the cylinder to move forward, in turn operating the valve 3.1. The valve operates the cylinder 3 to enact the feed to the work.

Fig 1



TOGGLE LEVER SYSTEM FOR WORK CLAMPING

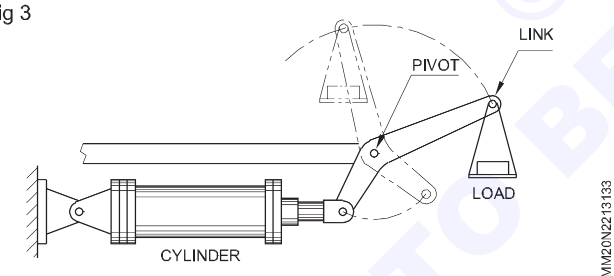
Fig 2



SLOT MILLING ON SPECIAL DUTY MACHINE

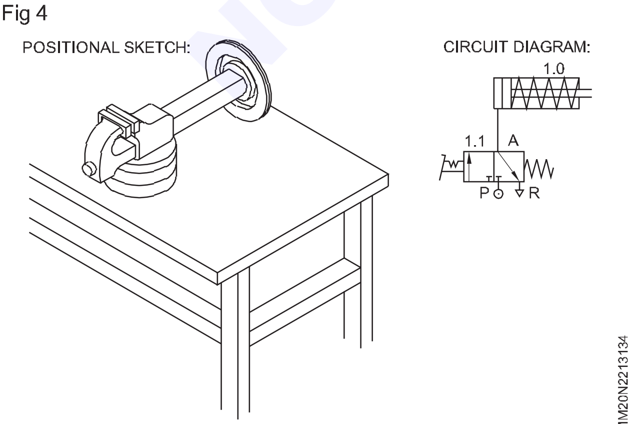
In Fig 3, the movement of the piston rod to the right till the pivoted link to the left. By this movement the load is swing to the left hand side.

Fig 3



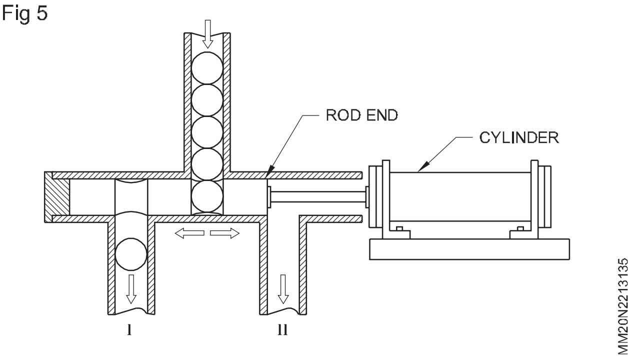
The operation of vice is shown in Fig 4. The 3/2 way valve extends and retreats the single acting cylinder attached to the movable vice.

Fig 4



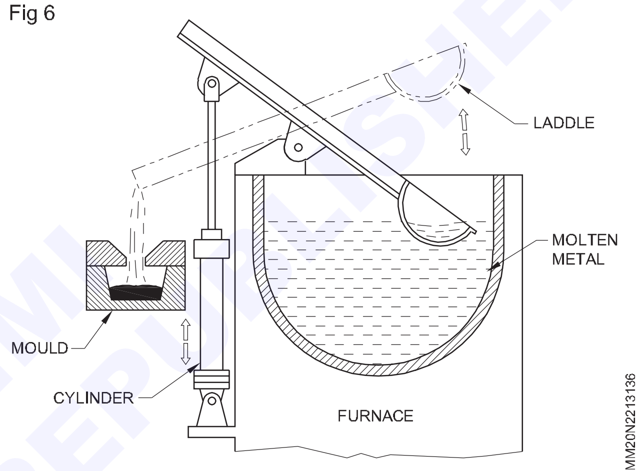
In Fig 5 the ball falling by gravity is distributed in two passages I & II, by means of the cylinder action.

Fig 5



In Fig. 6 the vertical movement of the piston rod lifts or lowers the laddle of molten metal to pour it into the mould.

Fig 6



Hazards & Safety precautions in pneumatic system

Whenever you are working with Pneumatic system you must take following safety precautions:

- Take precaution against corrosion in pneumatics components.
- Do not use compressed air to clean body parts.
- Never use kerosene to clean pneumatic system.
- Compressed air does not lignite but can explode due to pressure.
- Pneumatic system operates at high speed, most of the accidents happen due to crushing, hence take care when handling.
- Do not put hands in the path of operating components.
- Avoid contact of plastic pipes with sharp edges.
- Close main valve to unpressurise pneumatic system prior to maintenance work.
- Loose connection may cause withdrawal of pneumatic hose, that whips due air flow. This whipping action may cause injury.

Pneumatics actuators

Objectives: At the end of this lesson you shall be able to
- **define pneumatic actuators**
- **state the types of pneumatics actuators**
- **to calculate cylinder forces**
- **define stroke length.**

Pneumatic actuators

Pneumatic actuators are the devices used for converting pressure energy of compressed air into the mechanical energy to perform useful work. In other words, Actuators are used to perform the task of exerting the required force at the end of the stroke or used to create displacement by the movement of the piston. The pressurised air from the compressor is supplied to reservoir. The pressurised air from storage is supplied to pneumatic actuator to do work.

The air cylinder is a simple and efficient device for providing linear thrust or straight line motions with a rapid speed of response. Friction losses are low, seldom exceeds 5% with a cylinder in good condition, and cylinders are particularly suitable for single purpose applications and / or where rapid movement is required. They are also suitable for use under conditions which preclude the employment of hydraulic cylinders that is at high ambient temperature of up to 200 °C to 250 °C

Their chief limitation is that the elastic nature of the compressed air makes them unsuitable for powering movement where absolutely steady forces or motions are required applied against a fluctuating load, or where extreme accuracy of feed is necessary. The air cylinder is also inherently

Limited thrust output by the relatively low supply pressure so that production of high output forces can only by achieved by a large size of the cylinders.

Types of Pneumatics Actuators

Pneumatic cylinders can be used to make linear, rotary and oscillatory motion. There are three types of pneumatic actuator: they are

1 Linear Actuator or Pneumatic cylinders

2 Rotary Actuator or Air motors

3 Limited angle Actuators

Calculation of cylinder forces - metric based products

General Formula

The cylinder output forces are derived from the following formula:

$$F = \frac{P \times A}{10}$$

Where F = Force in N

P = Pressure at the cylinder in Bar

A = Effective area of cylinder piston in square mm.

Prior to selecting the cylinder bore size, proper size of the piston rod for tension (pull) or compression (push) loading. (See the piston Rod Selection Chart)

If the piston rod is in compression, use the 'Push Force' table below, as follows:

1 Identify the operating pressure closest to that required.

2 In the same column, identify the force required to move the load (always round up).

3 In the same row, look over to the cylinder bore required.

If the cylinder envelope dimensions are too large for the application, increase the operating pressure, if possible, & repeat the exercise.

If the piston rod is in tension, use the 'Deduction for Pull Force' table. The procedure is the same but due to the reduced area caused by the piston rod, the force available on the 'pull' stroke will be smaller. To determine the pull force:

1 Follow the procedure for 'push' force as described previously.

2 using the 'Deduction for Pull Force' table, identify the force indicated according to the rod & pressure selected.

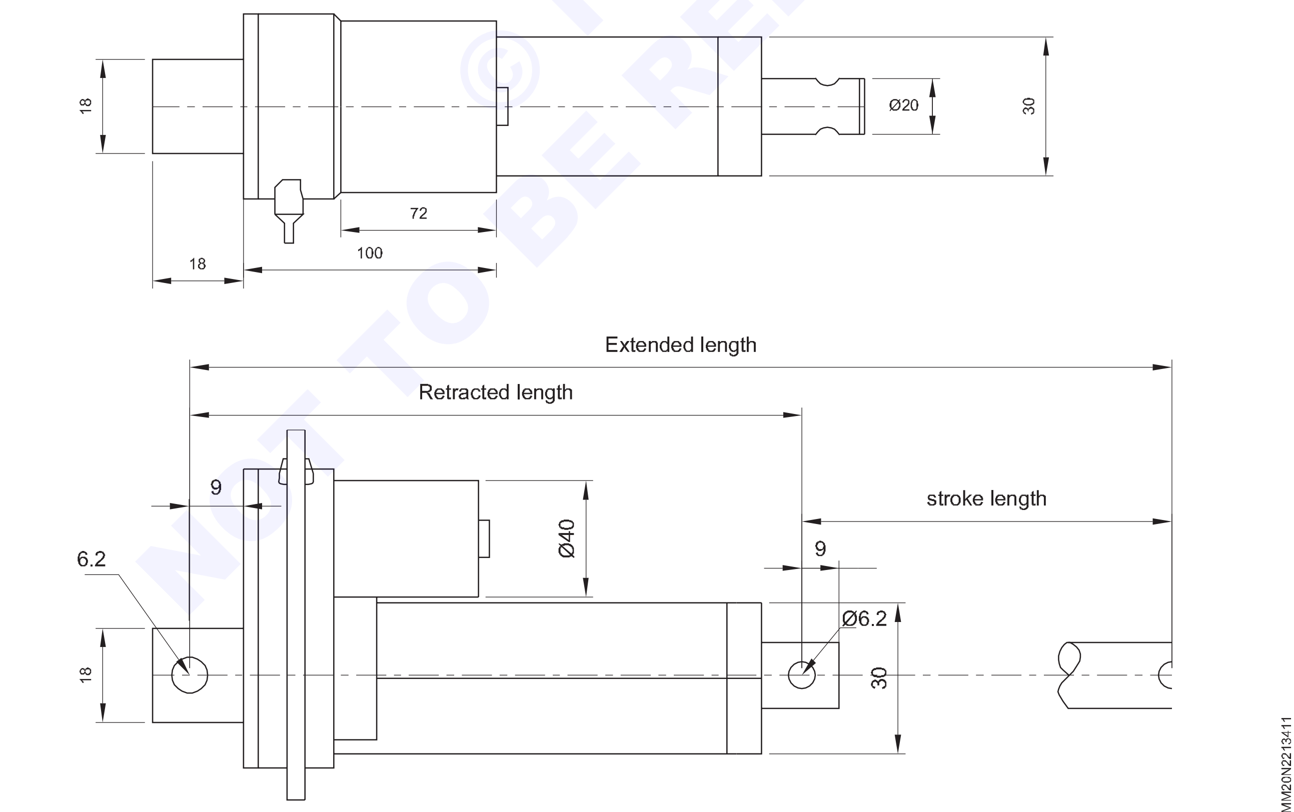
3 Deduct this from the original 'push' force. The resultant is the net force available to move the load.

If this force is not large enough, repeat the process & increase the system operating pressure or cylinder diameter if possible.

Stroke is the distance travelled by an actuator in motion. This is a measurement of the capability of a linear actuator. ... Stroke helps determine key factors such as the weight capacity of the actuator, how much time will it take, the speed of the motion, and the force that can be generated. (Fig 1)

Piston rod Size (mm)	Piston rod Area (mm^2)	Reduction in Force (N) at various Pressures in Bar			
		1	5	7	10
6	28	3	14	20	28
8	50	5	25	35	50
10	79	8	39	55	79
12	113	11	57	79	113
14	154	15	77	108	154
16	201	20	101	141	201
20	314	31	157	220	314
25	491	49	245	344	491
32	804	80	402	563	804
40	1257	126	628	880	1257
50	1963	196	982	1374	1963
63	3117	312	1559	2182	3117
80	5027	503	2513	3519	5027
100	7854	785	3927	5498	7854
125	12272	1227	6136	8590	12272
160	20106	2011	10053	14074	20106
200	31416	3142	15708	21991	31416

Fig 1



Single acting cylinder and its application

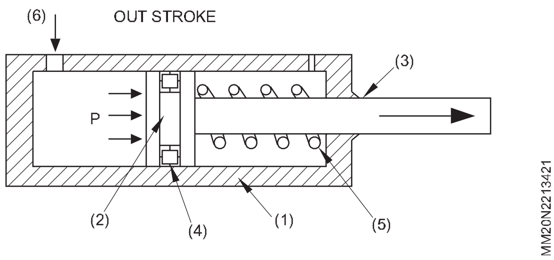
Objectives : At the end of this lesson you shall be able to
- **identify internal parts of single acting cylinder**
- **explain working principle of single acting cylinder**
- **explain working of 3/2 way valve**
- **interpret circuit to control single acting cylinder.**

Single acting cylinder

It is an actuator which moves load along the straight line. It can apply pneumatic force only in one direction therefore called single acting. Movement in opposite direction is caused by external force like spring or own weight of the load.

Construction: Construction of single acting cylinder is shown in the Fig 1.

Fig 1



Main parts of single acting cylinder are listed as follows:

1 Cylinder

2 Piston

3 Piston rod

4 Seal

5 Spring

6 Inlet Port

Working principle of single acting cylinder

Initially piston remains at the innermost position in the cylinder due to spring force (Fig 1)

When compressed air is supplied through inlet port, pressure acts on cross section of the piston.

Product of pressure and piston cross section area gives rise to a force which acts opposite to the spring force. If pneumatic force is greater than the spring force then spring gets compressed and piston starts moving.

Seal prevents air leak across the piston.

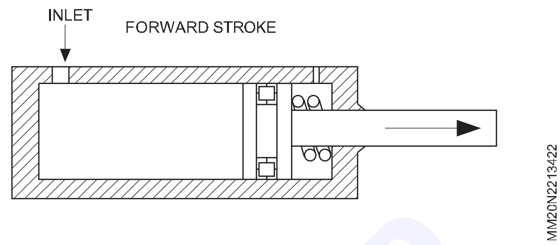
Continuous flow of air causes continuous motion of piston. Load is attached to piston through piston rod; therefore load also moves with piston.

Piston and load move till piston reaches to other end. At the end there is no further space for piston to move, hence piston and load movement stops. (Fig 2)

This piston movement is called forward stroke.

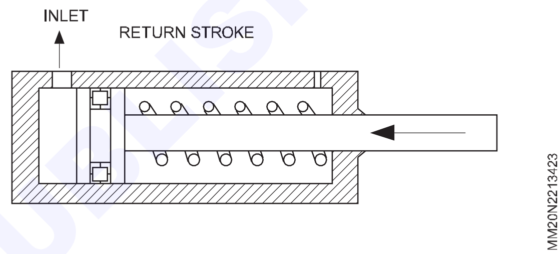
In forward stroke piston rod comes out of the cylinder. If we denote piston by A, then forward stroke is denoted by A

Fig 2



If pressure acting on piston is released, pneumatic force acting opposite to spring becomes weak, therefore spring pushes piston back. (Fig 3)

Fig 3



This stroke is called return stroke.

In return stroke piston rod goes inside the cylinder. Return stroke is denoted by A-.

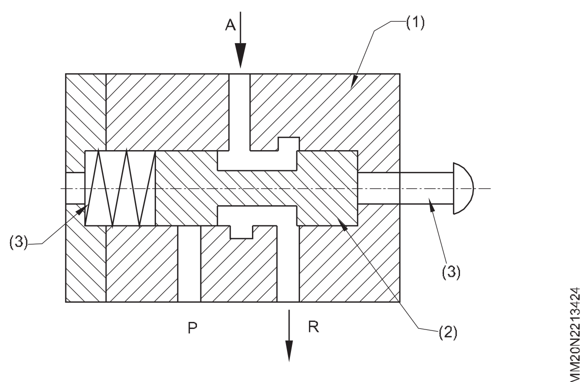
Direction control of single acting cylinder

To control single acting cylinder or in other words to push and pull load by single acting cylinder you always need 3 port 2 position direction control valve as main control element.

Construction of 3 port 2 position valve

Construction is shown in the Fig 4.

Fig 4



It consists of following parts:

1 Valve body

2 Spool

3 Actuation mechanism: Push button & Spring

4 Air flow path

5 Ports (P,A,R)

Valve body provides cavity whch accommodates spool, internal passage for air flow and actuation mechanism.

Spool is a piston shaped element which when shifts changes air flow path.

Actuation mechanism provides facility to shift the spool.

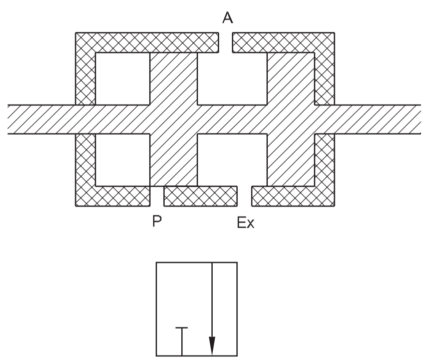
Port is a point where you can connect air pipe with the help of connector.

Working principle of 3 port 2 position valve

3 port 2 position valve gives two status or positions of air flow.

Input port is blocked and output is connected to exhaust. In this status compressed air does not flow through the valve. Also output port is connected to exhaust port so that output line remains at atmospheric pressure. (Fig 5)

Fig 5



Input port is connected to output port and exhaust port is blocked. In this status compressed air flow through the valve and push the piston. (Fig 6)

Fig 7 shows the circuit to operate single acting cylinder.

When compressor is switched on compressed air is available up to input port “1” (Fig 8)

When push button is pressed,direction of air changes due to valve shift. Piston moves forward. (Fig 9)

Push button is when released piston returns back. (Fig 8)

Fig 6

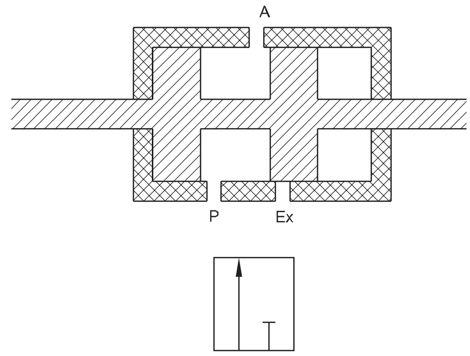


Fig 7

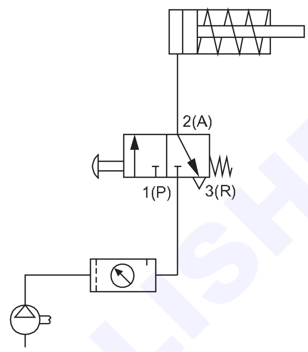


Fig 8

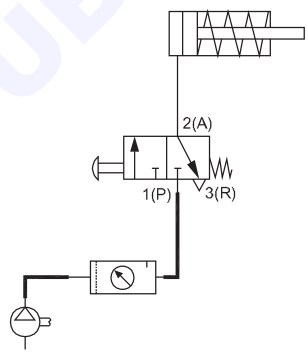
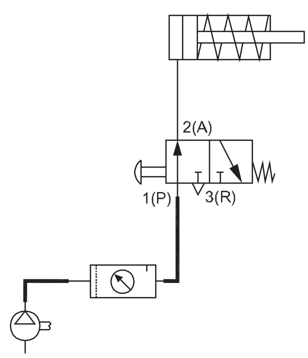


Fig 9

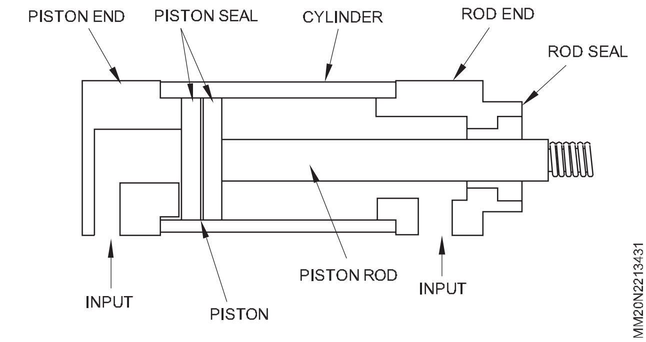


Double acting cylinder and its application

Objectives: At the end of this lesson you shall be able to
- **explain working principle of Double Acting Cylinder**
- **explain operation of 5/2 way valve**
- **use 5/2 way valve to operate double acting cylinder.**

Double acting cylinder is an actuator which can push and pull the load using compressed air. It has two ports for air supply. Fig 1 shows the construction of double acting cylinder.

Fig 1

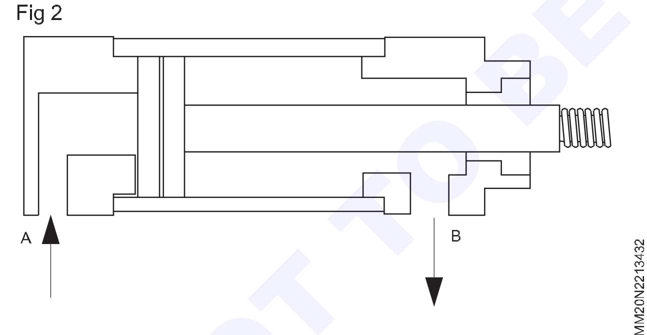


Input Ports: For air supply

- Piston: Element which moves to and fro inside the cylinder.
- Cylinder: It confines air for the piston movement.
- Piston rod: A rod which connects piston and a load.
- Piston Seal: Seal which prevent leakage across the piston.
- Rod Seal: Seal which prevents air leakage from cylinder to the atmosphere.
- Piston End: Part of the cylinder consisting air passage and connected to the piston side.
- Rod End: Part of the cylinder consisting air passage and connected to the piston side.

When air is supplied through port A, force is exerted on the piston so that it moves in forward direction. This movement is called forward stroke. During forward stroke air already present at the rod side exhausts through port B. (Fig 2)

Fig 2



Piston movement will stop if air does not exhaust.

When air is supplied through port B, air already present exhausts through port A and piston retracts. (Fig 3)

Symbol of double acting cylinder is shown in Fig 4

5 port 2 position valve

To operate double acting cylinder it is needed to change the direction of air between ports A & B. Therefore a valve is required whcih has two output ports. 5 port 2 position valve has two output ports. Construction is shown in Fig 5.

Fig 3

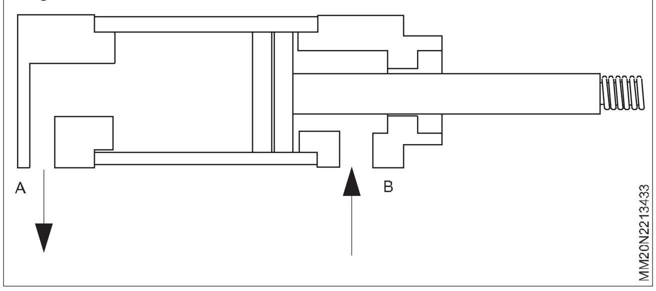


Fig 4

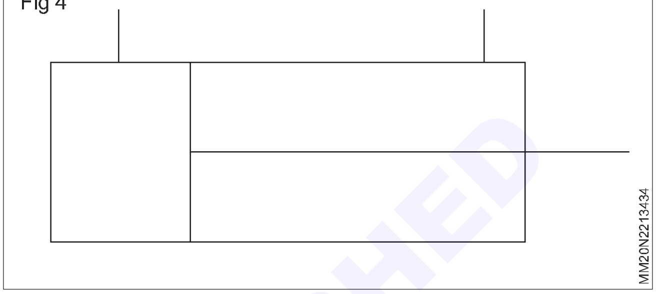
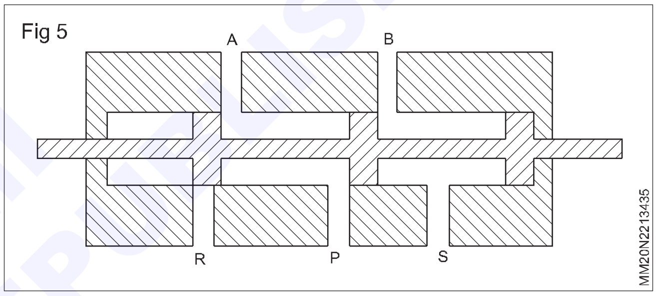


Fig 5



- Valve body: It provide cavity to move spool and ports.
- Spool: It is an element which change flow path when moves inside the valve body.
- Input port: Connection point where air enters into valve. It is denoted by 'P' or number '1'.
- Output port: Connection points from where air comes out of valve. Output ports are denoted by 'A" & 'B' or number '2' & '4' respectively.
- Exhaust port: Connection points from where air exhausts. Exhaust ports are denoted by 'R' & 'S' or number '3' & '5' respectively.

Position refers to status of direction of air flow path in the valve.

In one position port 'P' is connected to 'B' and port 'A' exhausts through 'R, but exhaust port 'S' closed. (Fig 6)

In other position port 'P' is connected to 'A' and port 'B' exhausts through 'S' but exhaust port 'R' is closed. (Fig 7)

Symbol of 5 port 2 position valve is shown in Fig 8

Fig 9 Shows circuit to operate double acting cylinder. Initially in normal position (Spring operated position), supply direction is from 1 (P) to 2 (B) and 4 (A) to (R) so that piston is always in retracted position unless actuated. (Fig 9)

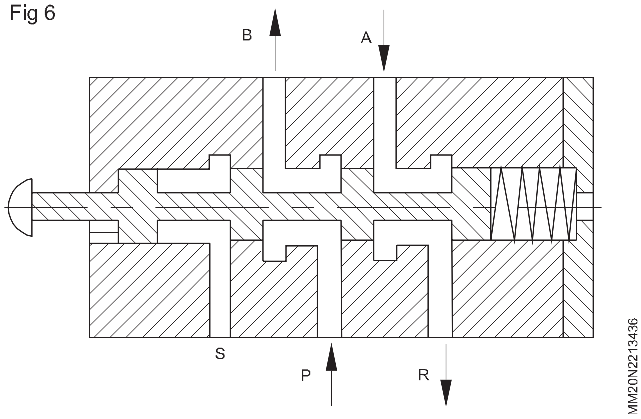


Fig 6

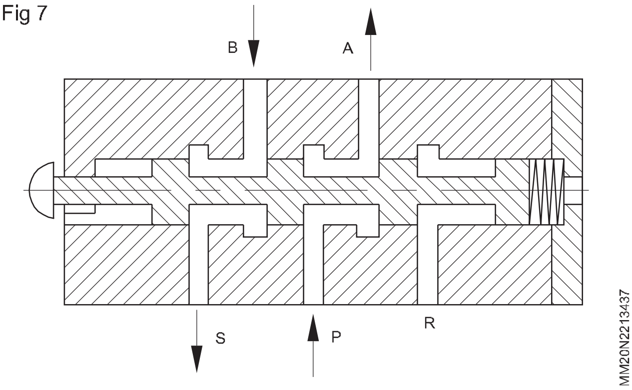


Fig 7

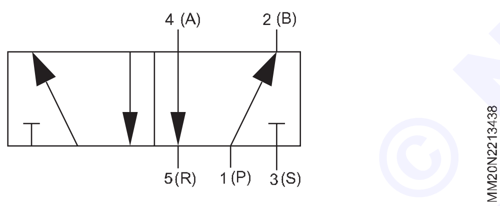


Fig 8

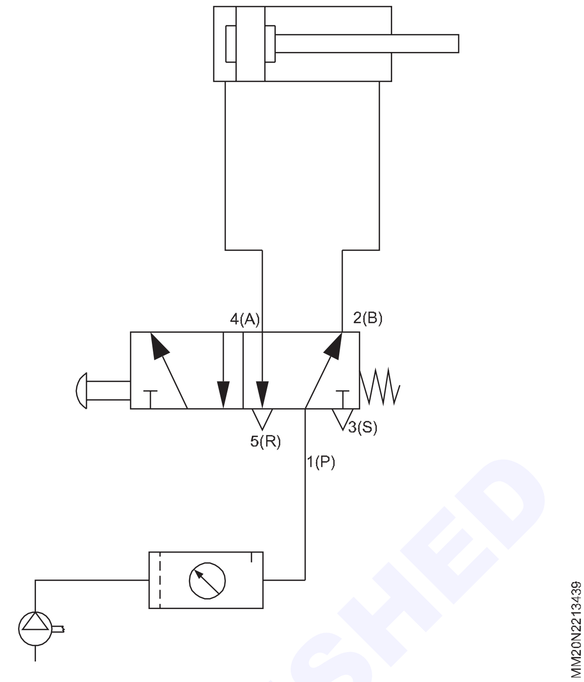


Fig 9

When push button is operated air flow path changes inside the valve so that supply direction is 1 (P) to 4 (A) and 2 (B) to 3 (S), thus gauses piston moves forward. (Fig 10)

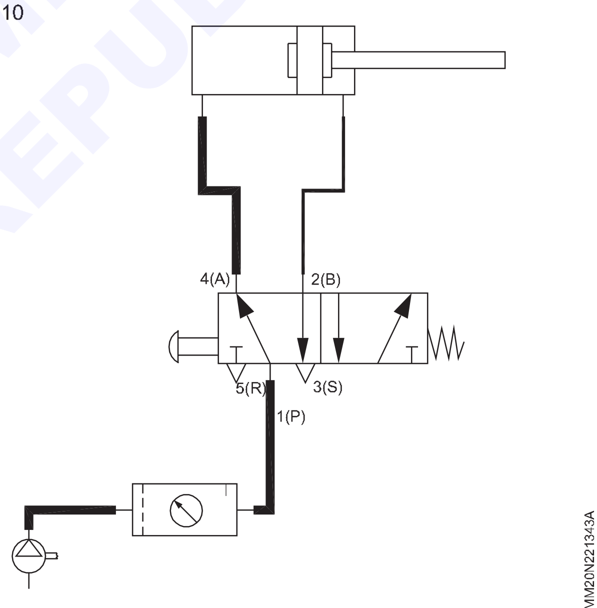


Fig 10

Pneumatic valves

Objectives: At the end of this lesson you shall be able to
- **state the directional control valve**
- **list the classification or directional control valve**
- **state the sealing action in valves**
- **explain the different types of directional control valve.**

Valves are the devices used to control, regulate commence, terminate or change direction of flow and pressure of fluid used in the system.

Valves in pneumatics are grouped according to their function. They are

- Directional control valves
- Non-return valves
- Pressure control valves
- Flow control valves.

These valves will be discussed in the following lessons.

Directional control valve

Directional control valves are used to control the (1) direction of flow of the fluid, (2) commencement and termination of the flow of fluid. Direction control valve finds its place in the circuit immediately before the cylinder/ air motor.

Classification of directional control valve

Directional control valves can be classified according to the following features by virtue of construction and function

- According to the internal design
- According to the number of ports and position
- According to the valve actuating mechanism.

According to the internal design

The design of the valve even though not affecting the function, plays an important role in terms of

- Life of valve
- Actuating force
- Means of actuation
- Means of connection.

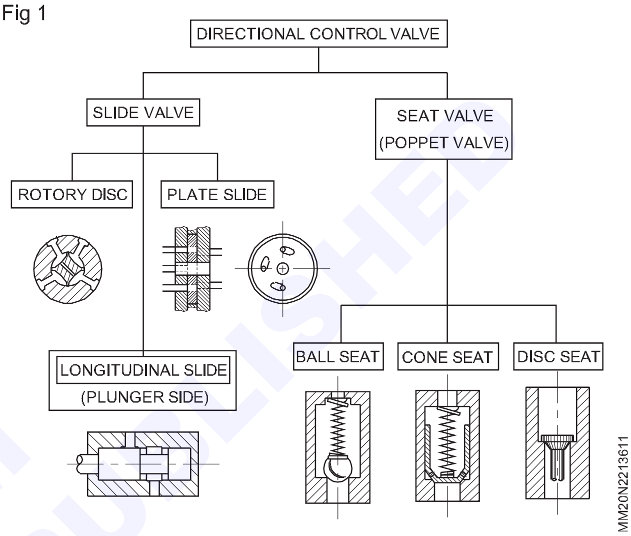
Directional control valves are classified in two major group as shown in Fig 1.

Slide valves

Slide valves are called so, because the opening and closing takes place by sliding of one of its member. Further in slide valve we have

- Rotary disc valve
- Longitudinal slide or spool valve
- Plate slide valve

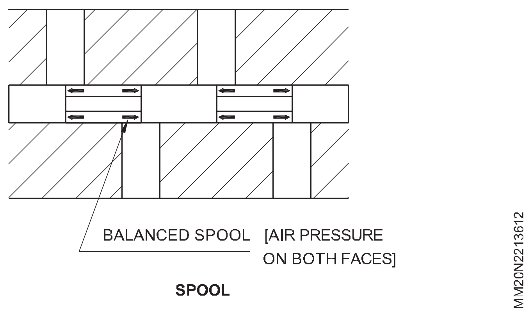
Fig 1



Slide valves are used extensively in pneumatics because of its advantages like.

- Balanced spool (Fig 2)
- Less force required to actuate

Fig 2



However they have their disadvantages also

- A fine finish and accuracy are required for sliding parts
- Sensitive towards dirt in the air
- Length of actuation is more
- Wear and tear is more
- Life is less.

Seat valves

Seat valves are also called as poppet valves. The valve is opened or closed by the lift of seating element.

These valves are further grouped as

- Ball seat valve
- Cone or taper seat valve
- Disc seat valve.

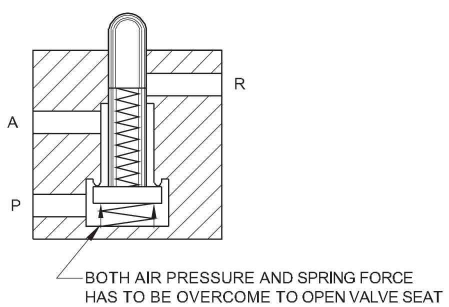
Seat valve are superior in terms of the following

- Wear and tear is minimum
- Actuating length or lift is very less
- Provides leakproof arrangement
- Long life
- Insensitive to dust/dirt

However these valve also have a few disadvantages

- Force, required to operate is more
- Balancing of force not adequate. (Fig 3)

Fig 3



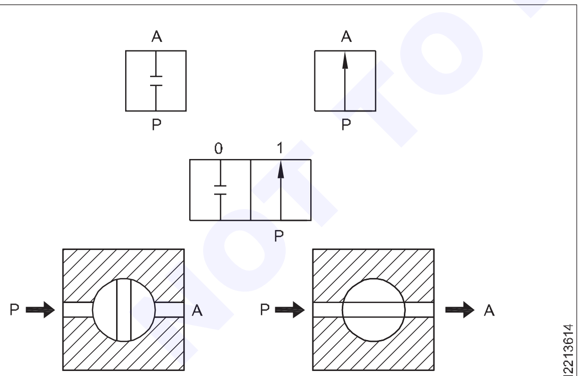
Valve classification according to the number of ports and position

A directional control valve has a number of ports through which air enters and exits.

It also takes various position according to flow path of air.

The valve shown has inlet(P) and outlet(A) position .(Fig 4)

Fig 4



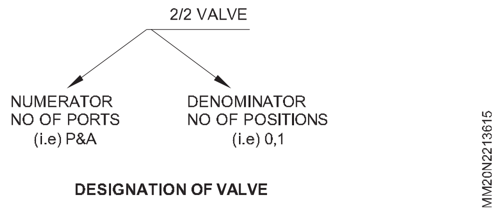
GRAPHICAL REPRESENTATION

It also has two positions.

Initial position - No flow. Final position - Full flow. This is graphically represented as one square for each operating position.

Inside this square the path of flow of air is indicated by arrow marks. The valve shown in the Figs 4 & 5 is designated a 2/2 valve.

Fig 5



DESIGNATION OF VALVE

The ports are named as follows:

P - Pressure port

This is to indicate the entry of the compressed air from the compressor into the valve. (which is represented by a square)

A,B,C - working ports

These ports supply air to the cylinder and receive air from cylinder.

R,S,T = Exhaust ports

These are the ports from where used air is exhausted.

X, Y, Z - Control or signal ports.

These ports are used as signal input and signal outputs.

The positions of valves are named as 0, 1 and 2 or 1, 2 according to the type of actuation.

Valve classification according to the type of actuation

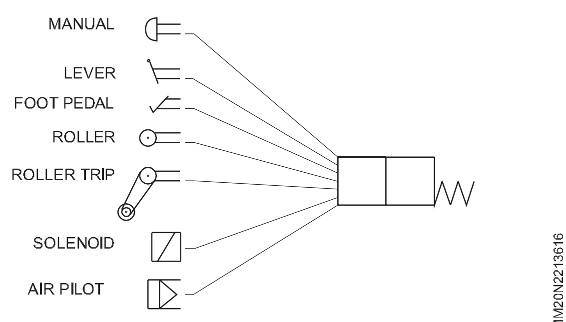
The valves have more than one marking position. For the position to change, an external force is required. The method of actuating the valve plays a very significant role to suit the purpose for which the valve is employed. This also determines the level of automation of the circuit. The actuation is grouped into 2 major groups as

- Spring return valve
- Detent valve

Spring return

In this mechanism the valve always assumes a particular position because of the spring. When operated it changes its position. Actuation of other end may be of the following types. (Fig 6)

Fig 6

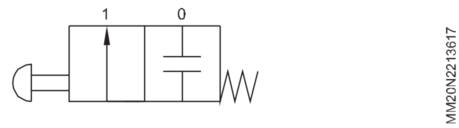


- Manual type
- Lever type
- Pedal type
- Roller type
- Roller trip type

- Solenoid
- Pilot operated

Initial position of a spring return valve is always named as '0' and other position as 1. (Fig 7)

Fig 7

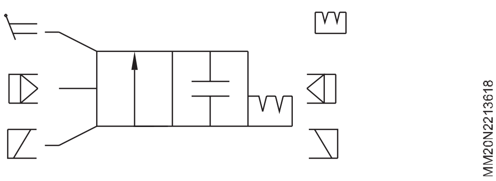


Detent valve

In this mechanism the change of position of the valve is retained (by latch), unless it is actuated, again. This type of valve is called a detent valve.

Under this category we have (Fig 8)

Fig 8

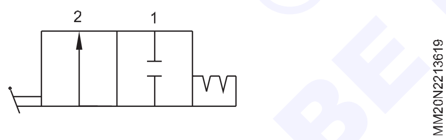


- Lever operated
- Impulse operated
- Solenoid operated

The return is also effected by any of the above mechanism.

The positions of these detent valves are indicated as 1 and 2 since it does not have a normal position, that is generally denoted by '0'. (Fig 9)

Fig 9



According to the proximity of actuation mechanism from control again actuations can be

- Direct or
- Remote

Direct actuations are hand lever,pedal,roller etc. (Fig 10)

Remote control is by air, air impulse solenoid et (Fig 11)

Fig 10

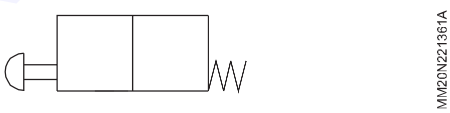
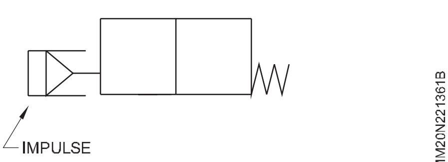


Fig 11



Various types of directional control valve

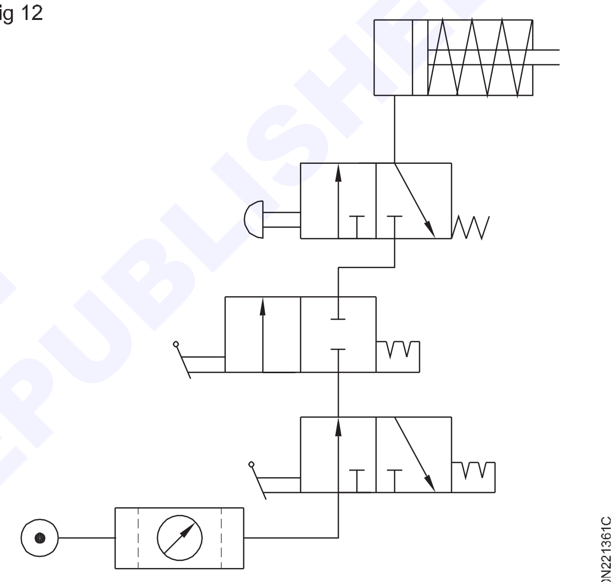
Here we discuss various types of valves according to their function. The type of actuation and constructions are not considered.

2/2 directional control valve

This has 2 ports and 2 positions

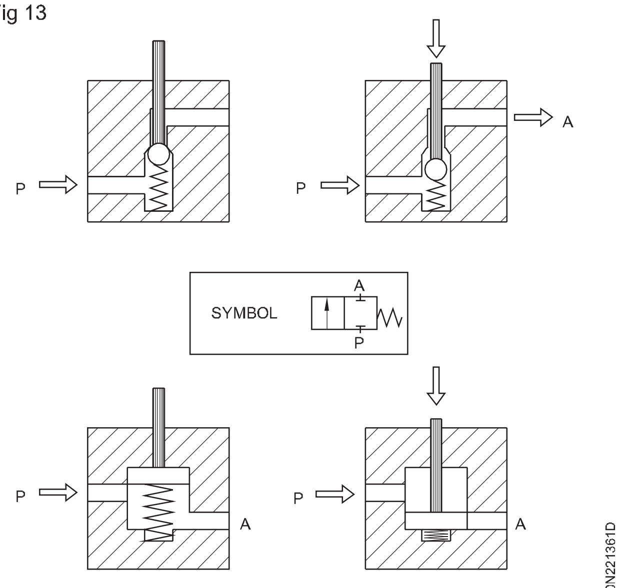
This valve normally is used for termination and commencement of air flow. This valve ideally serves as a cut-off valve in circuit. For emergency situations a cut-off valve shown in the circuit diagram, (Fig 12) can stop the cylinder movement, suddenly by cut-off the air supply. The various 2/2 valves according to the internal design are shown in Fig 13 in both normal and operated conditions. These valves can be normally closed type or opened type. (Fig 14)

Fig 12



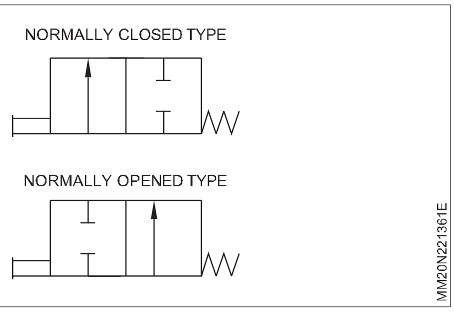
CUT OFF VALVE

Fig 13



VALVE POSITIONS

Fig 14



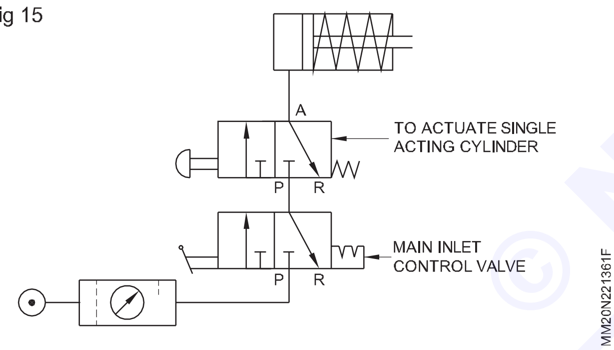
3/2 directional control valve

The main advantage of the 3/2 valve is that it gives vent for the used air through the exhaust port. It has 3 ports P, A and R. This facilitates to generate a signal and also to cancel the signal in the valve as shown in the Fig 15 initial position P is blocked, A is connected to R. In the actuated position P gets connected to A, R gets blocked.

A 3/2 valve is ideally suited for an application of inlet valve, and also for actuating a single acting cylinder (Fig 15).

This valve is also very ideal for remote control of main direction control valves as impulse and pilot type. The construction of various 3/2 valves in normal and actuated conditions are shown in Fig 15.

Fig 15



3/2 valves are available as both normally opened type or closed type, which can be selected according to the requirement of the circuit. (Fig 16)

4/2 directional valve

The main application of a 4/2 valve is in actuation of a double acting cylinder. This valve has 4 ports namely

P - Pressure port

A & B - Working port

R - Exhaust port

In normal position (Fig 17) P is connected to A and B is connected to R and vice-versa in the other position.

The application of a 4/2 valve to actuate of double acting cylinder is shown in Fig 18.

5/2 directional control valve

A 5/2 directional control valve functions similar to that of a 4/2 valve, to actuate a double acting cylinder. 5/2 valve has the advantage of having separate exhaust paths for forward and retraction motion, thereby the motion can be controlled independently. 5/2 valve also has advantage in its simple manufacturing process. 5/2 valve has 5 ports

Fig 16

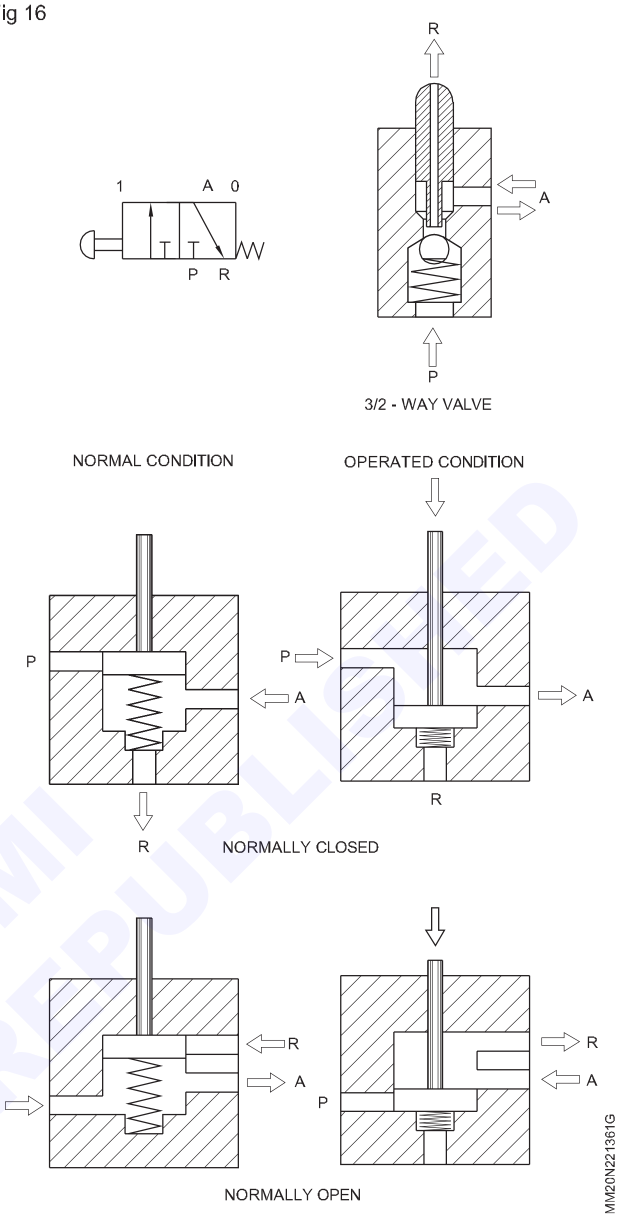


Fig 17

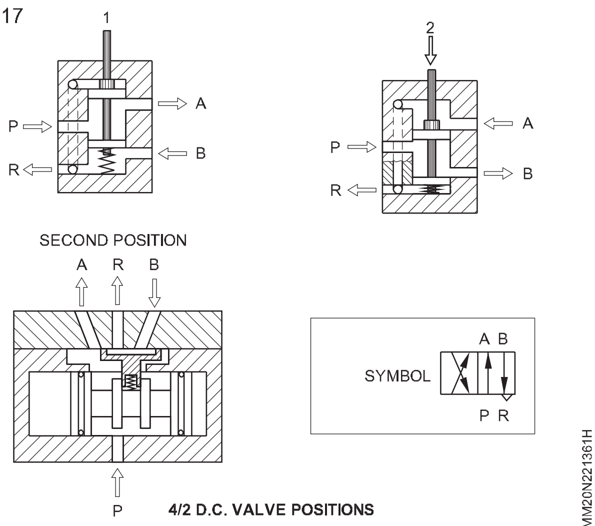
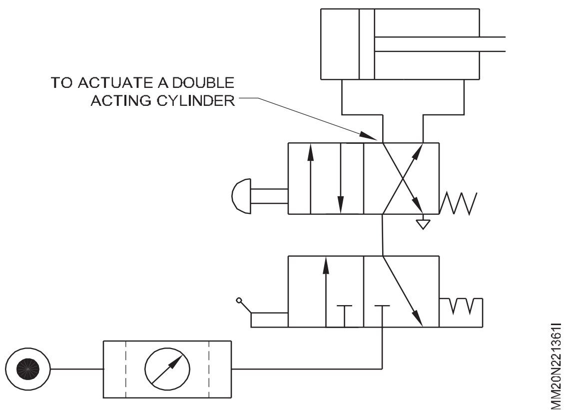


Fig 18



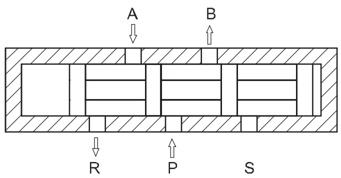
P - Pressure port

A & B - Working ports

R & S - Exhaust ports.

The construction of a 5/2 valve is shown in Fig 19.

Fig 19



Sealing action in valves

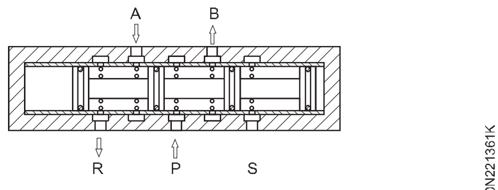
The body of the valve and the seat or the spool should have minimum leakage between them. This is a very important criteria in the design of valves.

The sealing is done by the following methods.

In spool valves

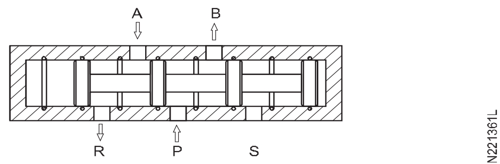
- The bore of the body and spool are matched by super finishing to have a minimum working clearance (Fig 19) and a metal to metal sealing.
- A separate sleeve (Fig 20) is inserted into the body of the valve. The sleeve ID and the spool have a close tolerance, with (Fig 21) 'O' rings on the spool creating a leak proof working.
- 'O' ring mounted on the bore of the body (Fig 21) also helps in sealing.
- Cup seats mounted on the spool also helps in having a leak proof (Fig 22) spool movement.

Fig 20



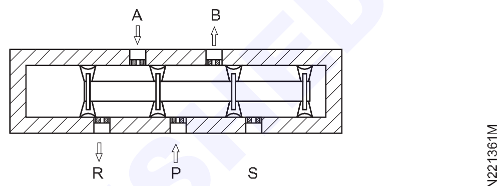
D.C. VALVE SLEEVE BORE

Fig 21



D.C. VALVE 'O' RING SPOOL

Fig 22

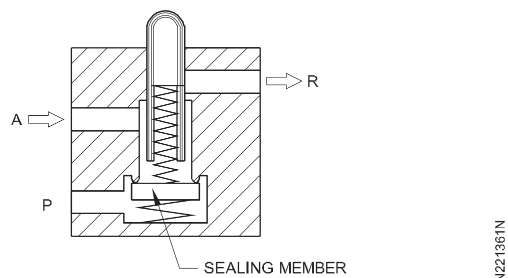


D.C. VALVE CUP SEALING ARRANGEMENT

Sealing in seat valve

In seat valves the seat or the disc is usually made of non-metallic substance line rubber nylon etc, so as to have perfect sealing of the ports. These valves have better sealing compared to slide valves. Hence seat valves are more reliable. (Fig 23)

Fig 23



SEAT VALVE

Pneumatic symbols

Objectives: At the end of this lesson you shall be able to
- **identify components using ISO 1219 symbol**
- **interprete symbol of direction control valve symbol.**

Symbol: It is a representation of pneumatic component. Commonly pneumatic symbols are drawn as pe IS 1219 standards.

Symbol does not indicate size of the Component.

It does not indicate orientation or arrangement of inner components.

Symbols uses common geometrical shape which is to catagorise the type of component. The shape used in general are:

Square: It represents a valve.

Circle: It represents compressor,pneumatic motor and gauge.

Line: it represents piping.

Dimond: It represents filter, dryer, lubricator.

Cylinder: It represents receiver.

Rectangle: It represents cylinders.

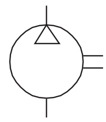
Dotted box: It represents an assembly of various components.

Triangle: It represents pneumatic energy i.e service air.

Symbol with circle:

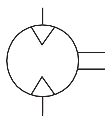
Unidirectronial (Fig 1)

Fig 1



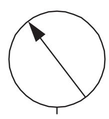
pneumatic Motor (Fig 2) Bidirectional

Fig 2



Pressure Gauge (Fig 3)

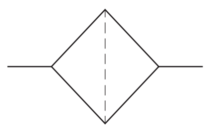
Fig 3



Symbol with diamond shape

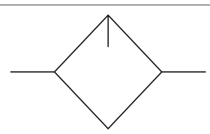
Filter (Fig 4)

Fig 4



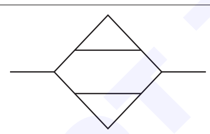
Lubricator (Fig 5)

Fig 5



Dryer (Fig 6)

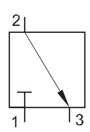
Fig 6



Symbol with square

As explained earlier square means valve. Look at the fig 7 given below.

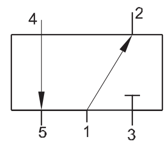
Fig 7



In this figure three extended lines 1,2,& 3 are shown which shows that the port, means where you connect pipes. Arrow inside the square shows the path of air flow inside the valve. The figure shows port 1 is closed but port 2 & 3 are connected internally.

In figure 8 there are 5 ports namely 1,2,3,4 & 5 where you can connect pipes. The figure shows that ports 1 & 2 are connected such a way that flow direction is from 1 to 2, similarly ports 4 & 5 are connected in such a way that flow direction is 4 to 5. But port 3 is closed.

Fig 8



The port numbering has certain meaning as follows:

Input port: Port where incoming compressed air is connected. It is always "1" and also represented by port "p".

Output port: From where air comes out of the valve is always even number "2" and "4". Output ports are also represented by port "A" & "B".

Exhaust port: From where air is vented to the atmosphere is always odd number "3" and "5". Output ports are also representd by port "R" & "S".

Types of Valves

There are three types of valves used in pneumatic system.

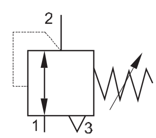
Pressure Valve: Used to control pressure there by force in the pneumatics. It is always represented by single square.

Direction control valve: Used to control the direction of movement of load connected to piston rod; like forward or reverse, clockwise or counter clockwise. It is always represented by combination of minimum two squares.

Flow control valve: Used to control speed of load, in this case square is not used.

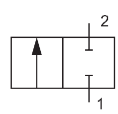
Pressure Regulator: Symbol of pressure regulator is shown in Fig 9.

Fig 9



Direction control valves: Look at the symbol shown in Fig 10.

Fig 10

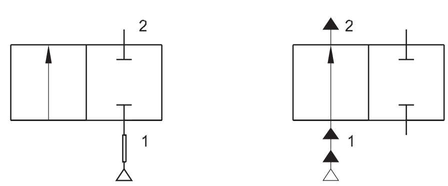


In this symbol there are two squares drawn side by side. A square indicates position, thus right square indicate one position and left square other position.

Position refers to status. In the right position port 1 & 2 are closed, but in the left position both ports are connected.

Let us compare the two positions as shown in Fig 11.

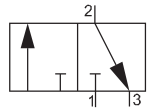
Fig 11



In this valve there are 2 ports and 2 positions, hence called two port two position valve or simply 2/2 way valve.

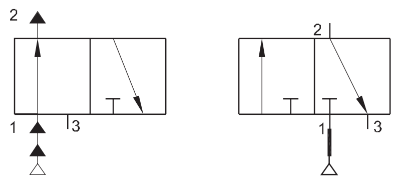
3/2 Way valve: By name it is clear this valve is having 3 ports and 2 position. Symbol is shown Fig 12.

Fig 12



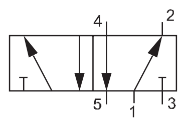
Compare the two positions as shown in Fig 13.

Fig 13



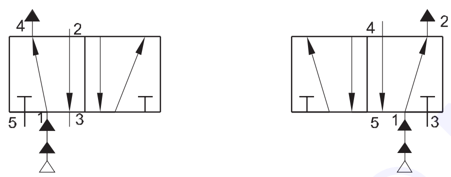
5/2 Way valve: By name it is clear this valve is having 5 ports and 2 position. Symbol is shown in Fig 14.

Fig 14



Compare the two positions as shown in Fig 15.

Fig 15



Actuation Type

It is a device which indicates how to operate the valve There are several types available but our scope is limited to following types.

- Manual Type
- Mechanical Type
- Pilot Type
- Solenoid Type

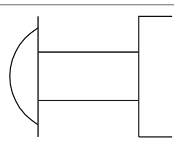
Manual Type

This mechanism is operated by a person, like

- Push Button
- Lever
- Foot pedal

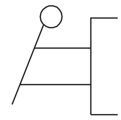
Push Button: It is a button type device when pressed by operator valve actuates (Fig 16)

Fig 16



Lever: It is a handle type device when pressed by operator valve actuates (Fig 17)

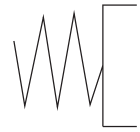
Fig 17



Mechanical Type: Valve is operated by some mechanical force.

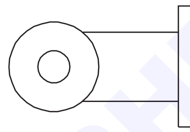
Spring: Common compression spring which actuates valve on de-compression. (Fig 18)

Fig 18



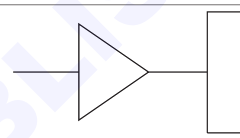
Roller: It is like a lever with small wheel type device when pressed by some object valve actuates. (Fig 19)

Fig 19



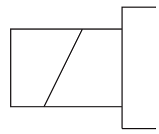
Pilot: It is air operated type. (Fig 20)

Fig 20



Solenoid: IT is electrical operated type. (Fig 21)

Fig 21



Identifying the direction control valve

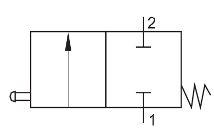
To identify direction control valve follow the procedure given below.

- Identify number of ports.
- Identify number of positions.
- Identify actuation mechanism.
- Observe air flow path in the symbol, in each position.

Observe the symbol given in Fig 22

In the Fig 22

Fig 22



- No of ports: Two (1 & 2)
- No of positions: Two; (2 Squares)
- Actuation methods: Push Button (at left side), spring (at right side)

Write this information in the format given:

--------Port-------- Postion--------operated-------return

So you get:

2 port 2 position push button operated spring return Direction control valve. Whenever you observe spring in the symbol it means “Normal” position exists. Normal position refers to predominant unactuated condition.

In the symbol shown in Fig 22, right side position is achieved due to spring when there is no force applied on push button, means right side position is the normal position.

> **It is important to note that whether input port**
>
> **(1 or p) is open or closed in normal position.**
>
> **If input port is closed, we say normally closed valve.**
>
> **If input is connected to output port (2,4 or A, B then we say normally open valve:**

In the symbol shown above, in normal position input port is closed therefore valve is normally closed valve.

We can rewrite complete designation of the valve as follows:

2 port 2 position push button operated spring return normally closed Direction Control Valve.

Lets try to identify valves given in the next pages.

(Fig 23 to Fig 59)

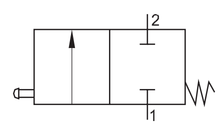
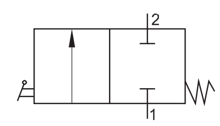
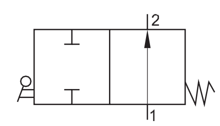
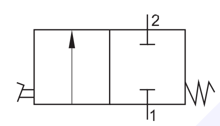
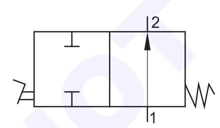
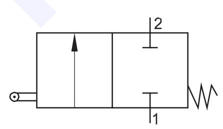
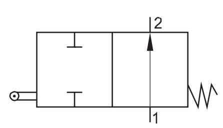
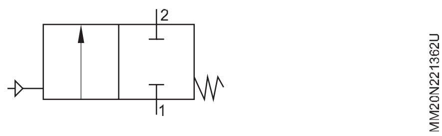
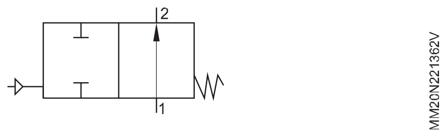
Symbol	Designation
Fig 23 	2 port 2 position push button operated spring return normally closed Direction Control Valve.
Fig 24 	2 port 2 position lever operated spring return normally closed Direction Control Valve.
Fig 25 	2 port 2 position lever operated spring return normally open Direction Control Valve.
Fig 26 	2 port 2 position foot pedal operated spring return normally closed Direction Control Valve.
Fig 27 	2 port 2 position foot pedal operated spring return normally open Direction Control Valve.
Fig 28 	2 port 2 position roller operated spring return normally closed Direction Control Valve.
Fig 29 	2 port 2 position roller operated spring return normally open Direction Control Valve.

Fig 30



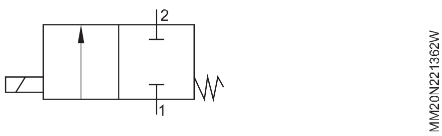
2 port 2 position pilot operated spring return normally close Direction Control Valve.

Fig 31



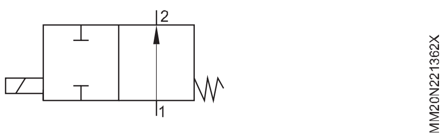
2 port 2 position pilot operated spring return normally closed Direction control Valve.

Fig 32



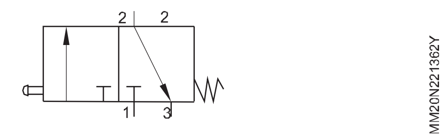
2 port 2 position Solenoid operated spring return normally closed Direction Control Valve.

Fig 33



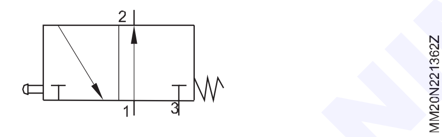
2 port 2 position Solenoid operated spring return normally open Direction Control Valve.

Fig 34



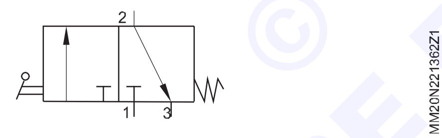
3 port 2 position push button operated spring return normally closed Direction Control Valve.

Fig 35



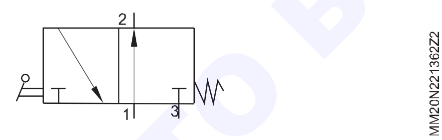
3 port 2 position push button operated spring return normally open Direction Control Valve.

Fig 36



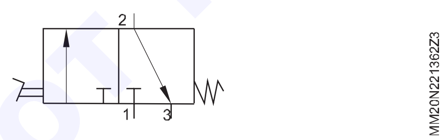
3 port 2 position lever operated spring return normally closed Direction Control Valve.

Fig 37



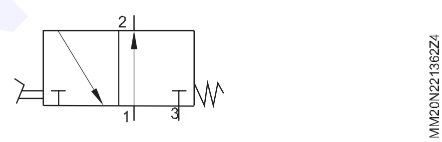
3 port 2 position lever operated spring return normally open Direction Control Valve.

Fig 38



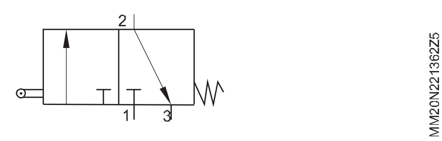
3 port 2 position foot pedal operated spring return normally close Direction Control Valve.

Fig 39



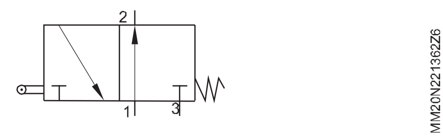
3 port 2 position foot pedal operated spring return normally open Direction Control Valve.

Fig 40



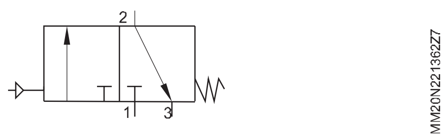
3 port 2 position roller operated spring return normally close Direction Control Valve.

Fig 41



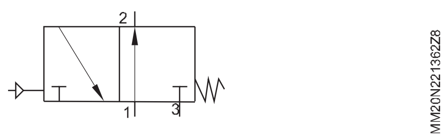
3 port 2 position roller operated spring return normally open Direction control Valve.

Fig 42



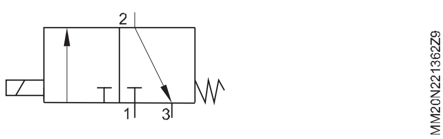
3 port 2 position pilot operated spring return normally close Direction Control Valve.

Fig 43



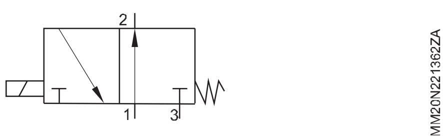
3 port 2 position pilot operated spring return normally open Direction Control Valve.

Fig 44



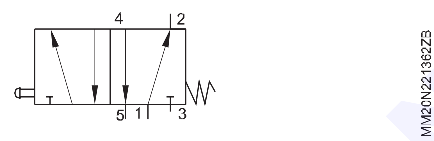
3 port 2 position solenoid operated spring return normally close Direction Control Valve.

Fig 45



3 port 2 position solenoid operated spring return normally open Direction Control Valve.

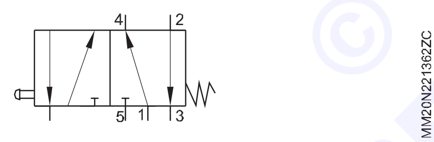
Fig 46



5 port 2 position push button operated spring return Direction Control Valve,normally 1 is connected to 2.

5 port 2 position push button operated spring return Direc-

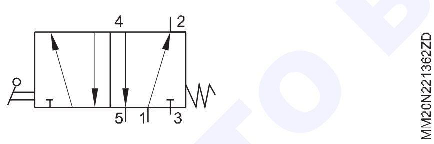
Fig 47



tion Control Valve, normally 1 is connected to 4.

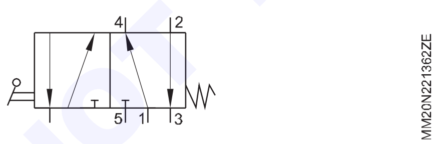
5 port 2 position lever operated spring return Direction

Fig 48



control valve,normally 1 is connected to 2.
5 port 2 position lever operated spring return Direction

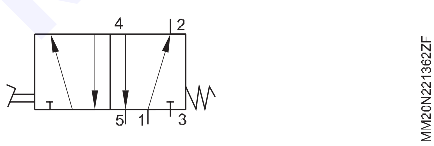
Fig 49



Control Valve normally 1 is connected to 4.

5 port 2 position foot pedal operated spring return Direc-

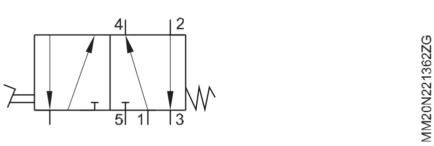
Fig 50



tion Control Valve normally 1 is connected to 2.

5 port 2 position foot pedal operated spring return Direc-

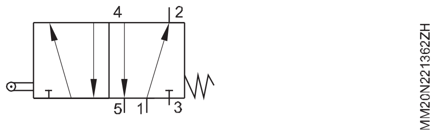
Fig 51



tion Control Valve normally 1 is connected to 4.

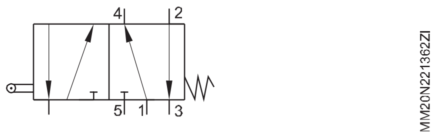
5 port 2 position roller operated spring return Direction

Fig 52



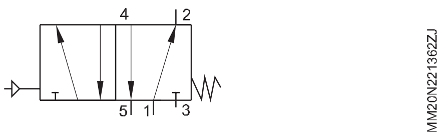
Control Valve normally 1 is connected to 2.

Fig 53



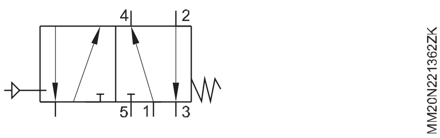
5 port 2 position roller operated spring return Direction Control Valve normally 1 is connected to 4.

Fig 54



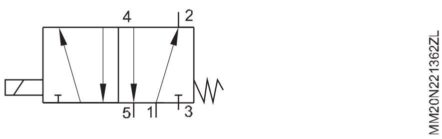
5 port 2 position pilot operated spring return Direction Control Valve normally 1 is connected to 2.

Fig 55



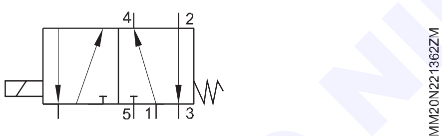
5 port 2 position pilot operated spring return Direction Control Valve normally 1 is connected to 4.

Fig 56



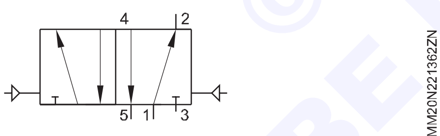
5 port 2 position solenoid operated spring return Direction Control Valve,normally 1 is connected to 2.

Fig 57



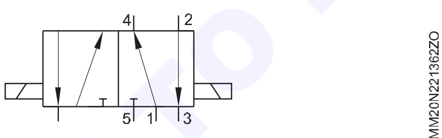
5 port 2 position Solenoid operated spring return Direction Control Valve, normally 1 is connected to 4

Fig 58



5 port 2 position double pilot operated Direction Control Valve.

Fig 59



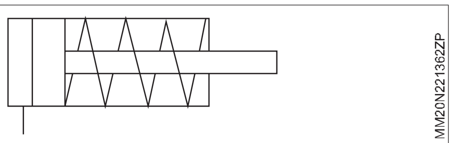
5 port 2 position double solenoid operated Direction Control Valve.

Symbol with Rectangle

In general rectangle is used to represent linear actuator like single acting cylinder and double acting cylinder.

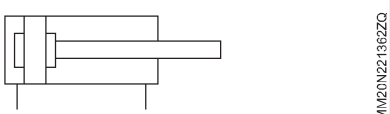
Single acting cylinder (Fig 60)

Fig 60



Double acting cylinder (Fig 61)

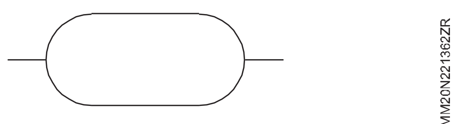
Fig 61



Symbol with cylinder:

In general cylindrical shape is used to represent air receiver or air storing device (Fig 62).

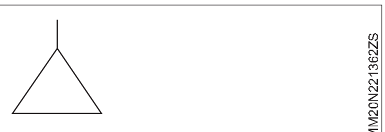
Fig 62



Symbol with triangle:

In general triangular shape is used to represent air source (Fig 63).

Fig 63

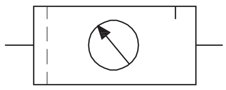


Symbol with dotted box:

Symbol shown in dotted box represents assembly of components like FRL, Time delay valve.

FRL: It is an assembly of Filter, regulator and lubricator. (Fig 64).

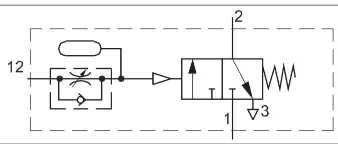
Fig 64



Time delay valve

It is an assembly of flow control valve, 3/2 way valve and an air receiver (Fig 65.)

Fig 65



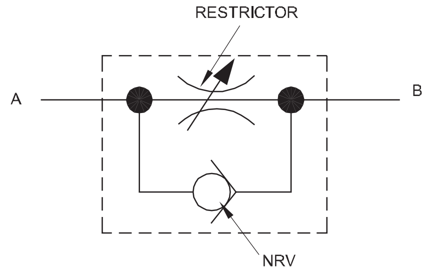
Other Symbols

Non return valve (Fig 66)

Fig 66

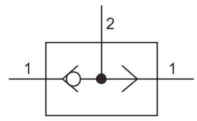
Flow control valve (Fig 67)

Fig 67



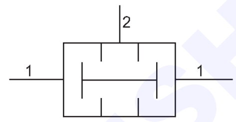
Shuttle valve (Fig 68)

Fig 68



AND valve (Twin pressure valve) (Fig 69).

Fig 69



Non-return valve/check valve

Objectives : At the end of this lesson you shall be able to
- **name the parts of a non-return valve**
- **state the working principle of a non-return valve**
- **differentiate between swing and ball type check valves**.

Non-return valve

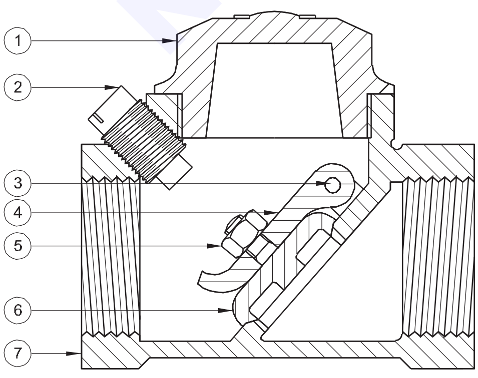
Water supply piping systems use several mechanical devices to control and regulate the fluids and gases flowing through them.

The non-return valve allows one-way flow in water supply or drainage lines. It is also called a check valve. Valves are made of cast iron, brass, bronze or plastic.

Sometimes two or more different kinds of material are used on a single valve. There are many types of check valves available in the market.

The swing check valve consists of the following parts. (Fig 1)

Fig 1



1 Cap

2 Stop plug

3 Hinge pin

4 Hinge

5 Disc hinge nut

6 Disc

7 Body

In the swing check valve, the flow of a fluid or gas in one direction lifts the disc and allows one-way flow only. The return of the disc to its seating position prevents the flow in the reverse direction.(Figs 2 & 3)

Fig 2

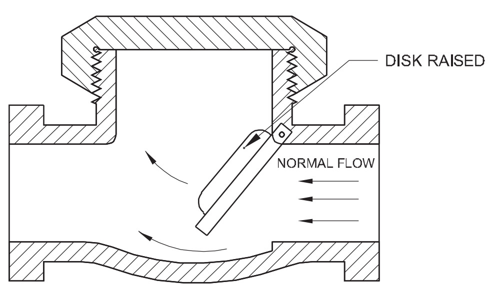
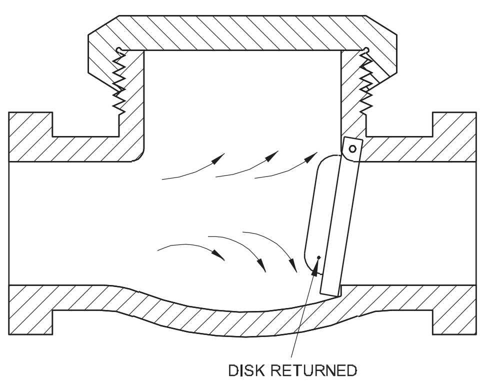
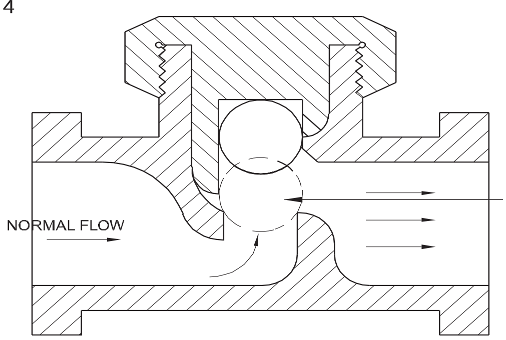


Fig 3



In the ball-type check valve, the flow of a fluid or gas in one direction lifts the ball; when the pressure is released the ball falls against its seating and prevents flow in the reverse direction. (Fig 4)

Fig 4



Flow control valve

Objectives : At the end of this lesson you shall be able to
- **explain the flow control valve**
- **state the difference between variable and one way flow control valve**
- **interpret and draw meter - in speed control hydraulic control**
- **explain meter - out speed control method**
- **explain bleed - off speed control circuit and its function.**

The purpose of flow control in a hydraulic system is to regulate speed of a cylinder or the R.P.M. of a motor. Since both values are dependent on the flow rate,however constant pumps supply a uniform flow rate.

Reduction in the flow rate is achieved according to the following principle

A reduction in the flow cross - section in the flow control valve causes an increase in pressure ahead of this. This pressure causes the pressure relief valve to open and flow rate is divided. This division of the flow rate causes enough flow volume required for the r.p.m. or speed to flow to the actuator and the excess delivery to be discharged via pressure relief valve.

Flow control valve is a orifice or restrictor in hydraulic system.

Orifices

- A simple orifice is the most elementary method for controlling flow.
- The orifice is always placed in series with the pump.
- A fixed orifice can be a drilled hole in a fitting, but variable orifice is a calibrated needle valve.

Fixed orifice (Fixed flow control valve)

Fixed orifice is a simple small opening in line which is not variable. (Fig 1)

Variable flow control valve

Throttle and orifice valves are used to achieve a certain pressure drop. This is done by creating a specific flow resistance.

If needle of flow control valve moves closer to the seat then opening is less and flow also reduced. (Fig 2)

When needle move away from valve seat (Fig 3) opening increases and flow also increases.

Fig 1

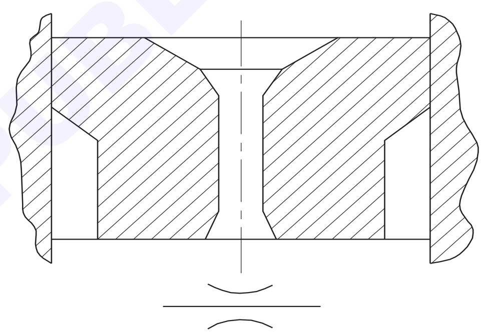


Fig 2

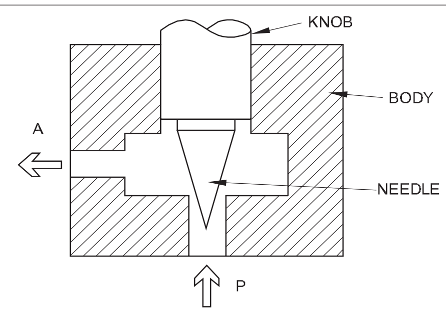
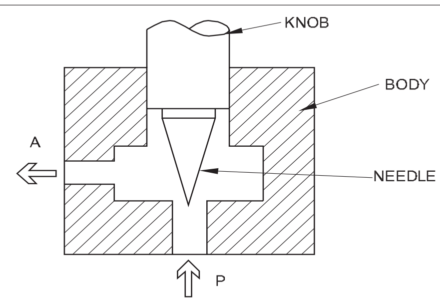
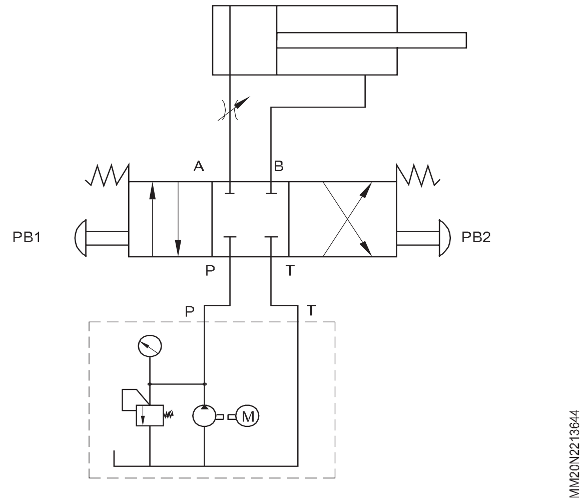


Fig 3



One advantage of this design is that it is simple and inexpensive. Hydraulic circuit diagram with variable flow control valve is given below in Fig 4.

Fig 4

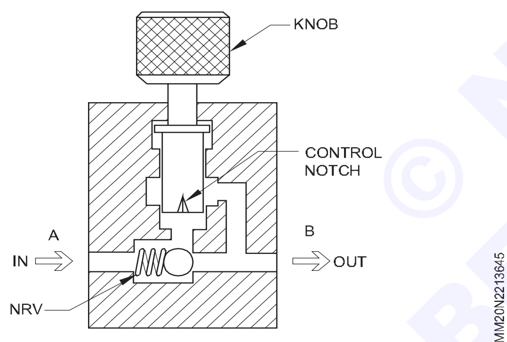


One - way flow control valve

The one - way flow control valve is a combination of an orifice or throttle valve and a non - return valve. The restrictor controls the flow rate in a single direction dependent on flow. In the opposite direction, the full cross - sectional flow is released and the return flow is at full, pump delivery.

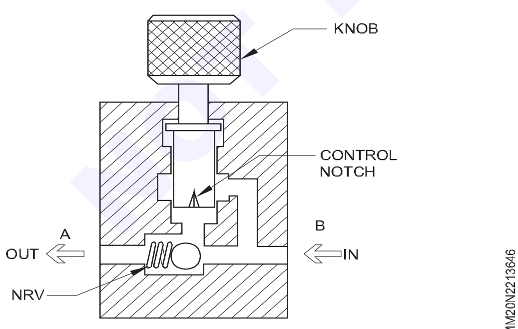
The flow is throttled in the flow direction from A to B. So less flow is going inside the actuator and speed of actuator is reduced. (Fig 5)

Fig 5



Flow is not restricted in the opposite direction from B to A because the non - return valve is lifted from its valve seat and the full cross - section flow is released. (Fig 6)

Fig 6



With adjustable one - way flow control valves, the throttling point can either be enlarged or reduced.

Speed - control Methods

Three methods are generally used to control the speed of actuator

- Meter - in speed control
- Meter - out speed control
- Bleed off speed control

Meter - in speed control

Fig 8 provides a schematic drawing of a meter - In flow control circuit restriction fluid as it enters an actuator port. Meter -in circuits work well with hydraulic fluids, but can give erratic action with air. Meter - in flow controls only work on resistive loads because a running - away load can move the actuator faster than the circuit can fill it with fluid.

The method in which the flow of oil is reduced which is going inside the actuator is known as meter - in speed control method.

In Fig 7 pump running in unload condition due to open centre valve. Notice that the check valves in the flow controls force fluid through the orifices as it enters the cylinder and lets fluid by pass them as it leaves.

Fig 7

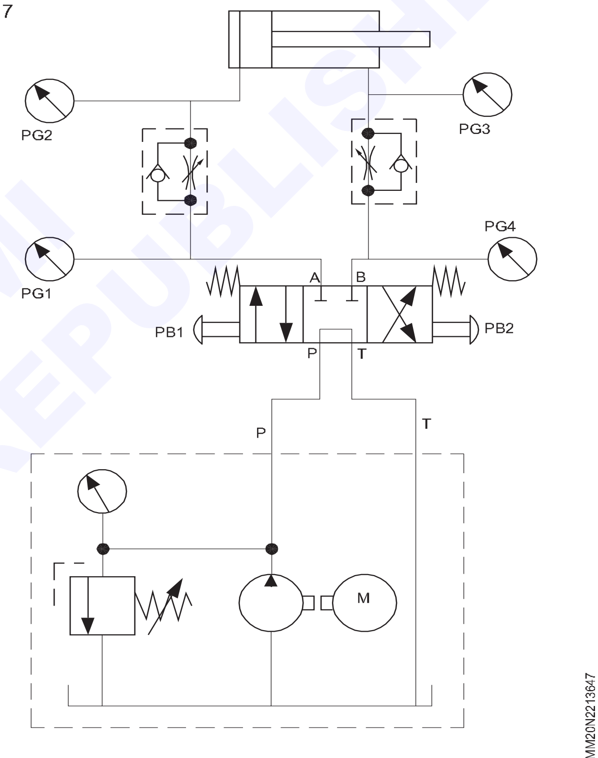
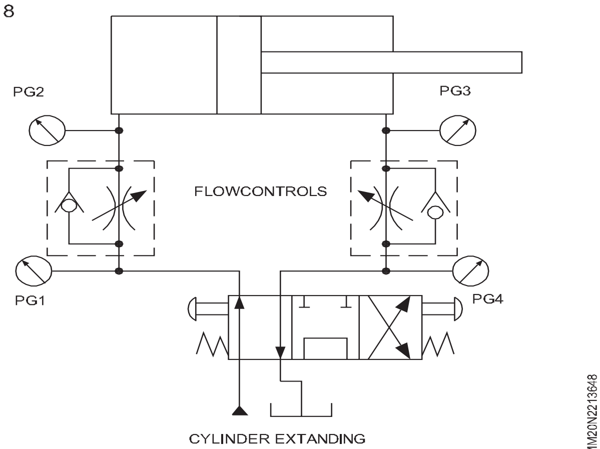


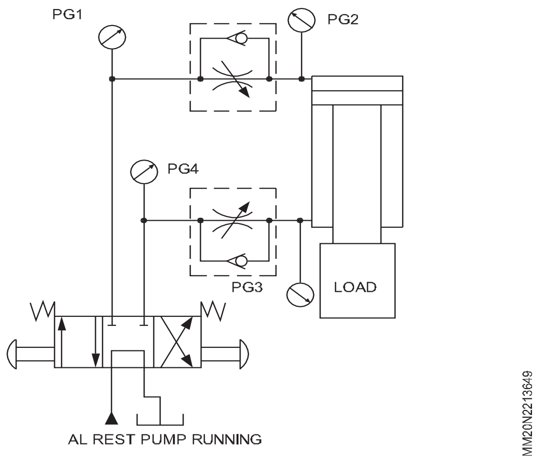
Fig 8



It is obvious that if the cylinder had an external force pulling on it, it would extend rapidly. Because fluid enters the cap end at a reduced flow rate, a vacuum void would form there until the pump had time to fill it.

- For any normal application meter - in speed control method is preferable.
- It gives finer & smooth speed control

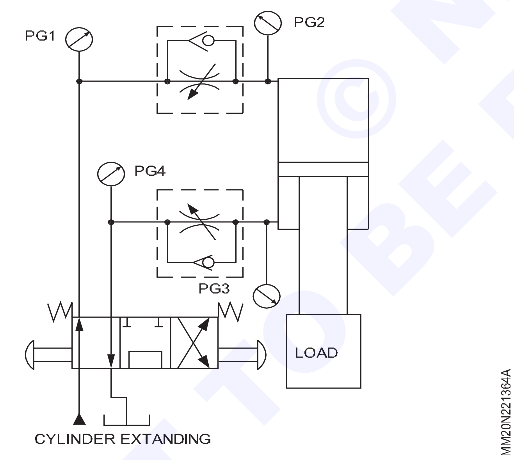
Fig 9



Meter - out speed control

Fig 10 shows a schematic drawing of a meter - out flow control circuit that restricts fluid as it leaves an actuator port. Meter - out circuits work well with both hydraulic and pneumatic actuators. Cylinder - mounting attitude is not important because outlet flow is restricted and an actuator cannot run away. Meter - out flow controls work on resistive loads or running away loads.

Fig 10



Speed control by regulating flow coming out of actuator is called Meter out method.

Below circuit in Figure 9 is shown at rest with the pump running. Notice how check valves in the flow controls allow fluid to by pass the orifices and freely enter the cylinder. As fluid leaves the cylinder, it is forced through the orifices at a set rate. Only PG3 pressure gauge will show the pressure because the load on the cylinder rod is inducing pressure at the valve's blocked port.

- If nature of load on actuator is pulling type or pushing type then meter - out speed control is preferable method to use.
- This circuit maintains a constant back pressure during rod extension if the load drops quickly or reverses.

The below circuit shows conditions when the cylinder is extending. The directional control valve shifts to straight arrows and pump flow by passes the upper flow control to go to the cylinder cap end. Fluid leaving the cylinder rod end is held back before it goes to tank even with an external load trying to move it. The cylinder extends at a reduced speed in hydraulic circuits until it meets a resistance.

Bleed - off speed control

Bleed - off flow control circuits are found only in hydraulic systems and normally only in those with fixed - volume pumps.

Speed control by metering part of the pump flow to tank is known as bleed off flow control (Fig 11)

Fig 11

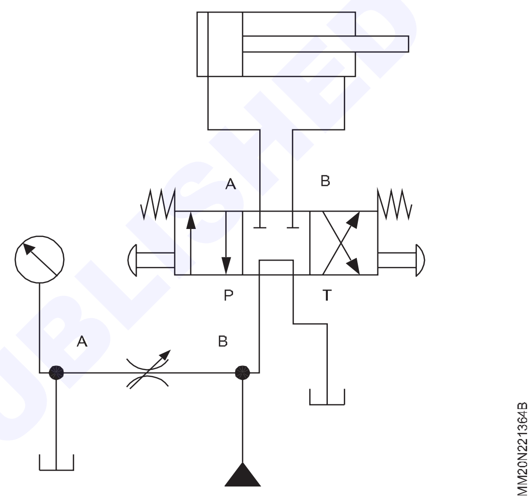
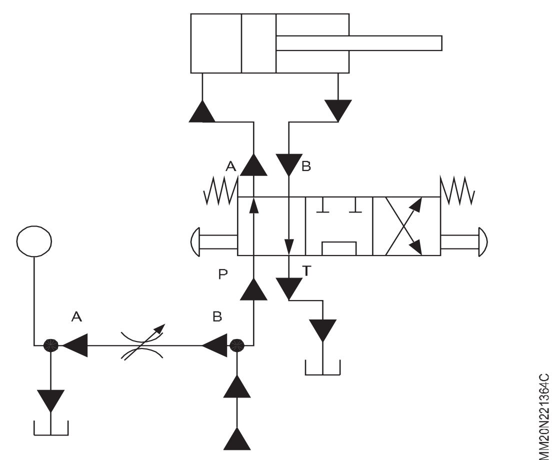


Fig 11 shows a bleed - off circuit at rest with the pump running. One port of flow control valve (Needle valve) is connected to P port or any output (A or B port) and another port of flow control valve is connected to T port.

When the directional valve in Fig 12 shifts or actuated in parallel port position then all pump flow passes from P port to A port through direction control valve.

Fig 12



On the way to the actuator, part of the flow is bled off to tank, so the actuator forward speed is decreased as per setting of bleed off flow control valve.

This circuit is more efficient than meter - in or meter -out, as pump output is only high enough to overcome resistance, but part of pump output is wasted.

Shuttle valve and application to control single acting cylinder

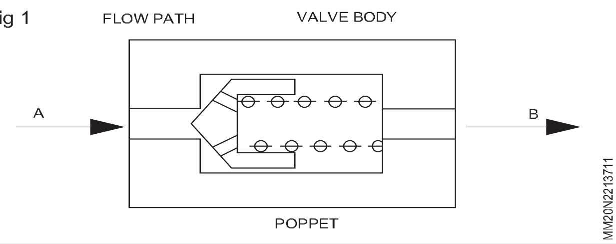
Objectives: At the end of this lesson you shall be able to
- **explain working principle of non return valve (NRV) and shuttle valve**
- **state use of shuttle valve in pneumatic applications**
- **draw circuit to operate single acting cylinder using two 3/2 way valves and shuttle valve.**

Working principle of Non Return Valve:

This valve allow air flow in one direction but does not allow air to flow in opposite direction. Non return valve is also known as check valve.

Fig 1 shows the construction of non return valve.

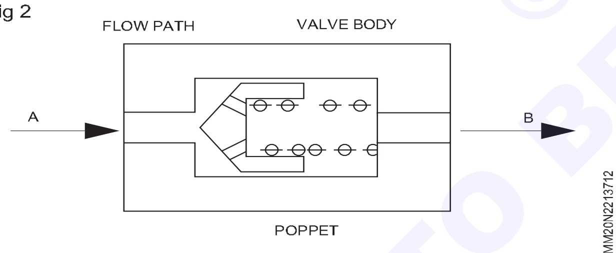
Fig 1



It consists of a valve body having flow path and accommodates poppet and spring. Spring exerts very small force on poppet so that it is closing the path and poppet does not dislocate even if NRV is connected vertically or at an angular position.

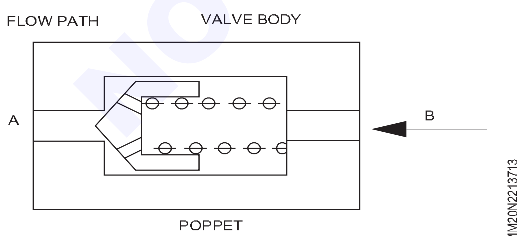
When air flows from port A to B, pneumatic force acts on poppet and spring gets compressed. It causes poppet to shift right side and air flow freely in A to B direction (Fig 2)

Fig 2



When flow direction is reversed (Fig 3) means directed from port B, air pressure acts on poppet which further blocks flow path tightly thus no flow from port A.

Fig 3



Symbol of NRV is shown if Fig 4

Working principle of Shuttle Valve

Shuttle valve is a combination of two NRV placed face to face, but having common poppet as shown in the Fig 5.

If air is supplied through port Y as shown in Fig 5, poppet shifts and block port x, thus air flow from Y to A.

Fig 4

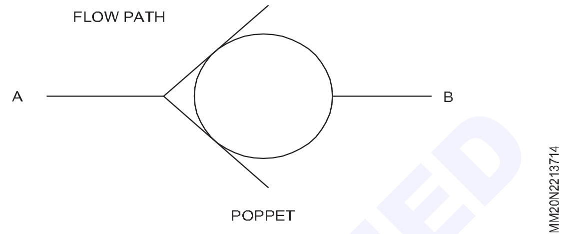
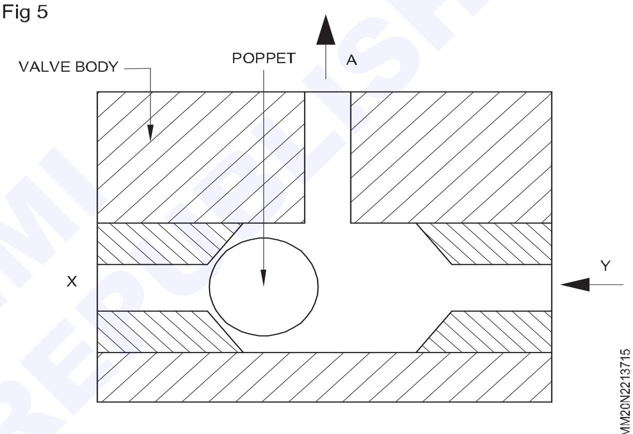
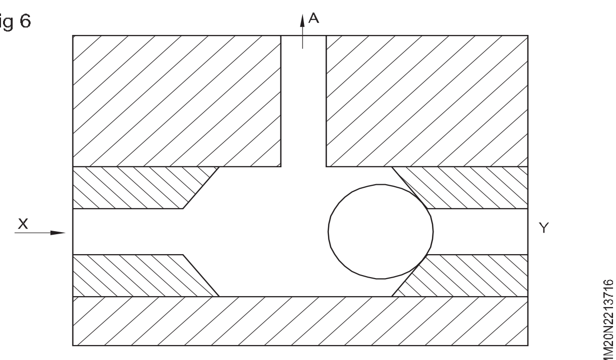


Fig 5



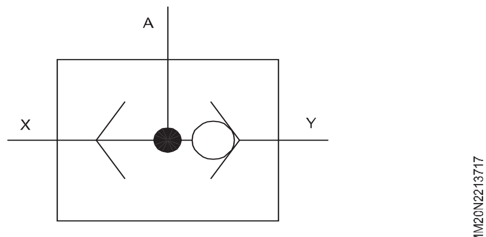
If air is supplied through port X as shown in fig 6 poppet shifts and block port Y, thus air flow from X to A

Fig 6



You can conclude that if air is supplied either from X or Y, poppet shuttles between the ports and you get the output from A. Symbol of shuttle valve is shown in Fig 7.

Fig 7

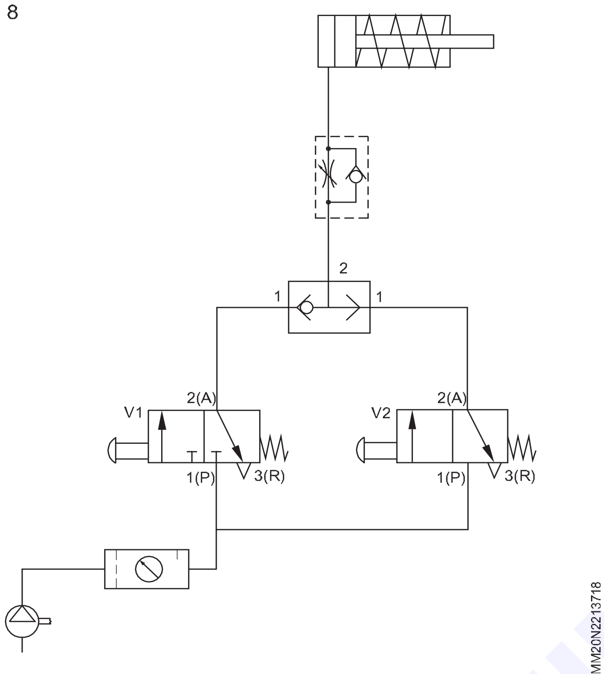


Application

If we use two 3/2 way valves and connect their outputs for ports x & y then on actuation of any of the valves we get output from A.

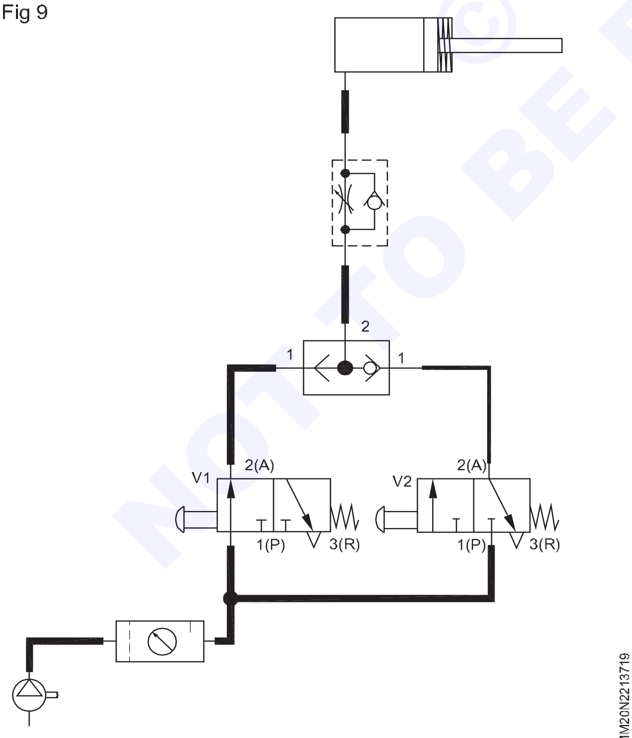
Fig 8 shows the application of shuttle valve in pneumatic circuit to operate single acting cylinder from two different locations.

Fig 8



When you operate valve V1 air flows through shuttle valve to cylinder and piston moves forward. (Fig 9)

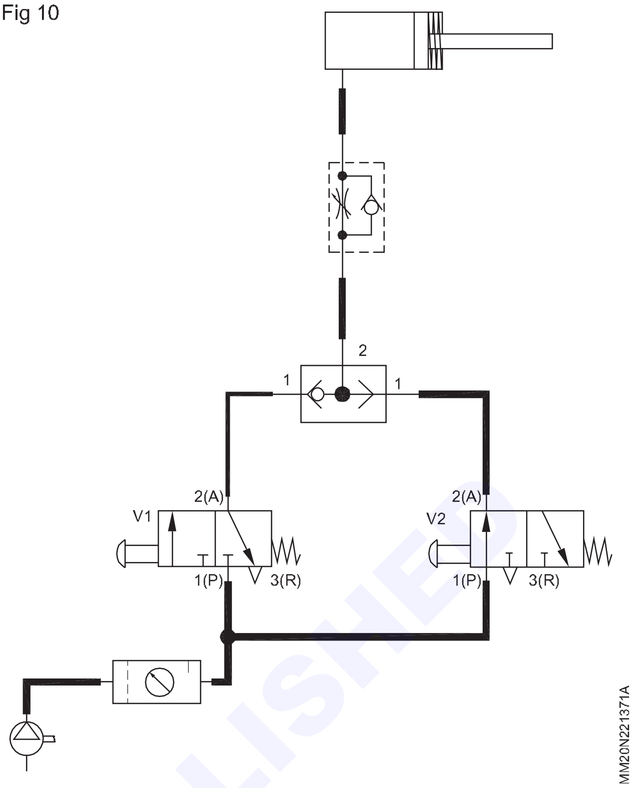
Fig 9



As soon as valve is released cylinder side air exhausts through valve V1 and piston retracts.

When Valve V2 is operated air flows through shuttle valve to cylinder and piston moves forward. (Fig 10)

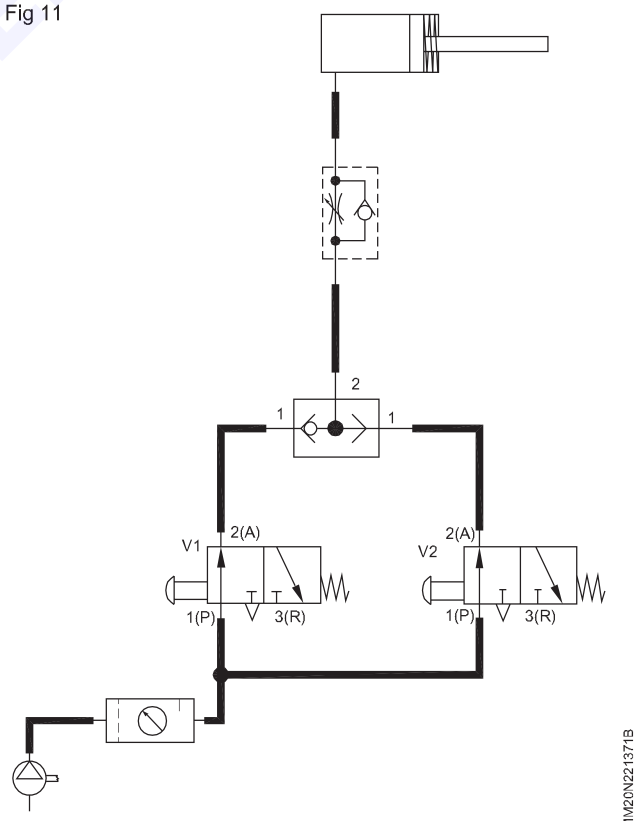
Fig 10



As soon as valve is released cylinder side air through valve V2 and piston retracts.

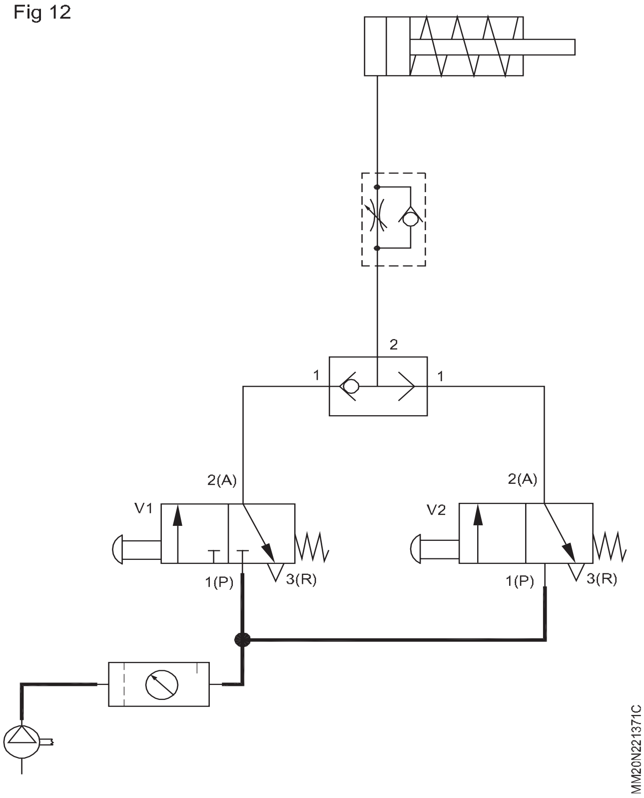
If you operate both valves V1 & V2 simultaneously, poppet shifts due to flow from either of the valves and air flow to cylinder, thus piston moves forward. (Fig 11)

Fig 11



As soon as both valves are released cylinder side all exhausts through either of the valves and piston retracts. (Fig 12)

Fig 12



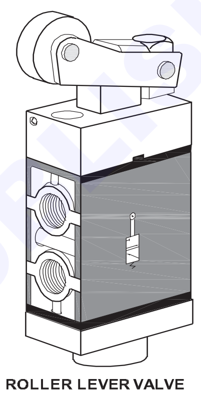
Roller valve

Pneumatic roller lever valves, used for mechanical position sensing in machine automation systems. The linear horizontal movement of a machine part of passing material, for example on a conveyor line, moving over the roller operates the valve. The wheel rotates in the direction of the moving part which reduces friction, this minimises wear and tear of both the pneumatic roller lever valve and the travelling part, for this reason, a preferred method of mechanical sensing.

Pneumatic roller lever valves, constructed from a die - cast zinc aluminium alloy that is machined and lacquered offering strength and reliability, an overall excellent quality product. We offer 2 or 3- way normally closed, or a 5 way roller lever valve in either poppet or spool designs. Choose from a standard pneumatic roller lever valve or a compact design should space be limited. An air pilot assisted version can be ordered, used when less force is available to actuate the lever for lighter operation.

Order one- way or two - way roller levers with spring return, air pilot return or double rollers. A double roller lever is used on machine carriages to reverse the direction of travel. Port sizes are G 1/8 as standard.

Fig 13



Pressure control valve

Objectives : At the end of this lesson you shall be able to
- **differentiate pressure relief valve, pressure reducing valve, pressure regulator and explain their function**
- **interpret counter balancing and sequencing.**

To control and regulae the pressure various pressure valve are used in hydraulics systems, like:

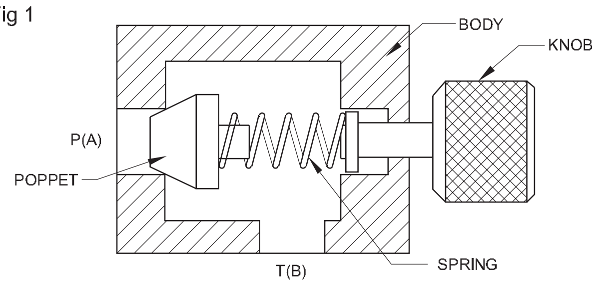
Classification of Pressure control valve

- Pressure relief valve.
- Pressure reducing valve
- Pressure regulator.

Pressure relief valve

The pressure in the system is set and restricted by pressure relief valve. Pressure relief valve also help to remove excess among of oil from system to tank to overcome excess pressure. (Fig 1)

Fig 1

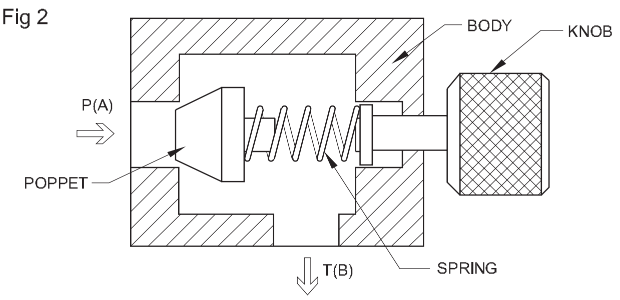


In this design incorporating a poppet valve, a seal is pressed against the inlet port P by a spring when the valve is in its normal position. The input pressure (P) acts on the surface of the sealing element generates the force. (Fig 2)

$$F= p_1 A_1$$

The Spring force by which the sealing element is pressed onto the seat is adjustable

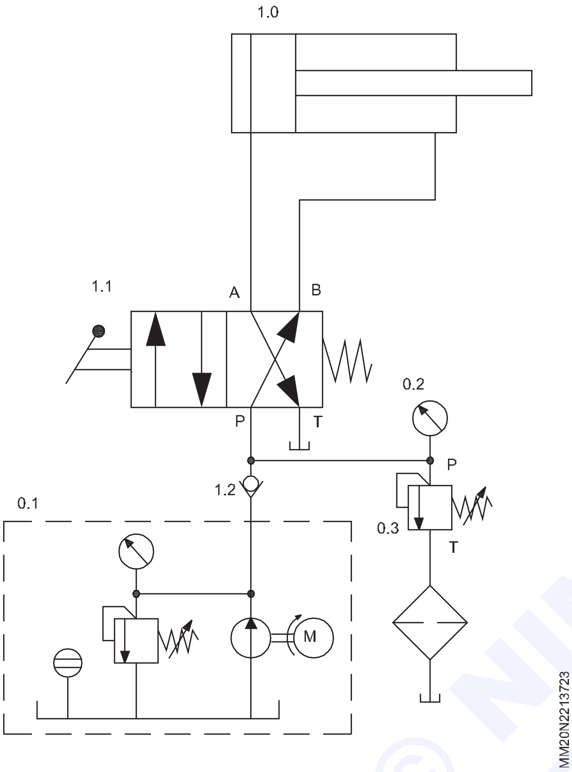
Fig 2



If the force generated by the input pressure exceeds the spring force, the valve starts to open. This causes a partial flow of the liquid to the tank. If the input pressure continues to increase, the valve opens until the complete pump delivery flows to the tank.

The resistances at the outlet (tank line. filter) must be added to the force of the spring in the pressure relief valve. Application of PRV is shown in the Fig 3

Fig 3

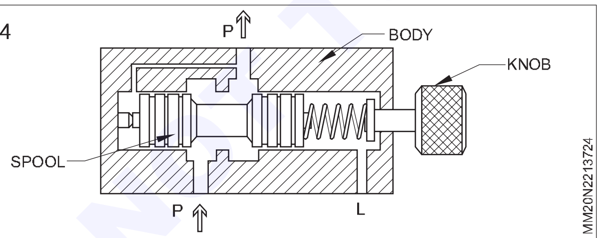


Pressure reducing valve (2 - way valve)

Pressure regulators reduce the inlet pressure to an adjustable outlet pressure. It is appropriate to use these in hydraulic system only if different pressures are required.

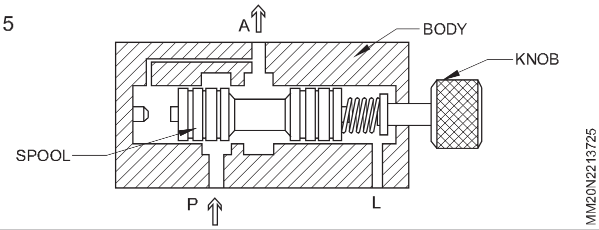
This valve is normally open. The outlet pressure (A) acts via a pilot on the left - hand surface of the pilot piston against an adjustable spring force. (Fig 4)

Fig 4



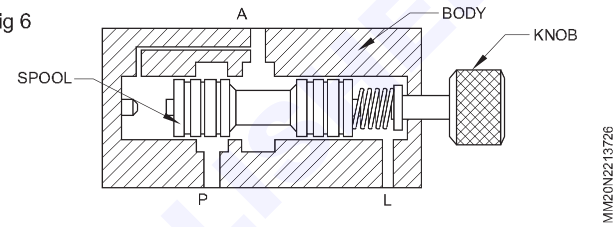
When the pressure rises at outlet A, the force at the left hand surface of the pilot piston becomes increases, the piston is displaced to the right and the throttle gap becomes narrower. This causes a pressure drop. In the case of slide valves, it is also possible to design the control edges in such way that the opening gap increases only slowly. This gives greater control precision. (Fig 5)

Fig 5



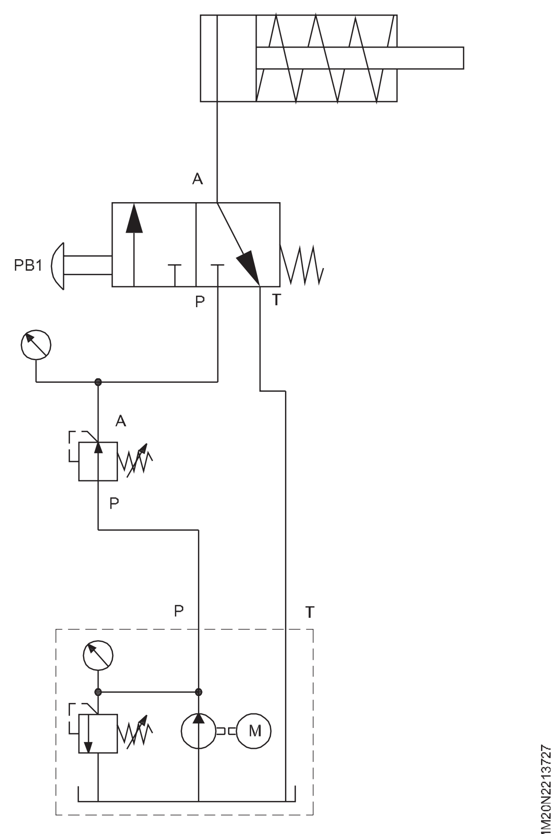
When the preset maximum pressure is reached, the throttle point closes completely. (Fig 6)

Fig 6



The pressure at the outlet A of the pressure regulator is less than the system pressure at P and constant. The piston rod of the cylinder is now in its forward end position. Application of pressure reducing valve is shown in the Fig 7.

Fig 7



Electro- pneumatics

Objectives: At the end of this lesson you shall be able to
- **explain about the electro pneumatic control system**
- **list the basic electrical devices**
- **explain the operation of switches**
- **describe the purpose and constructional details of solenoid valves**
- **explain purpose and operation of relay.**

Introduction

Electro pneumatic control consists of electrical control systems operating pneumatic power system. In this solenoid valves, are used as interface between the electrical and pneumatic system. Devices like switches are used as feedback elements.

In electro pneumatics, the signal medium is the electrical signal either AC or DC source is used. Working medium is compressed air. Operating voltages from around 12 V to 220 V are used. The final control valve is actuated by solenoid activation.

In electro pneumatic controls, mainly three important steps are involved.

Signal input devices

Signal generation such as switches and contactor, various types of contact and proximity sensors.

Signal processing

Use of combination of contactors of relay or using programmable logic controllers.

Signal outputs

Outputs obtained after processing are used for activation of solenoids, indicators or audible alarms.

Basic electrical devices

Basic electrical devices commonly used in the control of fluid power systems are

Manually actuated push button switches

Limit switches

Pressure switches

Solenoids

Relays

Temperature switches

Push button switches

A push button is a switch used to close or open an electric control circuit. They are primarily used for starting and stopping of operation of machinery. They also provide manual over ride when the emergency arises. Push button switches are actuated by pushing the actuator into the housing. This causes set of contacts to open or close.

Push buttons are of two types

Momentary push button

Maintained contact or detent push button

Momentary push buttons return to their unactuated position when they are released. Maintained (or mechanically latched) push buttons has a latching mechanism to hold it in the selected position.

The contact of the push buttons, distinguished according to their functions.

- Normally open (NO) type
- Normally closed (NC) type
- Change over (CO) type.

The cross section of various types of push buttons in the normal and actuated positions and their symbols are given in the fig 1. In the NO type, the contacts are open in the normal position, inhibiting the energy flow through them. But in the actuated position, the contacts are closed, permitting the energy flow through them. In the NC type, the contacts are closed in the normal position, permitting the energy flow through them. And, the contacts are open in the actuated position, inhibiting the energy flow through them. A changeover contact is a combination of NO and NC contacts.

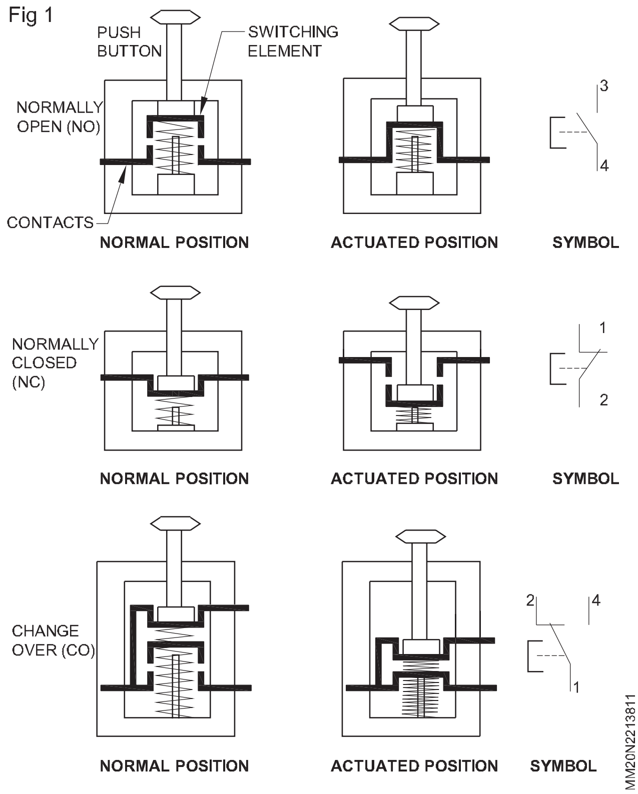
Type of devices	**Terminal numbers**	
	Normally closed contacts	**Normally open contacts**
Push buttons and relays	1 and 2	3 and 4

Limit switches

Any switch that is actuated due to the position of a fluid power component (usually a piston rod or hydraulic motor shaft or the position of load is termed as limit switch. The actuation of a limit switch provides an electrical signal that causes an appropriate system response.

Limit switches perform the same function as push button switches. Push buttons are manually actuated whereas limit switches are mechanically actuated.

Fig 1

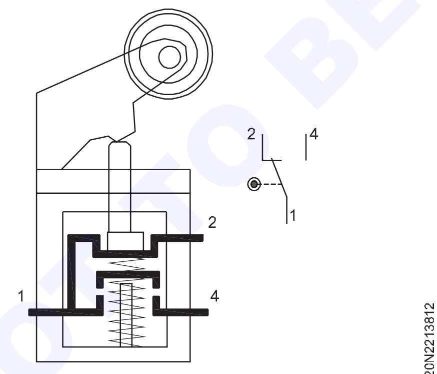


There are two types classification of limit switches depending upon method of actuation of contacts

- Lever actuated contacts
- Spring loaded contacts

In lever type limit switches, the contacts are operated slowly. In spring type limit switches, the contacts are operated rapidly. Fig 2 shows a simplified cross sectional view of a limit switch and its symbol.

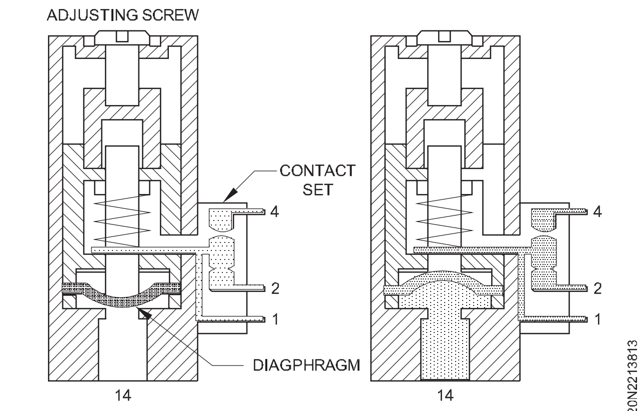
Fig 2



CROSS SECTIONAL VIEW OF A LIMIT SWITCH

A pressure switch is a pneumatic - electric signal converter. Pressure switches are used to sense a change in pressure, and opens or closes an electrical switch when a predetermined pressure is reached. Bellow or diaphragm is used to sense the change of pressure. Bellows or diaphragm is used to expand or contact in response to increase or decrease of pressure. Figure. 3 shows a diaphragm type of pressure switch. When the pressure is applied at the inlet and when the pre-set pressure is reached, the diaphragm expands and pushes the spring loaded plunger to make/break contact.

Fig 3



CROSS-SECTIONAL VIEW OF A PRESSURE SWITCH

Temperature switch

Temperature switches automatically senses a change in temperature and opens or closes an electrical switch when a predetermined temperature is reached. This switch can be wired either normally open or normally closed.

Temperature switches can be used to protect a fluid power system from serious damage when a component such as a pump or strainer or cooler begins to malfunction.

Solenoids

Electrically actuated directional control valves form interface between the two parts of an electro pneumatic control. The most important tasks of electrically actuated DCVs include.

Switching supply air ON or OFF

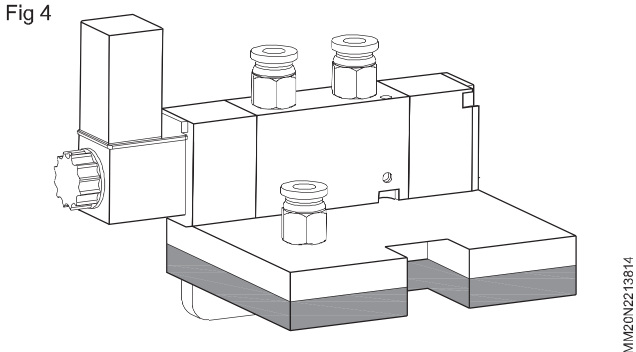
Extension and retraction of cylinder drives.

Electrically actuated directional control valves are switched with the aid of solenoids. A solenoid is like a coil of the relay. When it is energized, it will switch on the valve, similar to turning on the hand lever of a normal valve.

They can be divided into two groups

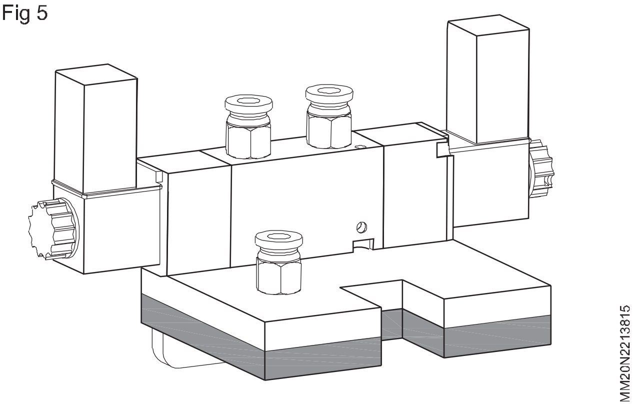
- Spring return valves (single solenoid valve) only remain in the actuated position as long as current flows through the solenoid (Fig 4)

Fig 4



- Double solenoid valves (double solenoid valve) retain the last switched position even when no current flows through the solenoid. (Fig 5)

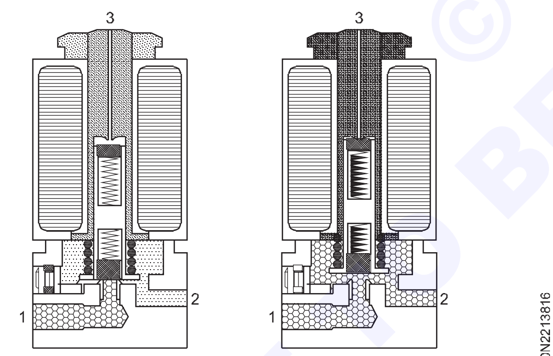
Fig 5



In the initial position, all solenoids of an electrically actuated DCVs are de- energized and the solenoids are inactive. A double valve has no clear initial position, as it does not have a return spring. The possible voltage levels for solenoids are 12V Dc, 12V Ac, 12V 50/60 Hz, 24V 50/60 Hz, 110/120V 50/60 Hz,220/230V 50/60 Hz

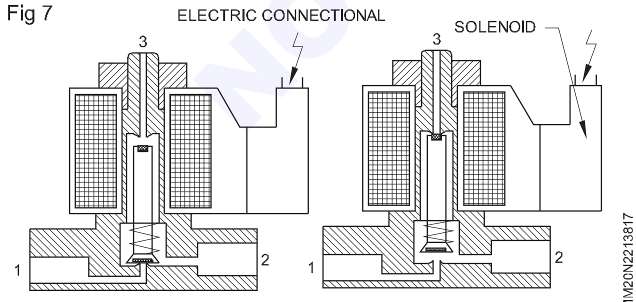
3/2 way signal solenoid valve, spring rectors : The cross sectional view of 3/2 way single solenoid valve in the normal and actuated positions are shown in Fig 6. In the normal position, port 1 is blocked and port 2 is connected to port 3 via back slot (details shown in the circle) when the rated voltage is applied to coil, armature is pulled towards the centre of the coil and in the process the armature is lifted away from the valve seat. The compressed air now flows from port 1 to port 2, and ports 3 is blocked. When the voltage to the coil is removed, the valve returns to the normal position. Fig 7 shows 2/2 solenoid operated valve.

Fig 6



CROSS SECTIONAL VIEW OF A 3/2 SINGLE SOLENOID VALVE

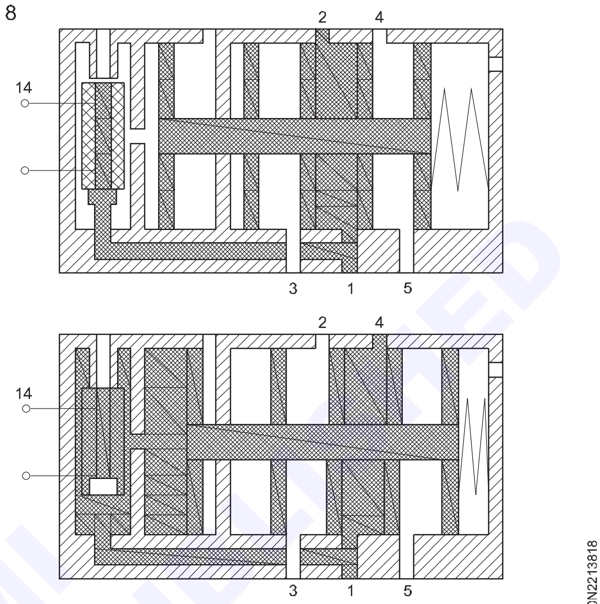
Fig 7



5/2 way single solenoid valve, spring return

The cross section view of 5/2 way single solenoid in the normal and actuated positions are shown in Fig 8. In normal position, port 1 is connected to port 2, port 4 is connected to port 5, and port 3 is blocked. When the rated voltage is applied to coil 14, the valve is actuated through an internal pilot valve. In actuated position, port 1 is connected to port 4, port 2 is connected to port 3, and port 5 is blocked. The valve returns to the normal position when the voltage to the armature coil is removed. This type of valves is normally used as final valve to control double acting cylinders.

Fig 8

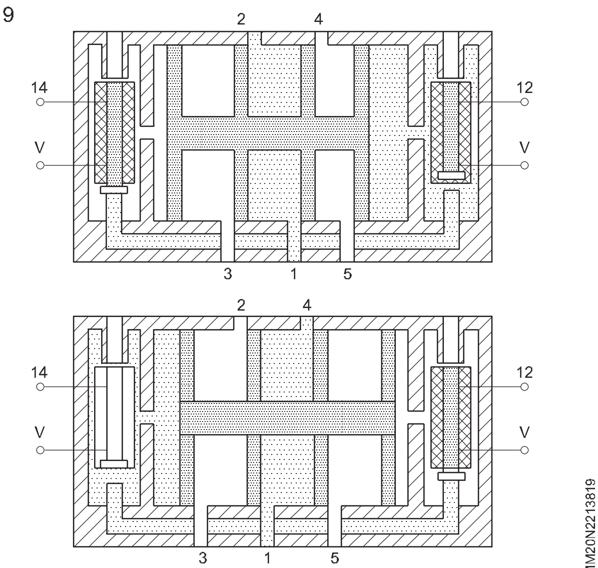


CROSS SECTIONAL VIEW OF A 5/2 WAY SOLENOID OPERATED VALVE

5/2 way single double solenoid valve

The cross section view of 5/2 way double solenoid in the normal and actuated positions are shown in the fig 9 when the rated voltage is applied to coil 14, the valve is actuated to a one switch in position with port 1 connected to port 4, port 2 connected to port 3, and port 5 blocked. When the rated voltage is applied to the coil 12, the valve is actuated to the other switching position with port 1 connected to port 2, port 4 connected to port 5 and port 3 blocked. (Fig 9)

Fig 9



The symbols for the various solenoid/pilot actuated valves are given in table 1 (Fig 10)

Fig 10

TABLE 1

SYMBOL	DETAILS
	3/2 WAY SINGLE SOLENOID VALVE (SPRING RETURN)
	3/2 WAY PILOT OPERATED SINGLE SOLENOID VALVE (SPRING RETURN)
	5/2 WAY SINGLE SOLENOID VALVE (SPRING RETURN)
	5/2 WAY DOUBLE SOLENOID VALVE
	5/2 WAY PILOT OPERATED DOUBLE SOLENOID VALVE (SPRING RETURN)

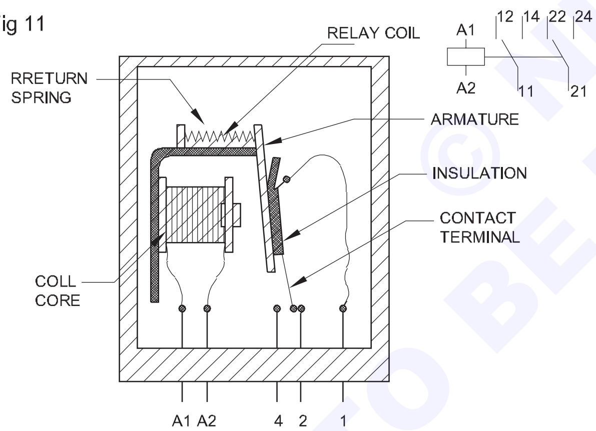
VARIOUS SYMBOLS FOR DCVs

MM20N221381A

Relay

A relay is an electro magnetically actuated switch. It is a simple electrical device used for signal processing. Relays are designed to withstand heavy power surges and harsh environment conditions. When a voltage is applied to the solenoid coil, an electro magnet field results. This causes the armature to be attracted to the coil core. The armature actuates the relay contacts, either closing or opening them, depending on the design. A return spring returns the armature to its initial position when the current to the coil is interrupted. Cross sectional view of a relay is shown in Fig 11.

Fig 11



CROSS SECTIONAL VIEW OF A RELAY

MM20N221381B

A large number of control can be incorporated in relays in contrast to the case of a push button station. Relays are usually designated as K1, K2, and K3 etc. Relays also possess interlocking capability that is an important safety feature in control circuits. Interlocking avoids simultaneous switching of certain coils.

Logic controls (Fig 12)

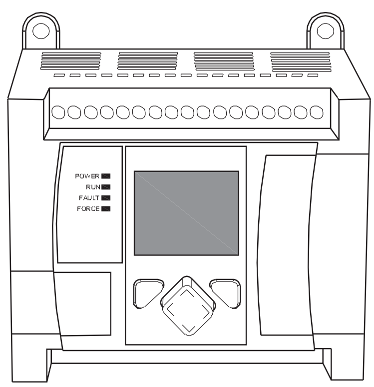
Logic controls refer to the use of logical principles and devices to manage and regulate various processes or systems. In essence, they enable machines or systems to make decisions and perform specific actions based on predefined rules or conditions.

Think of logic controls as the "brains" behind automation. They use logical operations, such as AND, OR, and NOT, to process input signals and determine the appropriate output. These input signals can come from various sources, including sensors, switches, or even manual inupts.

For example, consider a simple scenario of an automatic door. The logic control system might use sensors to detect if someone is approaching the door. When a person is sensed, the system processes this input and makes a decision. If the person is within a certain range and the door is not locked (Logical conditions), the system triggers the door to open. If the conditions are not met, the door remains closed.

Logic controls are vital in various fields, from manufacturing and robotics to traffic lights and home automation. They improve efficiency, safety, and consistency by allowing machines to make precise decisions based on logical rules and conditions.

Fig 12



LOGIC CONTROLLER

MM20N221381C

Symbols for hydraulic components

Objectives: At the end of this lesson you shall be able to
- **read and interpret the circuit symbol**
- **state the uses of symbol in hydraulic components.**

In a hydraulic circuits individual component to impart representation of hydraulics system in diagrams. A symbol identifies a component and its function. These symbols are as per ISO 1219 standards.

Pump and motor

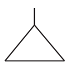
Hydraulic pump and motor are represented by means of a circle. Triangle within the circle represent the direction of flow and position of triangle differentiates between the symbol of pump or motor.

If triangle is filled darkened means it is meant for hydraulics fluid but if triangle is not filled means it is for gaseous pressure media or Pneumatic energy.(Figs 1 & 2)

Fig 1

HYDRAULIC ENERGY

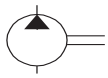
Fig 2



PNEUMATIC ENERGY

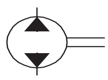
Symbols of pump and motor (Figs 3 to 9)

Fig 3



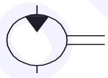
UNIDIRECTIONAL FIXED DISPLACEMENT PUMP

Fig 4



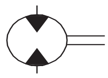
BIDIRECTIONAL FIXED DISPLACEMENT PUMP

Fig 5



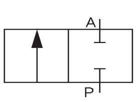
UNIDIRECTIONAL HYDRAULIC MOTOR

Fig 6



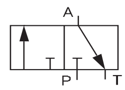
BIDIRECTIONAL HYDRAULIC MOTOR

Fig 7



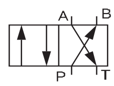
2/2-WAY VALVE

Fig 8



3/2-WAY VALVE

Fig 9



4/2-WAY VALVE

Direction control valve

Direction control valves are represented by several connected squares.

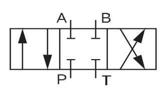
- The number of squares indicates the number of switching positions.
- Arrows in the squares indicate the direction of flow.
- Lines indicate how the ports are interconnected in the different switching position.

Port designation

P	Pressure port
T	Tank port
A	Service port (output port)
B	Service port (output port)
L	Leakage port

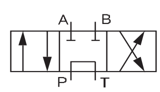
Symbols of Direction control valve (Figs 10 to 11)

Fig 10



4/3-WAY CLOSE CENTRE VALVE

Fig 11



4/3-WAY OPEN CENTRE VALVE

Port should always be represented in the neutral position of valve.

The neutral position is a position which automatically come in valve due to spring force when no any command is available in valve, it is also the initial position unless otherwise actuated.

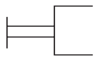
Actuating mechanism of Valve

The switching position of direction control valve can be changed by various actuation methods.

Different mechanisms of actuation of valve are shown in fig.12 to fig.19.

Mechanical actuation

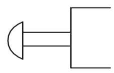
Fig 12



GENERAL MANUAL OPERATED

MM20N221401C

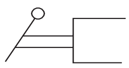
Fig 13



PUSH BUTTON

MM20N221401D

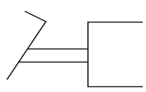
Fig 14



LEVER

MM20N221401E

Fig 15

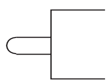


PEDAL

MM20N221401F

Manual actuation

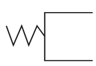
Fig 16



PUSH PIN

MM20N221401G

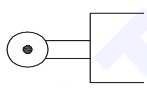
Fig 17



SPRING

MM20N221401H

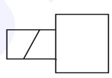
Fig 18



ROLLER

MM20N221401I

Fig 19



SOLENOID

MM20N221401J

Electrical actuation

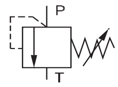
Pressure control valve

Pressure control valve are represented by a single squares. Arrow within the square indicate the direction of fluid flow.

The position of arrow within the square indicates whether the valve is normally open or normally closed.

Symbols of pressure control valve(Fig.20 to Fig.22)

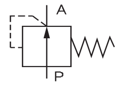
Fig 20



PRESSURE RELIEF VALVE

MM20N221401K

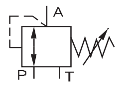
Fig 21



PRESSURE REDUCING VALVE

MM20N221401L

Fig 22



PRESSURE REGULATOR

MM20N221401M

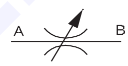
Flow control valve(Fig.23 to Fig.25)

Fig 23

FIXED FLOW CONTROL VALVE

MM20N221401N

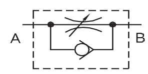
Fig 24



VARIABLE FLOW CONTROL VALVE

MM20N221401O

Fig 25



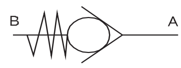
ONE WAY FLOW CONTROL VALVE

MM20N221401P

Non-return valves

The symbol of non-return valve is a ball which is pressed against a sealing seat. (Fig. 26 to Fig.28)

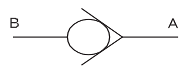
Fig 26



SPRING LOADED NRV

MM20N221401Q

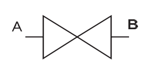
Fig 27



UNLOADED NRV

MM20N221401R

Fig 28



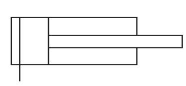
SHUT-OFF VALVE

MM20N221401S

Cylinder

Single acting cylinders have one port and double acting cylinder have two ports.(Fig.29 to Fig.31)

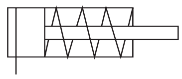
Fig 29



SINGLE ACTING CYLINDER

MM20N221401T

Fig 30



SINGLE ACTING CYLINDER WITH SPRING

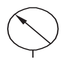
Fig 31

DOUBLE ACTING CYLINDER

Measuring devices

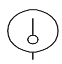
Measuring devices are shown in the Fig.32 to Fig.36.

Fig 32



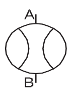
PRESSURE GAUGE

Fig 33



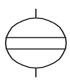
TEMPERATURE GAUGE

Fig 34



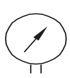
FLOW METER GAUGE

Fig 35



LEVEL GAUGE

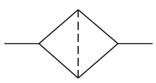
Fig 36



DIFFERENTIAL PRESSURE GAUGE

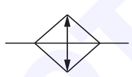
Other symbols(Fig.37 to Fig.39)

Fig 37



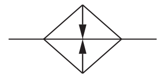
FILTER OR STRAINER

Fig 38



COOLER

Fig 39



HEATER

Symbols using Line (Fig 40 to Fig 46)

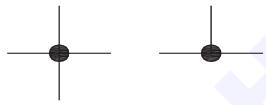
Fig 40

WORKING LINE

Fig 41

DRAIN OR BLEED LINE

Fig 43



PIPELINE JUNCTION

Fig 44

CROSSED PIPELINES

Fig 45

PLUGGED ON EQUIPMENT OR LINES

Fig 46

QUICK-ACTING COUPLING

Hydraulic oil Functions and properties

The primary function of a hydraulic fluid is to convey power. In use, however, there are other important functions of hydraulic fluid such as protection of the hydraulic machine components. The table below lists the major functions of a hydraulic fluid and the properties of a fluid that affect its ability to perform that function:

Function	Property
Medium for power transfer and control	Non compressible (high bulk modulus) Fast air release Low foaming tendency Low volatility
Medium for heat transfer	Good thermal capacity and conductivity

Sealing Medium	Adequate viscosity and viscosity index Shear stability
Lubricant	Viscosity maintenance Low temperature fluidity Thermal and oxidative stability Hydrolytic stability / water tolerance Cleanliness and filterability Demulsibility Antiwear characteristics Corrosion control
Pump efficiency	Proper viscosity to minimize internal leakage High viscosity index
Special function	Fire resistance Friction modifications Radiation resistance
Environmental impact	Low toxicity when new or decomposed Biodegradability
Functioning life	Material compatibility

Types of Hydraulic fluids

According to ISO there are three different types of fluids according to their source of availability and purpose of use.

Mineral- Oil based Hydraulic fluids

As these have a mineral oil base, so they are named as Mineral- Oil-Based Hydraulic fluids. This kind of fluids will have high performance at lower cost. These mineral oils are further classified as HH, HL and HM fluids.

Type HH fluids are refined mineral oil fluids which do not have any additives. These fluids are able to transfer power but have less properties of lubrication and unable to withstand high temperature. These types of fluid have a limited usage in industries. Some of the uses are manually used jacks and pumps, low pressure hydraulic system etc.

The HL fluids are refined mineral oils which contain oxidants and rust inhibitors which help the system to be protected from chemical attack and water contamination. These fluids are mainly used in piston pump applications.

HM is a version of HL- type fluids which have improved anti- wear additives. These fluids use phosphorus, zinc and sulphur components to get their anti-wear properties. These are the fluids mainly used in the high pressure hydraulic system.

Fire Resistant Fluids

These fluids generate less heat when burnt than those of mineral oil based fluids. As the name suggests these fluids are mainly used in industries where there are chances of the hazards, such as foundries, military, die-casting and basic metal industry. These fluids are made of lower BTU (British Thermal Unit) compared to those of mineral oil based fluids, such as water-glycol, phosphate ester and polyolesters. ISO have classified these fluids as HFAE (soluble oils), HFAS (high water-based fluids),HFB(invert emulsions), HFC(water glycols), HFDR(phosphate ester) and HRDU (polyolesters).

Environmental Acceptable Hydraulic Fluids (EAHF)

These fluids are basically used in the application where there is a risk of leakage or spills into the environment, which may cause some damage to the environment. These fluids are not harmful to the aquatic creatures and they are biodegradable. These fluids are used in forestry, lawn equipment, off - shore drilling, dams and maritime industries. The ISO have classified these fluids as HETG (based on natural vegetable oils), HEES (based on synthetic esters), HEPG (polyglycol fluids) and HEPR (polyalphaolefin types).

Controlling of Contamination

While the fluid is at operating temperature, completely drain the system. paying attention to the reservoir, all lines, cylinders, accumulators, filter housings or any area of fluid accumulation. Also, replace the filters.

With a lint-free rag, clean the reservoir of all sludge and deposits. Make sure the entire reservoir is free of any soft or loosened paint.

Flush the system with a lower viscosity fluid that is similar to the fluid to be used. A Reynolds number more than 4,000 should be selected to achieve enough turbulence to remove particles from the lines. Stroke valves frequently to ensure they are thoroughly flushed. The fluid should be filtered and the flushing should continue until reaching one level beyond the system's target cleanliness levels. For example,if the target is ISO 15/13/11, continue to flush the system until ISO 14/12/10 is reached.

Drain the flushing fluid as hot and as quickly as possible. Replace the filters and inspect/ clean the reservoir again.

Fill the system to approximately 75 percent with the fluid to be used. Bleed/vent the pump. If the pump has a pressure relief or bypass, it should be wide open. Run the pump for 15 seconds, then stop and let it sit for 45 seconds. Repeat this procedure a few times to prime the pump.

Run the pump for a minute with the bypass or pressure relief open. Stop the pump and let it sit for a minute. Close the bypass and permit the pump to operate loaded for no more than five minutes. Allow the relief valve to lift to confirm that it is flushed as well. Do not operate the actuators at this time. Stop the pump and let the system sit for about five minutes.

Start the pump and operate the actuators one at a time, allowing fluid to return to the reservoir before moving to the next actuator. After operating the final actuator, shut down the system. Keep an eye on the fluid level in the reservoir. If the level drops below 25 percent, add fluid and fill to 50 percent.

Refill the reservoir to 75 percent and run the system in five- minute intervals. At each shutdown, bleed the air from the system. Pay close attention to the system sounds to determine if the pump is cavitating.

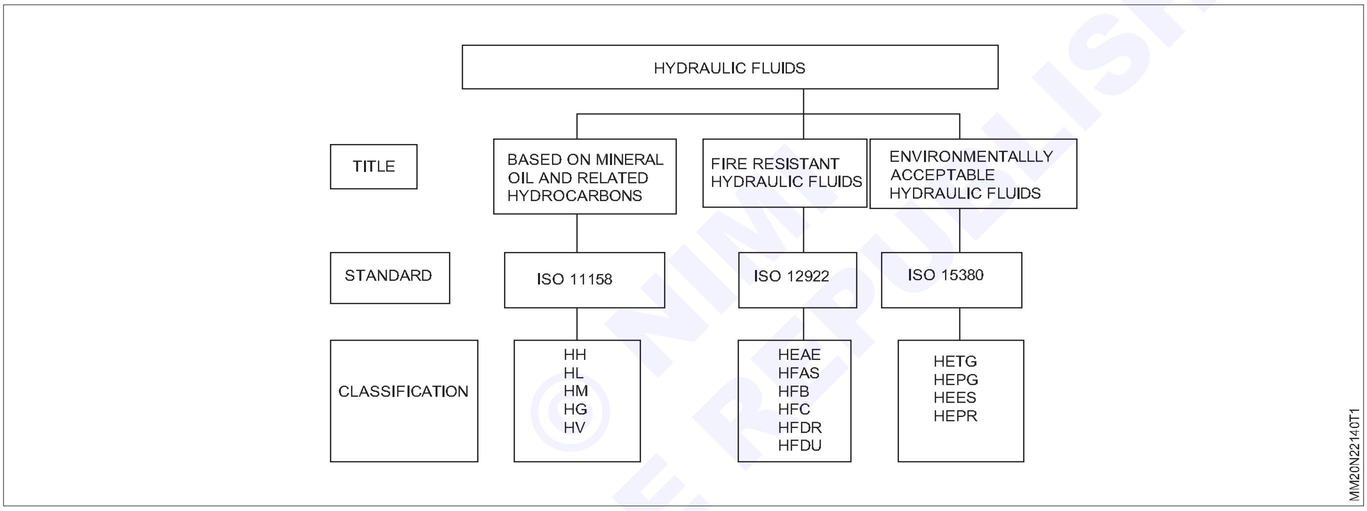
Run the system for 30 minutes to bring it to normal operating temperature. shutdown the system and replace the filters. Inspect the reservoir for obvious signs of cross-contamination. If any indication of cross-contamination is present, drain and flush the system again.

After six hours of operation, shut down the system, replace the filters and sample and test the fluid.

The sampling frequency should be increased until you are confident that the system fluid is stable.

Contamination of oil and its control

Contamination in hydraulic systems can be classified into particle contaminants (Metal particles from wear,dirt ingression) or chemical contaminants (water, air ,heat, etc). Examples of damage from contamination are: accelerated component wear, orifice blockage, formation of rust or other oxidation, depletion of additives, formation of other chemicals, oil degradation.



Types of contamination

Particle contaminants

Particle sizes are generally measured in microns. Some examples of microns: Grain of salt 100 microns, human hair 70 microns, lower limit of visibility 40 micron, milled flour 25 micron, average bacteria 2 micron. Note that most damage-causing particles in hydraulic or lubrication systems are smaller than 14 mm micrometers, so they cannot be seen.

Chemical contaminants

Water

The most common chemical contaminant in hydraulic systems is water. The presence of water in hydraulic oil can have wide- ranging effects on system components because of its effect on the physical and chemical properties of hydraulic oil. Rust in tanks, reduced lubrication characteristics resulting in accelerated metal surface wear are some of the most obvious physical results of excessive water, however the effects could be as diverse as the jamming of components due to ice crystals at low temperatures. Chemical effects include additive depletion or deposition, oxidation, unwanted reactions which can result in the formation of acids, alcohols or sludges. Oil becomes cloudy when it's contaminated with water above its saturation level. The saturation level is the amount of water that can dissolve in the oil's molecular chemistry and is typically 200 to 300 ppm at 20°C for mineral hydraulic oil. SKF state that hydraulic oil containing just 0.1% water by volume cuts bearing life in half, while 1% reduces bearing life by 75%

Air

Air in hydraulic system can exist in either a dissolved or entrained (undissolved, or free) state. Dissolved air may not pose a problem, providing it stays in solution. When a liquid contains undissolved air, problems can occur as it passes through system components. There can be pressure changes that compress the air and produce a large amount of heat in small air bubbles. This compressibility of air means that control of the system is lost. Air bubbles and frothing in the oil reservoir can cause major damage to pumps or it can also cause oil to "boil" out of the tank.

Heat

Excessive heat in hydraulic systems can also result in additive depletion or chemical changes to the oil.

Hydraulics filter

Objectives: At the end of this lesson you shall be able to
- **explain hydraulic filters**
- **list the types of filters**
- **state the difference between mechanical, absorbent, adsorbent and magnetic filter.**

Filter

Filter is a device which removes solid contaminants from the fluid.

Hydraulic filters are available in several shapes, sizes, micron ratings and construction materials. Hydraulic filters provide in built protection and minimize hydraulic system breakdowns that are quite often caused by contamination.

The life of a filter in a hydraulic system depends primarily on the system pressure, level of contamination and nature of contaminants.

Filters is a very important components used in hydraulic system for the reliable functioning and long service life of the components.

Filter and Strainer are the two terms commonly used.

Use of Hydraulic Filters

One of the main cause of failure or poor functioning of a hydraulic system is contamination of hydraulic oil or fluid. Hydraulic filters are used for handling and removing contamination from hydraulic oil.

Contaminants of hydraulic fluid are broadly defined as any substance that impairs the proper functioning of the fluid.

Contaminants are classified as

- Solids
- Liquids
- Gaseous
- Bacteria
- Organic

Types of Filters

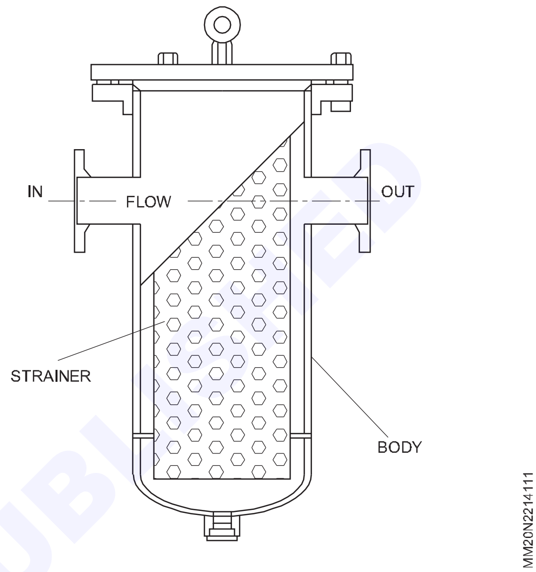
There are four types of filters generally used in hydraulic system.

- Mechanical filter
- Absorbent filter
- Adsorbent filter
- Magnetic filters

Mechanical filter

Mechanical filters contain closely woven metal screens or discs. They generally remove only fairly coarse particles. Mechanical filter is known as strainer in hydraulic system. These filters are located in the suction line of the pump, hydraulic oil is drawn from the reservoir through the filter. (Fig 1)

Fig 1



Grade of Mechanical filter: 60-100 mm

mm is the micron which is 1/1000 part of 1 mm. (ie)

1 mm = .001 mm

Absorbent filter

Absorbent filters, such as cotton, wood pulp, yarn, cloth, or resin, remove much smaller particles; some remove water and water-soluble contaminants. The elements often are treated to make them sticky to attract the contaminants found in hydraulic oil.

These filters are installed in the pressure line of a hydraulics system at the pressure port of the pump.

Since this filter is subjected to the maximum operating pressure, it must be of robust design. (Fig 2)

Adsorbent filter

A filter used for trapping various sizes of particulate matter. Adsorbent filters consist of clay, chemically treated paper and desiccant. (Fig 3)

Magnetic filter

Magnetic filters are basically used to remove the ferrous material from oil along with contaminants.

Magnet are geometrically arranged outside or inside the filter which produce a strong magnetic field that help to arrest the ferrous particles from oil.

In most of magnetic filter permanent magnet is used to create magnetic field.

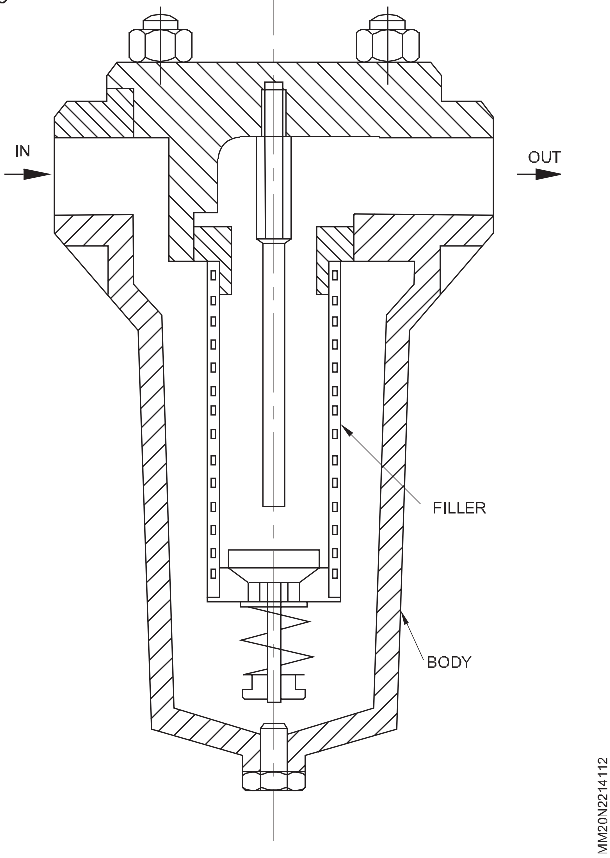


Fig 2

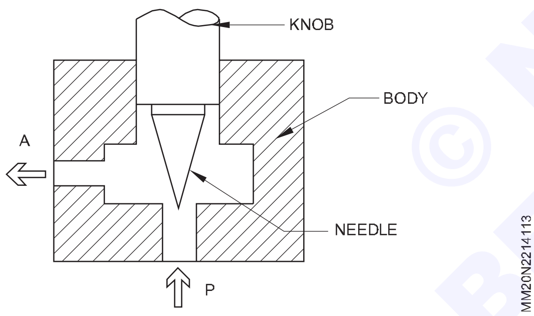


Fig 3

These filters are commonly used in the automotive industry but are also utilized in a number of low-pressure industrial applications.

Filter is wrapped by magnetic ring which transmit a magnetic field through the steel filter bowl in order to trap ferromagnetic debris it is held tightly against the internal surface of the bowl which we can easily separate during servicing. (Fig 4)

Generally filter can be classified on the basis of their location in hydraulic system:

- Suction stainer
- Pressure line filter
- Return line filter
- Off line filter

Filter types on the basis of location

Suction stainer

Suction filters serve to protect the pump from fluid contamination. They are located in the upstream of pump's inlet port. Inlet strainers are submersed in fluid in the tank. Suction filters have relatively coarse elements, due to cavitations limitations of pumps.(Fig 5)

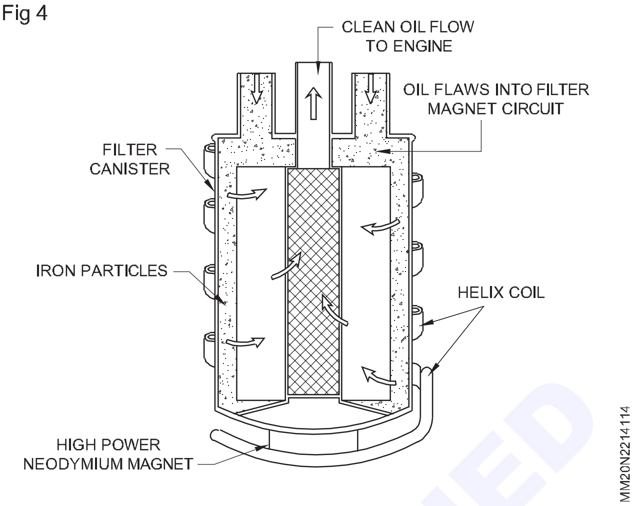


Fig 4

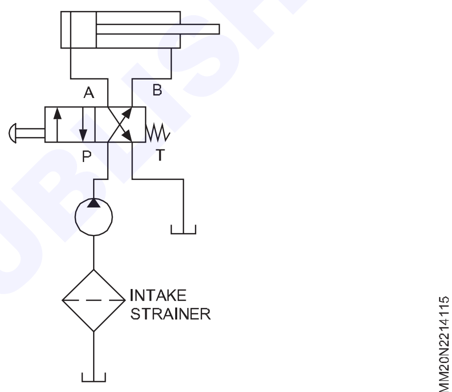


Fig 5

Return line filter

Return line filters may be the best choice if the pump is particularly sensitive to contamination. In most systems, the return filter is the last component through which fluid passes before entering the reservoir. Therefore, it captures wear debris from all of the system's working components and any particles that enter through worn cylinder rod seals before such contaminant can enter the reservoir and be pumped back into the system. Because this filter is located immediately upstream from the reservoir, its pressure rating and cost can be relatively low. (Fig 6)

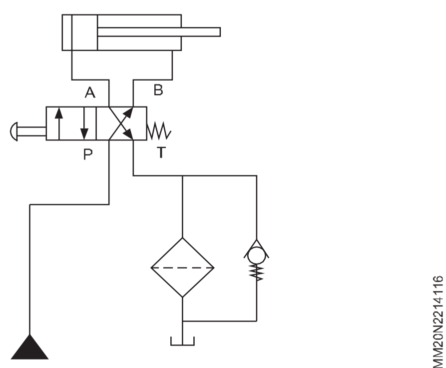
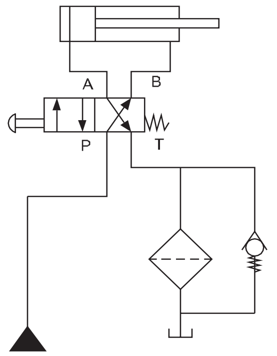


Fig 6

Pressure line filter

Pressure filters are located downstream from the system pump. They are designed to handle the system pressure and are sized for the specific flow rate in the pressure line where they are located. Pressure filters are especially suited for protecting sensitive components, such as servo valves, because pressure filters are located just downstream from the pump, they also help to protect the entire system from any pump-generated contamination. (Fig 7)

Fig 7



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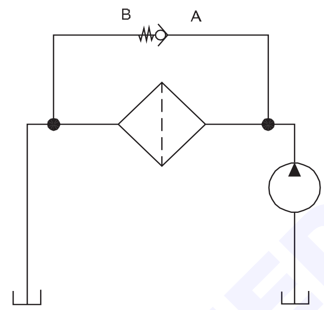
Off line filter

An off-line filtration circuit includes its own pump and electric motor, a filter and the appropriate connecting hardware. These components are installed off-line as a small subsystem separate from the working lines, or they may be included in a fluid-cooling loop. Fluid is pumped continuously out of the reservoir, through the off-line filter and back to the reservoir (Fig 8).

Fig 8



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Hazard and safety precautions in hydraulic system

Objectives : At the end of this lesson you shall be able to
- **state the safety precaution while working with hydraulic fluids**
- **describe related hazards of hydraulic fluid.**

Safety precautions

There are numerous hazards involved, like skin irritation, fires, explosions, environmental damage and a slippery workplace. But hydraulic fluids are required for many machines to function. Therefore it is necessary to follow certain precautions while using these fluids. With proper knowledge of these hazards, working with hydraulic fluid can be safe.

- In order to avoid skin irritations, it is necessary to wash contaminated skin immediately. It is also necessary to keep your clothing clean.
- Wearing masks and gloves while using hydraulic fluids is also helpful.
- To avoid environmental dangers,there is biodegradable hydraulic fluid option,though it is more expensive.
- To avoid fires,materials and fluids soaked in hydraulic fluid should be stored in sealed metal containers and disposed of at proper places.
- To check for leaks, use cardboard.
- Never use hands or fingers to search for hydraulic leaks.
- Maintain a clean work area free of slipping hazards.
- Use chemical resistant gloves, splash goggles and a chemical resistant apron to avoid prolonged or repeated skin or eye contact.
- Never begin work on a hydraulic system until fully trained.

Related hazards

Health problems while using hydraulic fluids

People can become exposed to the chemicals in hydraulic fluids. The exposure to chemicals may be due to inhalation, ingestion or touch. There are instances of people suffering from skin irritation or weakness in hands while handling hydraulic fluids. There are also cases of intestinal bleeding, pneumonia or death through hydraulic fluid ingestion though no serious hazards are reported with hydraulic fluid inhalation.

Similar to ingestion, fluids can be accidentally injected into the skin as well. This takes place when the high pressure hydraulic system hose is disconnected and toxic fluids are leaked and injected into the skin. If there is a small leak in the hydraulic pipe and someone runs there hand along it, at 2000 psi, they can easily incur an injection of hydraulic fluid and may not even be aware that it happened until gangrene begins to set in.

Fire dangers associated with hydraulic fluids

When working with hydraulic fluid, there is every chance that the hydraulic fluid gets heated to high temperatures. And it is evident that most petroleum - based hydraulic fluids will burn and thereby create explosions and burns.

Environmental problems related to hydraulic fluids

Another hazard of hydraulic fluid is that when the hydraulic hose or pipe leaks, the chemicals of the fluids can either stay on top of the soil or sink into the ground. If the chemicals get mixed in a water body, they will sink to the bottom. In fact in such cases the chemicals can stay there for more than a year. Aquatic life can absorb the toxic hydraulic fluid, leading to illness or death to the animal or anything higher on the food chain. For example, a hawk that eats a fish that has been contaminated by hydraulic fluid that was mixed in water could become ill as well.

Fluid texture problems

Although the slimy texture of hydraulic fluids may not seem like a danger or a problem, a spill can cause a person to slip and fall. Also when there is fluid on the hands of a person, it can cause him to slip while climbing on a machine. It can also cause the operator to lose steering control.

Injuries from loose hydraulic hoses

Due to high pressure with in a hydraulic system, the impact force of a disconnected and flailing hydraulic hose can cause abrasions, temporary unconsciousness, bruise, fractures and lacerations. Proper maintenance and good pre - shift equipment inspections can minimise these hazards

Hydraulic pumps

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

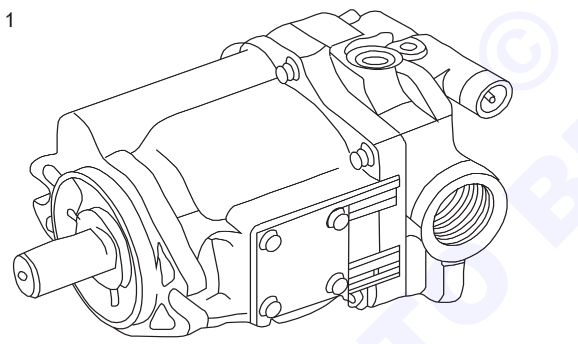
- **define hydraulic pump**
- **differentiate between positive and non-positive displacement pump**
- **explain working of gear pump**
- **explain the working of vane pump**
- **explain the working of piston pump.**

Hydraulic Reservoir and Accessories

Hydraulic reservoirs are storage tanks that hold liquids or gases used for fluid power applications. They are usually rectangular and cylindrical shaped. The purpose of the hydraulic reservoir is to hold a volume of fluid, transfer heat from the system allow solid contaminants to settle and facilitate the release of air and moisture from the fluid.

A hydraulic pump Fig 1 is a device which converts mechanical force and motion into hydraulic energy. Many different sources provide mechanical power to the pump. They are electric motors, air motors, engines and manual operation.

Fig 1



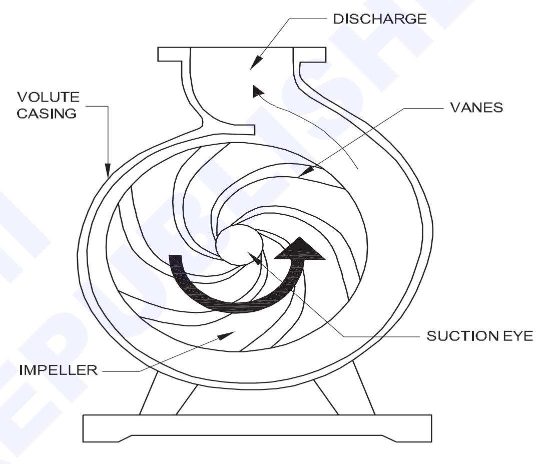
Classification of pumps

Pumps are classified as either non-positive or positive displacement. This describes the fundamental division of pumps.

Non-positive displacement pumps

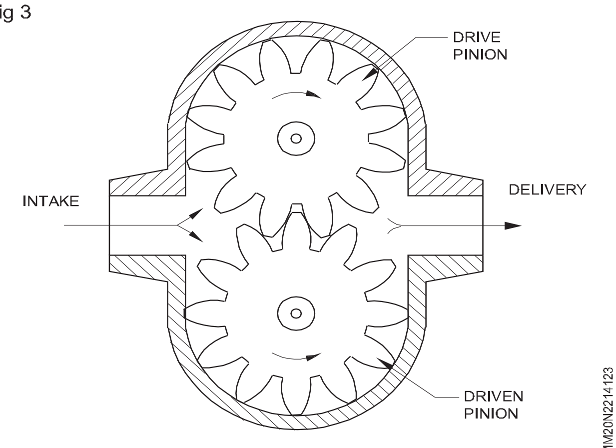
- The non-positive displacement type pump gives continuous discharge.
- The non-positive displacement pump does not provide a good seal against slippage, causing pump output to vary as the system pressure changes.
- The volume of fluid delivered during each cycle will depend on resistance to flow in the system.
- Centrifugal pumps are the Non-positive displacement pumps. (Fig 2)

Fig 2



Positive displacement pumps (Fig 3)

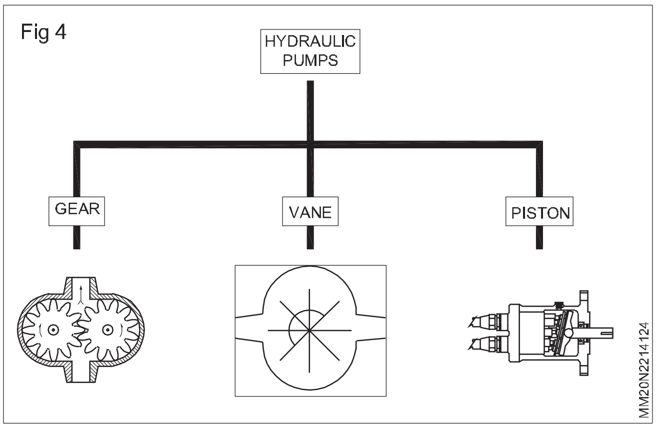
Fig 3



- A positive displacement pump provides positive internal seal against slippage.
- This type of pump is capable of delivering a definite volume of fluid for each cycle of pump operation.
- Closing the outlet of a positive displacement pump causes an instantaneous increase of pressure. This increase in pressure can stall the equipment or break up of components.
- Gear pump is an example of positive displacement pump.

Types of Hydraulic pumps(Fig 4)

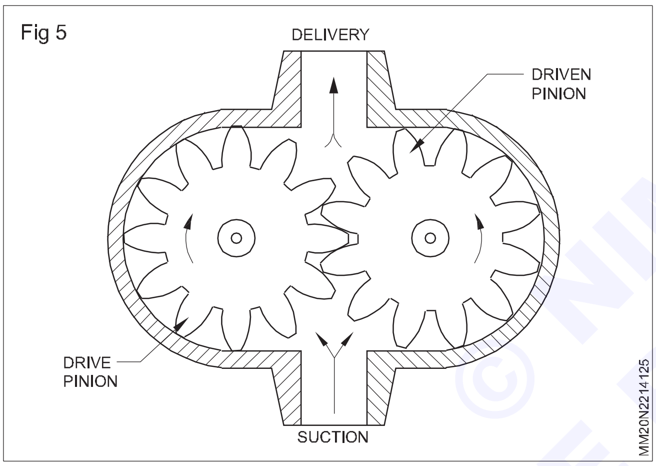
Fig 4



External Gear pump

External gear pump is the most common type rotary pump. In this pump the drive gear is turned by a drive shaft, which engages the power source. The inlet port is connected to the supply line and the outlet is connected to the pressure line. (Fig 5)

Fig 5



As gears rotate the volume of area on the inlet increases, thereby decreasing the pressure and making it possible for the atmospheric pressure exerted on the surface of the liquid in the reservoir to push the liquid into the inlet port. This causes liquid to be trapped in the gear space as the gears rotate and to be carried from the inlet port to the discharge port.

This action produces flow of liquid into the system.

A tighter seal against slippage can be accomplished by a metallic contact between the teeth ensures the seal against slippage. (Fig 6)

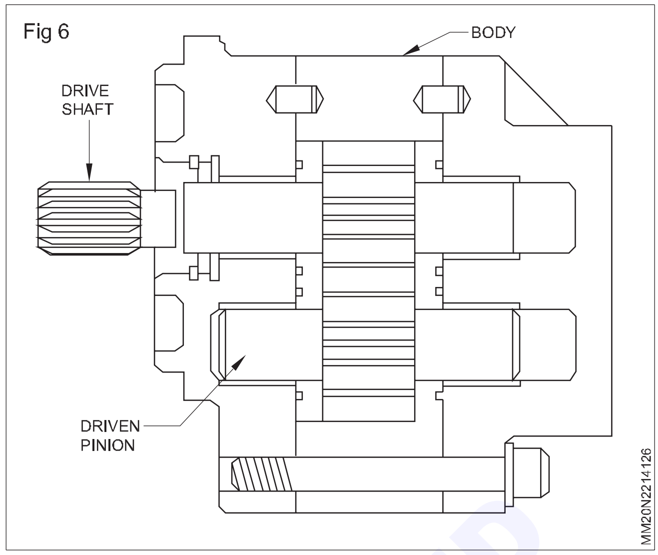
Important parameters

- Displacements volume 0.2 to 200 Cm^3/rev
- Suitable for pressure up to 300 bar
- Fixed displacement only
- Generally noisy
- Compact and low weight
- Low cost

Gear pump applications

Gear pump is generally used to transfer lubricating oil in industrial & automobile application. Some time it is also used in some hydraulics power application.

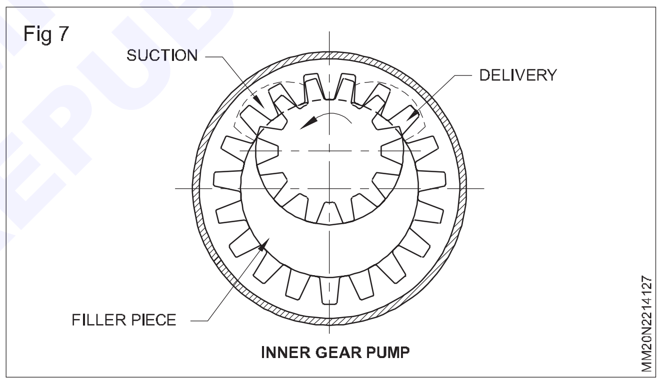
Fig 6



Internal gear pump

Two gears are available in internal gear pump. The spur gear is mounted inside a large ring gear (outer gear). The smaller spur gear is in mesh with one side of the larger gear and kept apart by a crescent-shaped separator on the other side. The crescent-shaped separator isolates the inlet port from the outlet port. In the internal gear pump, both gears rotate in the same direction. (Fig 7)

Fig 7



INNER GEAR PUMP

As the gear teeth un-mesh, a partial vacuum is created on the inlet side. Atmospheric pressure forces liquid into the space created, and with the rotation of the gears, liquid is carried around the periphery of the gears and the crescent-shaped separator until it reaches the outlet port. A continuous flow of liquid is pushed out through the outlet port.

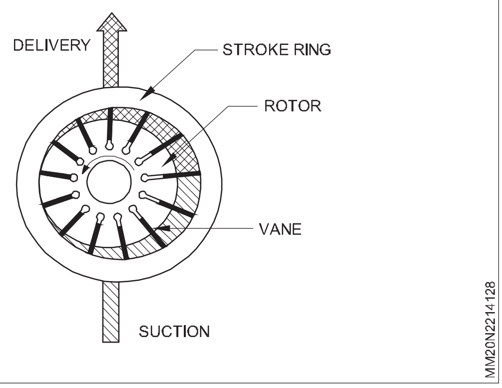
Important parameters

- Internal gear pumps are suitable for pressure up to 3500 psi.
- Working a wide viscosity range up to 2200 cSt, depending on flow rate.
- Generally quiet.
- Internal gear pumps have a high efficiency even at low fluid viscosity.

Vane Pump

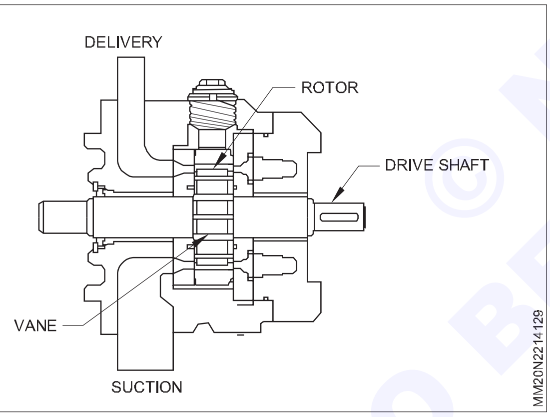
Vane pump is very common type of pump. The vanes pump having slots in the rotor. When the rotor spins, centrifugal force pushes the vanes out to touch the casing, where they trap and propel fluid. Springs are use to push the vanes outward. When the vanes reach the delivery side they are pushed back into the rotor by the casing. Fluid escapes through a channel or groove of the casing. In this vane pump there is considerable unbalanced force is acting on the drive shaft because high-pressure area is available on outlet side. (Fig 8)

Fig 8



The inlet port is located in that part of the pump where the chambers expand in size so a partial vacuum is formed to allow liquid to flow into the pump. The liquid is trapped between the vanes and is carried to the outlet side of the pump. The chambers at the outlet side contract in size, and this action forces liquid through the outlet port into the system. (Fig 9)

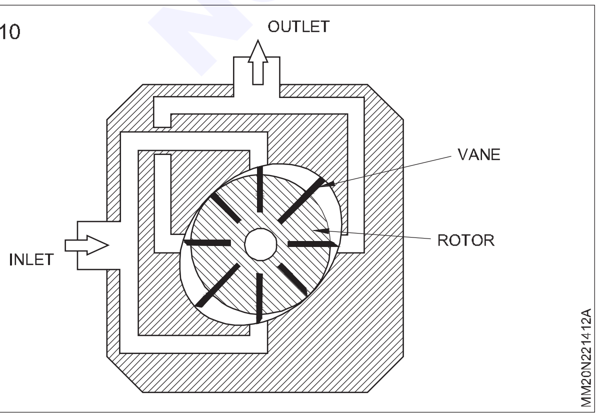
Fig 9



Balance Vane pump

This design results in two pressure cycles per revolution. The two outlet ports are spaced 180° apart so that the pressure forces on the rotor are balanced. These pumps can develop much higher pressures at high rotational speeds. (Fig 10)

Fig 10



Vane pump characteristics

- Typical use for higher flow application.
- Typical pressures upto 160 bar
- Simple multiple assemblies
- Range of pump controls
- Low noise

Vane pump applications

Vane pump is used for higher discharge & low pressure application. It is used to transfer lubricating oil in industry & also used in medium machine tools and presses.

Piston pump

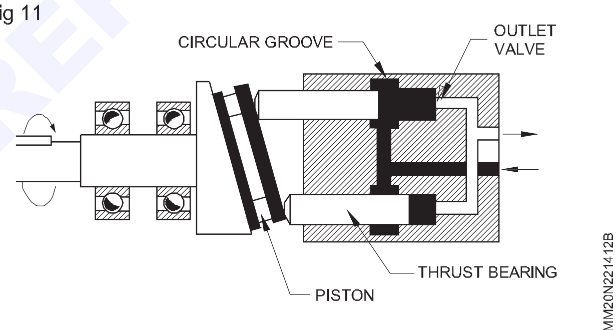
Piston pump is a common pump used for high pressure application. Following three types of pump are come in this category:-

- Axial piston pump
- Bent axis piston pump
- Radial piston pump

Axial piston pump

In the axial piston pump the block and the piston rotates on a shaft in such a way that the piston reciprocates in their cylinders bores, axially. This motion is called axial motion. The pumping action is made possible by a universal joint or a link and a swash plate. (Fig 11)

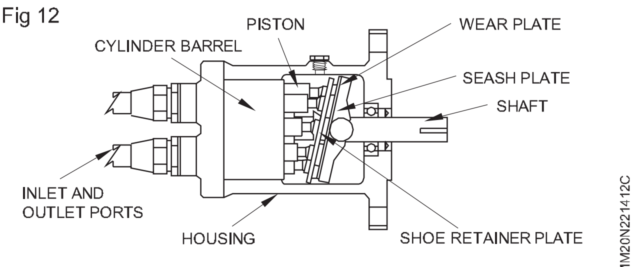
Fig 11



The main parts of the pump are the drive shaft, pistons, cylinder block, and the swash plate. Atmospheric pressure forces liquid in one port; and it is forced out the other port by the reciprocating action of the pistons.

A fill port is located in the top of the cylinder housing. The opening is normally plugged but it can be opened for testing pressure in the housing or case. If a new or repaired pump is installed, this plug must be removed and the housing filled with the recommended fluid. (Fig 12)

Fig 12



As the drive shaft rotates, it rotates the cylinder block and the pistons. The offset position of swash plate in pump block causes the pistons to move back and forth in the cylinder block. The shaft, pistons and cylinder block rotate together.

As the pistons reciprocate in the cylinder block, liquid enters through one port and is forced out through the other. This action provides a steady, non-pulsating flow of liquid.

Pumping action depends upon tilt angle of the swash plate. If there is no tilt; there is no pumping action.

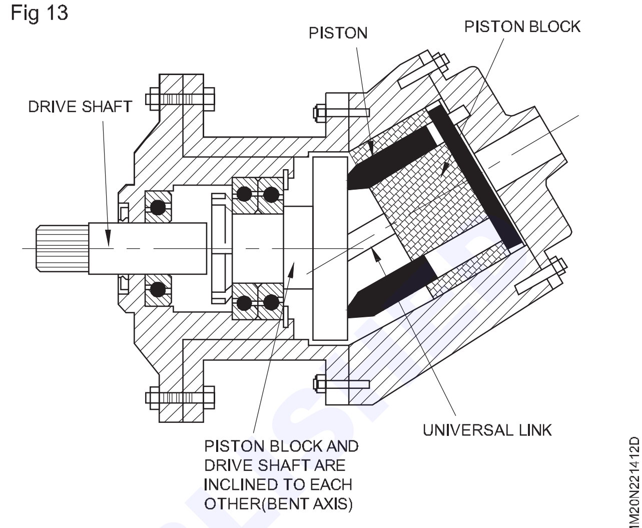
Bent axis piston pump

Like the swash plate pump, this pump is also of the axial piston type. There are several pistons those are parallel to each other and reciprocate axially in a piston-block. However unlike the swash plate pump, the drive shaft is inclined at an angle to the piston-block and hence the termed bent axis (Fig 13).

There are several piston housing within slots in the piston-block and they are connected to the drive shaft-flange. A universal link key the piston-block to the drive shaft to maintain alignment and to assure that they rotate together.

As the drive shaft rotates, it transmits drive to the pistons and piston-block. At the suction side, along the direction of rotation between the piston-block and drive shaft-flange distance increases and the piston are pulled out, thus resulting induction. Alternately, the pistons are pushed in as they pass along the discharge port, thus resulting in discharge. This reciprocating of the piston as the drive shaft rotates result in the pumping of the liquid.

Fig 13

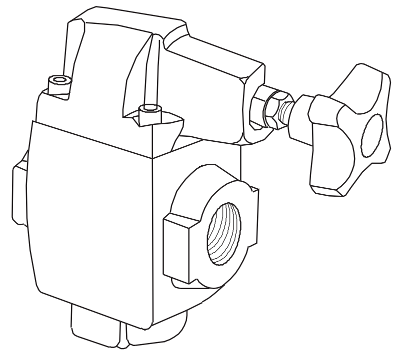


Pressure relief valve

Objectives: At the end of this lesson you shall be able to
- **identify different parts of a pressure relief valve**
- **explain the functional features of a different parts of a pressure relief valve**
- **explain the constructional features of a pressure relief valve.**

The general outlook of a pressure relief valve is shown in (Fig 1). Knob is the main controlling element from outside.

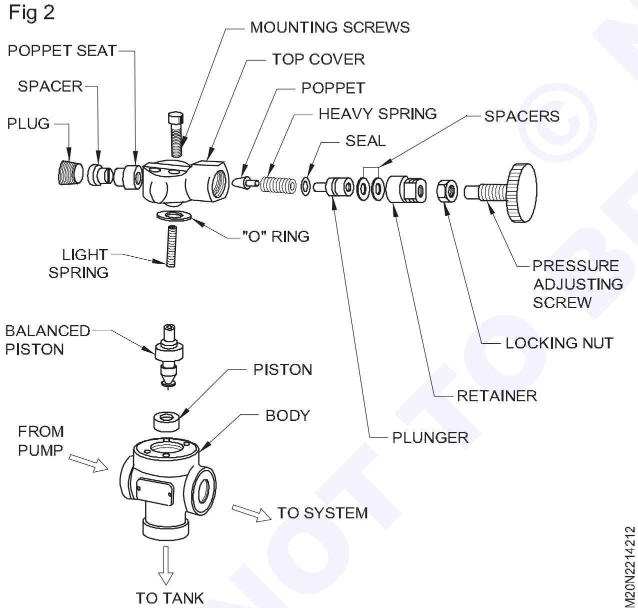
Fig 1



PILOT OPERATED PRESSURE - RELIEF VALVE

The following are main parts (Fig 2) of a pilot operated relief valve:

Fig 2



Body	Poppet
Top cover	Poppet seat
Piston	Heavy spring
Light spring	Adjusting screw
Piston seat	

Body

Body of the valve is a fine grade cast iron. The inside of the casting is accurately machined to accommodate piston, piston seat and tight spring. Body is fixed with top cover by screws. Ports for inlet outlet and drain connections are provided in the body, as threaded holes. The body accommodates the main relieving mechanism.

Top cover

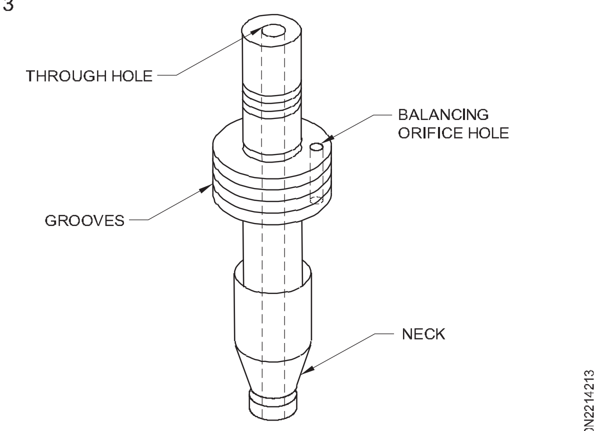
The top cover is also a fine grade casting. It is machined inside to accommodate - poppet, heavy spring, adjusting screws, seals and vent plug. The top cover is fixed with the body by means of screws. The top cover houses the pilot operating mechanism, by means of the stated elements.

Piston

It is the main relieving valve element in the body. It is made of wear resistant steel, hardened and ground. The sliding portions of the valve are provided with shallow grooves. These groove retain oil, to give oil film for lubrication. There is a through hole at the centre of the valve piston. (Fig 3) There is an orifice hole on a flat side of large diameter. The purpose of through hole is to relieve oil at the time of cracking. The orifice hole fill up the area above piston from the inlet pressure area to balance the piston.

The bottom of the valve is tapered to have a cone seating in closed condition. Piston is accommodated in the body.

Fig 3



PISTON VALVE

Light spring

The purpose of light spring is to retain the piston down against the seat in a balanced condition. It is accommodated in between the large diameter of the piston and body portion around the upper stem of the piston. This spring is not adjustable one, for its tension.

Piston seat

It is a liner bush tightly fixed in the body. It is made of wear-resistant steel, hardened and ground. The inner side of the bush has a taper to seat the tapered portion of the piston valve.

Pilot operated type

Poppet

Poppet is a conical member housed in the top cover. Poppet serves as a pilot valve. It is held in position by a heavy spring. It is also made of a wear resistant steel with a fine conical ground surface.

This conical seat will have perfect sealing against oil from pilot port. Poppet is retained by a heavy spring.

Poppet seat

It is a seat for the poppet valve. It has got a conical seat within to match the tapered surface of a poppet. It is a hardened ground and rigidly fixed inside the top-cover by press-fit.

Heavy spring

This spring has to seat the poppet in the pilot port.

This spring is housed in between a plunger and maximum diameter of the poppet. When the force exerted by the oil at pilot port is more, the heavy spring lift off the poppet, to relive oil. The tension of spring is adjustable by means of knob.

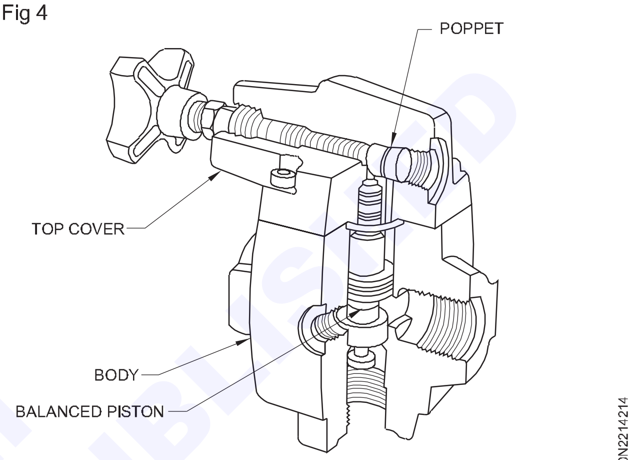
Adjusting screw

Adjustable screw is a fine pitched screw along with knob accommodated in the top cover. The matching thread for this screw is provided by the retainer rigidly fixed in the body, by a locking nut. Spacers are used in initial setting to adjust the tension of spring.

Leakage between the cast bodies and screw end are prevented by suitable seals made of heat and oil resistant rubber. Plug is used to dummy the port.

The complete assembly of all parts in a pilot operated relief valve is shown in Fig 4 by a cross-sectional view.

Fig 4



CROSS - SECTION VIEW OF A PILOT OPERATED PRESSURE RELIEF VALVE

Tube and pipe assembly

Objective: At the end of this lesson you shall be able to
- **state the various types of tubes and pipes fitting in an hydraulic system.**

Tubings in hydraulic system

In any hydraulic system the fluid should pass from one element to the other without breaking. For this purpose tubing is employed. Tubes act as a leakproof carrier for hydraulic fluid from and to the various elements used in the hydraulic circuits.

These pipes/tubes should be capable of withstanding pressure and also temperature. Thus the pipes also act as a area where the fluid dissipates the heat.

Normally the term tube and pipe is always leading to a confusion. What is the exact definition of a tube?

Difference between a tube and pipe

The difference between a pipe and tube is very narrow. Tube walls are usually thin contrary to the pipe walls which are thicker.

Tube generally is seamless in its design, whereas pipe may beveled.

Tubes, because of its thin wall cannot be threaded, whereas pipes can be threaded without affecting the strength.

Both tube and pipe are available in steel, but tubes are available in copper, brass, steel and also in plastic.

Bending of tubes are relatively easier compared to pipes, so tube have better flexibility over the pipes.

A main difference of the tube to a pipe is the inner wall of a tube is smooth, so as to provide a smooth flow of liquid resulting in a LAMINAR flow, which usually is a turbulent flow in a pipe, having not such a smoother inner side.

But generally even now in workplaces, both pipes and tubes are mentioned not precisely.

Tube material

Tubes are usually specified by their outside diameter and the length. Usually the length is made to customer requirement by cutting the tubes. Tubes are available in various materials such as copper, brass, aluminium, carbon steel and stainless steel. All tubes are usually seamless drawn tubes.

Classification of pipe fitting in hydraulics

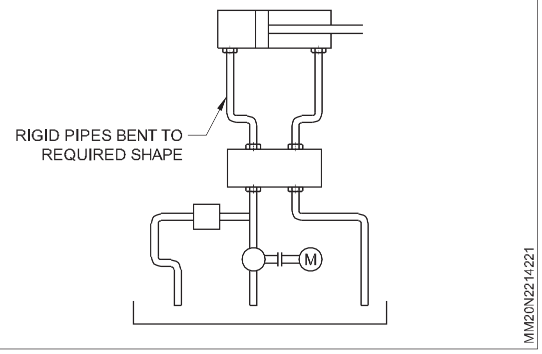
Tube/pipe fitting in hydraulics is usually classified as

- Rigid connections
- Flexible connection.

Rigid connections

Rigid tubing in done using metallic tubes. The tube is bent to the required length and shape and the various elements of the circuit is connected. (Fig 1)

Fig 1



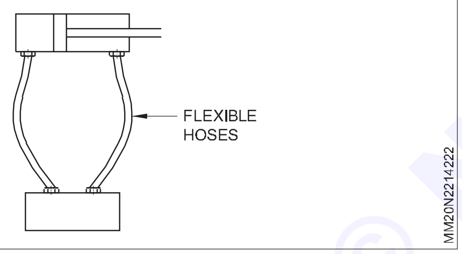
This type of connection is done where the circuit only built will not have any change in design or change in the position of the elements in future.

If there is a change then the existing pipes have to be disconnected and new pipes have to be bent fresh.

Flexible connection

This is a system in which the elements are connected with flexible tubes normally called as hoses. Flexible hoses are made of synthetic rubber tube reinforced with one or two braids of high tensile steel wire or with synthetic yarn suitably covered with weather resistant rubber. (Fig 2)

Fig 2



Flexible hoses are very good in taking up pulsating pressure which is dampened by the hose itself. In case of rigid pipe this would have resulted in vibration ultimately causing breakage or loosening of connector.

Advantages of using hoses

- Insulates against shock noise and vibration
- Connects stationary parts
- Makes connection easier in congested space
- Makes good temporary connections
- Provides connections and disconnections which are to be frequently changed.

Types of flexible hoses

Flexible hoses again are available to cater various pressures and temperature ranges.

Hoses are usually classified according to the:

Type of construction

a Wire braided-single (Figs 3 & 4) or double braid

b Synthetic yarn braid (Cotton, fibre, asbestos etc).

Normally the flexibility of synthetic yarn braided hoses are more flexible but the operating pressure is a limitation.

Fig 3

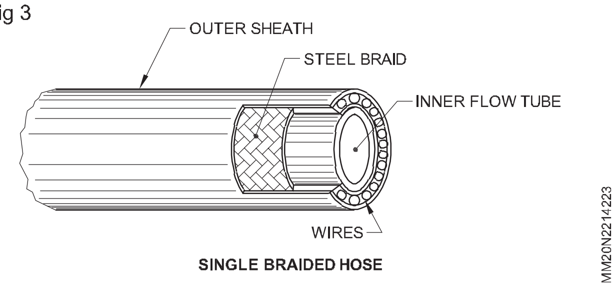
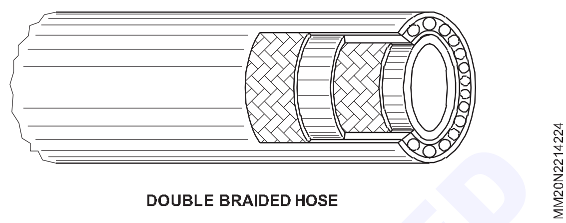


Fig 4



Whereas wire braided hoses because of steel wire used is good in withstanding high pressures up to 300 cm^2 but is not as flexible as synthetic yarn braided hose.

Pressure and temperature withstanding capacity

Hoses are used in hydraulic circuits and are subjected to pressure from the oil flowing through it. So hoses are classified according to its pressure withstanding capacity also this is given by the specification standard SAEJ517 as SAE100R1, SAE100R2 etc.

The number R1, R2 indicates the withstanding capacity in pressure and temperature and the construction. This has to be noted while selecting the hoses keeping in mind the maximum pressure produced in the circuit under construction. For actual valves of pressure and temperature the manufacturers catalogue has to be referred.

Type of pipe end fitting

Since hoses are used in various applications and has to mounted to suit a variety of connectors, it is also available with various end fitting. There are many type of end fitting available as required by customer. Some of them shown in the Fig 5.

Specification of hoses

Flexible hoses are specified according to the following informations,

- Internal diameter
- Length between the two end connectors
- Pressure and temp withstanding capacity
- Type of end fitting.

All these can be readily referred from manufacturers catalogue for the specific application. An example is given below.

dia.10 x 1000 x SAE100R2 x both ends female nuts.

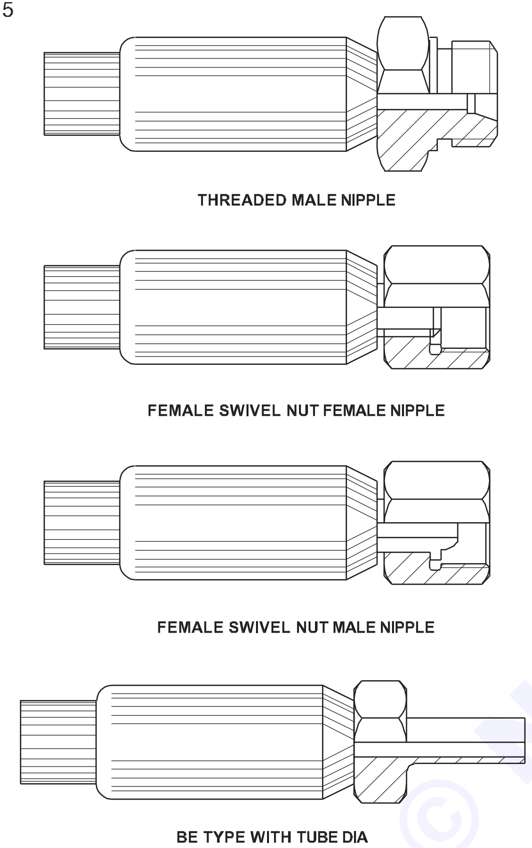
Connectors

Connectors are the elements which connects the tube ends to the body of the various hydraulic elements.

Connectors also serve various other purposes like change in size of tube, change in direction of flow, restriction of flow etc. Connectors can be grouped according to various parameters.

- According to the type of sealing design.
- According to the shape, size and purpose used for.

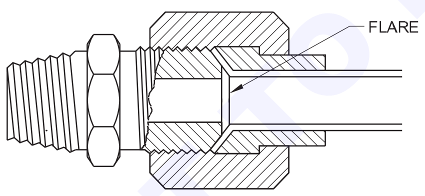
Fig 5



According to the type of sealing design

Flared fitting (Fig 6)

Fig 6

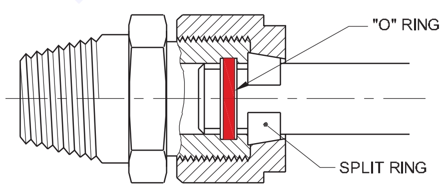


FLARE FITTING

In this, the pipe is flared and fitted to the suitable connector.

'O' ring compression fitting (Fig 7)

Fig 7



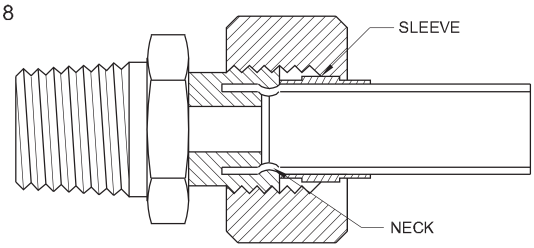
"O" RING COMPRESSION FITTING

In this type of `O' ring seals the pipe outside diameter. The split ring clamps the pipe in position.

Sleeve compression fitting (Fig 8)

In this the pipe is formed the neck seals the path for oil along with the sleeve.

Fig 8

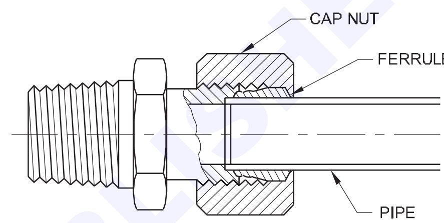


SLEEVE COMPRESSION FITTING

Ferrule compression fitting (Fig 9)

In this, the ferrule is of a special design, ferrule bites into the tube to form a permanent seal.

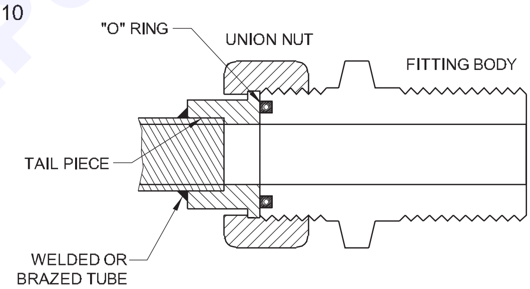
Fig 9



FERRULE COMPRESSION FITTING

O' ring fitting (Fig 10)

Fig 10



"O" RING FITTING

The pipe is welded with a ring with a flat face, this face seals against a 'O' ring.

Various fitting have been illustrated, each of these fittings have the corresponding connectors. The connection will be perfect only when the connection is made according to the manufacturers instructions.

The selection of the right type of connector depend upon various factors like

- Working pressure of system
- Frequency of assembly and disassembly
- Vibration or shock level in circuit
- Working area.

According to the size, shape and purpose of use

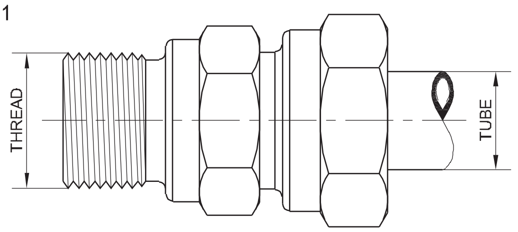
Connectors are used to connect either a tube to the body of a hydraulic element or a tube end to another tube end.

To connect a hydraulic element to a tube end

The connector shown (Fig 11) has threads which is screwed on to the body of the hydraulic element. On the other side a tube is fixed with proper sealing. This sealing is done by various methods as discussed in the previous exercise.

These connectors are available in various size according to the pipe it has to accommodate. The chart shows the pipe size and the threads on the connector.

Fig 11



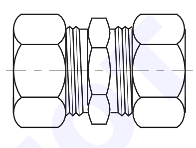
Pipe outside dia	British standard pipe thread (BSP)	Metric Fine thread
6	R 1/4”	M22 x 1.5]
8	R 1/4”	M14 x 1.5
10	R 3/8”	M16 x 1.5
12	R 3/8”	M18 x 1.5
14	R 1/2”	M20 x 1.5
16	R 1/2”	M22 x 1.5
20	R 3/4”	M27 x 2
25	R 1	M33 x 2
30	R 11/4”	M42 x 2
38	R 11/2”	M48 x 2

The various types of connectors in this category to take care of the flow direction of fluid as follows

Straight connector (Fig 12)

To connect tube perpendicular to the body.

Fig 12

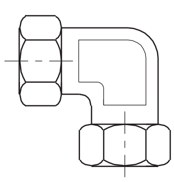


STRAIGHT CONNECTOR

Elbow connector (Fig 13)

To connect the tube end parallel to the body of the hydraulic elements.

Fig 13

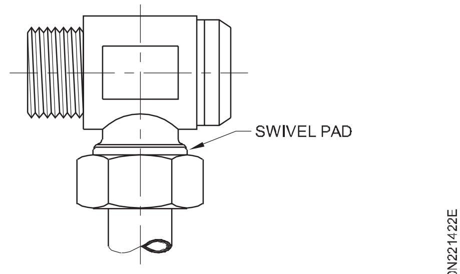


ELBOW CONNECTOR

Banjo connector (Fig 14)

Banjo connector is similar to a elbow, but has the flexibility to turn 360 degree with the port axis. This helps in easy positioning of the pipe, with hydraulic elements.

Fig 14

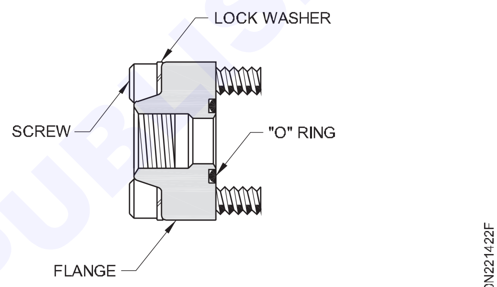


BANJO CONNECTOR

Flange connection (Fig 15)

Big size valves do not have threaded ports. They only have a hole as a port. In these case a flange is mounted on the body and the connector is mounted on the flange. This is also called as flush mounting.

Fig 15



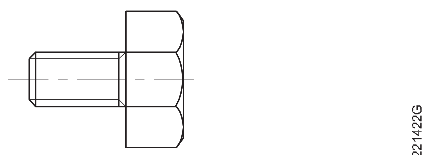
FLANGE CONNECTION

Plug (Fig 16)

A plug is used to block any port of the hydraulic element.

To connect a tube end to another tube end

Fig 16

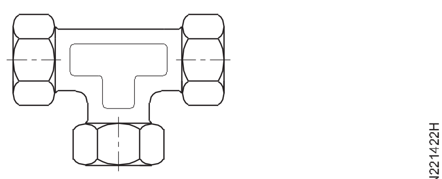


PLUG

‘T’ connector (Fig 17)

Used to connect three pipe ends at a junction.

Fig 17



TEE CONNECTOR

4 way connector (Fig 18)

Connect 4 pipe ends at a junction.

Reducer (Fig 19)

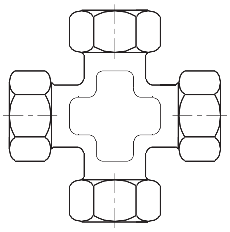
Connect two pipe ends of different size.

Do's and don'ts in tube/hose fitting:

Life of tube/hose fitting depends very much on how the fitting has been designed and installed.

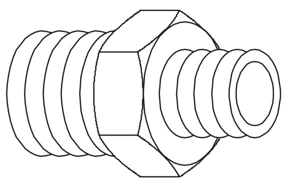
In case of the rigid connections the following has to be observed:

Fig 18



4 WAY CONNECTOR

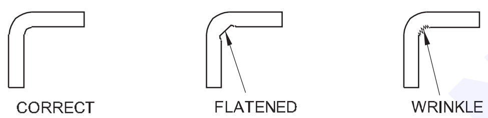
Fig 19



REDUCER

Tubes should be bent such that the bend has no flats or wrinkle at the bent corners. (Fig 20)

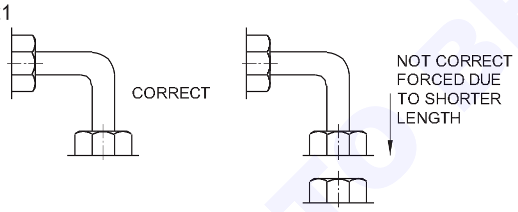
Fig 20



TUBE BEND

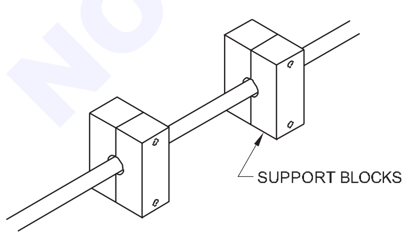
Tubes should be installed and removed without springing, bending or damaging the tubing. (Fig 21)

Fig 21



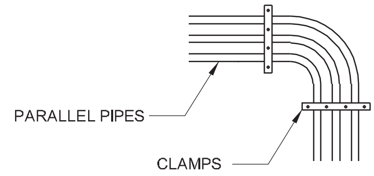
Support for tubes along the length if more than 1 meter long. (Fig 22)

Fig 22



- Use minimum number of connectors.
- Use minimum number of bends in tubing.
- Design pipe lines in a neat and straight way to make fixing and maintenance easy. (Fig 23)

Fig 23



- Use tubes and connectors according to the working pressure of the circuitry.
- Make sure tubes are kept clean and clear from chips dust etc. That enables to deduct apparent oil leakages.

Points to note while using flexible hose connections

- Flexible hoses are costly. Use of them has to be justified.
- Remember that the hose will change in length from +2% to +4% when pressurised. Provide slack or bend in the hose to compensate for any change in length which might occur. (Figs 24 and 26)

Fig 24

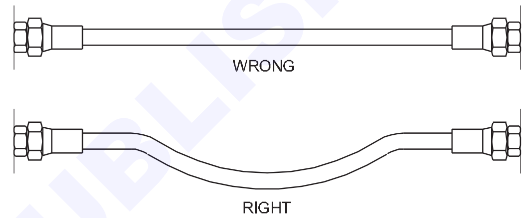


Fig 25

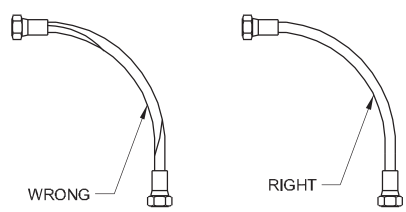
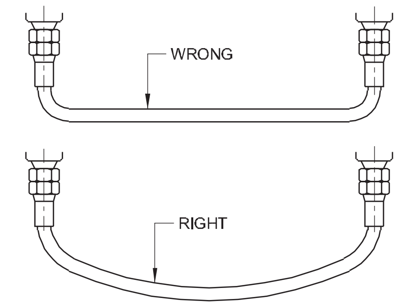


Fig 26



- If high operating pressures are applied to a twisted hose, the hose may fail or the attaching nut becomes loose.
- Keep the bend radii of the hose as large as possible to avoid collapsing of line and restriction of flow. (Figs 26 and Fig 25)
- When hose lines pass close to a hot exhaust manifold protect the hose with a fire proof boot or metal baffle. (Fig 27)

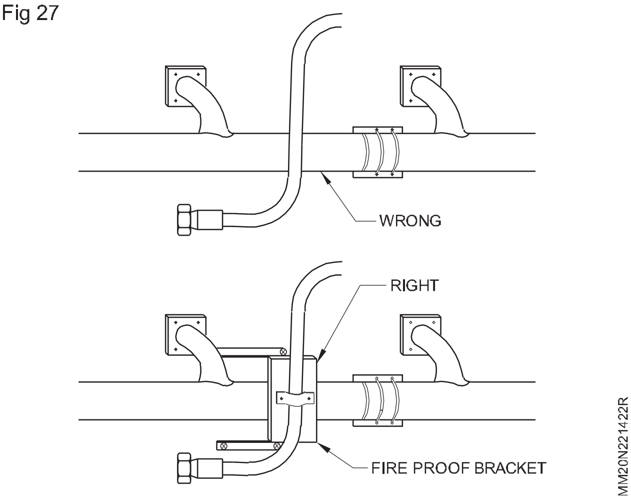


Fig 27

- Use elbows and adapters to ensure easier, cleaner installation for quick inspection and maintenance. (Fig 29)
- When a hose assembly is to be subjected to considerable flexing or vibration remember that the metal hose fittings are not part of the flexible portion. (Figs 28, 29, 30)

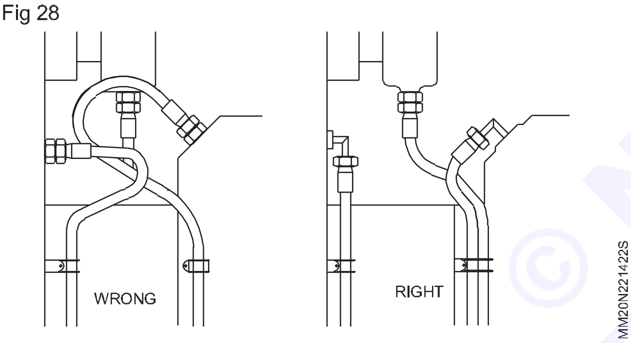


Fig 28

- Hose must be bent in the same plane as the motion of the part to which the hose is connected. (Figs 28, 29 and 30)
- Use metal wire mesh to cover the tube in areas where the hoses may come in contact with hot chips etc. (Fig 31)

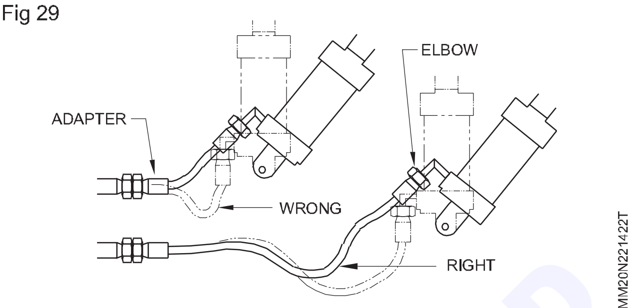


Fig 29

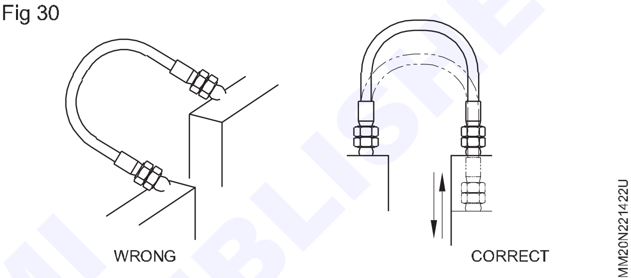


Fig 30

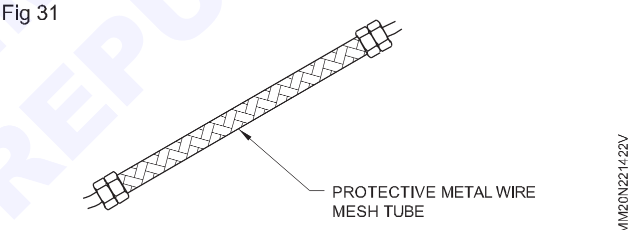


Fig 31

Hydraulic cylinders (linear actuators)

Objectives: At the end of this lesson you shall be able to
- **state the basic principle of hydraulic cylinder**
- **explain the construction of hydraulic cylinders**
- **state the sealing arrangement in a hydraulic cylinder**
- **name the parts of the hydraulic cylinder**
- **specify the hydraulic cylinder**
- **state the application of hydraulic cylinders**
- **calculate speed and force of a cylinder.**

Linear actuator

A hydraulic linear actuator is basically a cylinder, used to convert the hydraulic pressure and flow into a linear mechanical motion or force. Cylinder can be coupled with different types of mechanical linkages to produce enhanced or restricted movements in the combination of linear and rotary motions. Likewise with the arrangements, force can be multiplied or reduced.

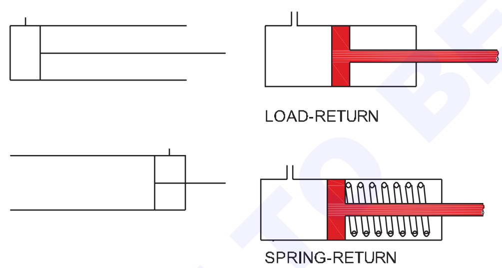
In a cylinder, the hydro-static pressure energy of the oil is converted into mechanical motion.

Working principle

Single acting cylinder

The Fig 1 shows the cross-section of a single acting cylinder. Pressurised oil from the pump enter the pressure port. The pressure of oil exerts onto the piston and piston is moved (also against the force of spring tension), to other side.

Fig 1



SINGLE-ACTING CYLINDERS

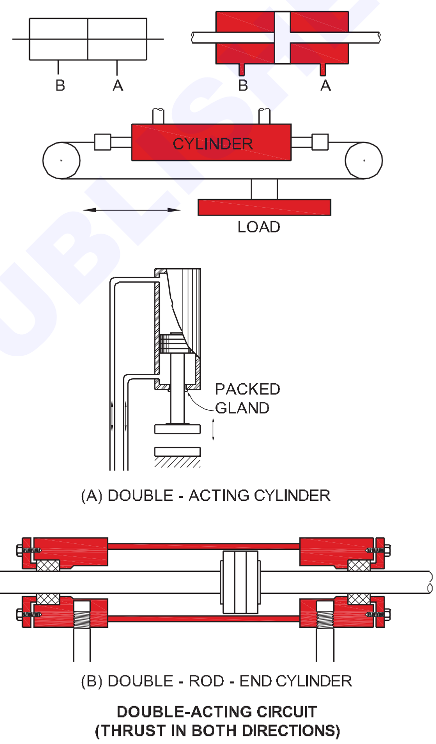
Useful work or movement can be attained from the free end of the piston-rod. After expansion of the oil, the spring tension overcomes the oil pressure. Now the spring pushes the piston to the left hand side. The oil is expelled through the same port.

Double acting cylinder

In a double acting cylinder Fig 2. Oil is supplied to both the sides of piston through ports A and B. When oil is supplied to port B, piston moves slowly. This is due to lesser area on the port side B, because force is proportional to the area. When the piston starts moving from left to right side, by the supply of oil pressure through port A, pressureless oil present on the right side is expelled through port `B' and vice versa.

To have an equal force on both the strokes, piston rod is provided on the left side of the piston also. (Fig 2a and 2b)

Fig 2



DOUBLE-ACTING CIRCUIT
(THRUST IN BOTH DIRECTIONS)

Construction of a double acting cylinder (Fig 3a)

The general construction of a double acting cylinder is shown in Fig 3a. Piston rod is made of a chrome plated and piston is made of cast steel. Cylinder head is honed inside and has rod bearing support and a port. Cylinder cap blocks the end of the cylinder and firmly attached to head by means of tie-rods and nuts.

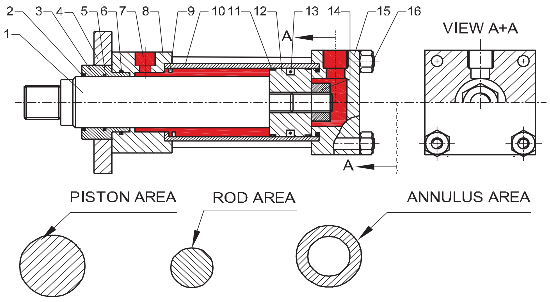
Static seals keeps the cylinder air-tight. Viper seals prevent the dust or other foreign particles from entering inside. The rod-bearing is usually replaceable by means of fasteners.

Piston seal prevents the oil from either-side of the piston, piston rings are made of high quality alloy steel/cast iron. (Fig 3b) For high pressures, cup packed seals are used.

These seals generally made of composition of rubber. For some right temperature applications, teflon seals are also used. Ports are threaded to connect the pipe ends/ connectors.

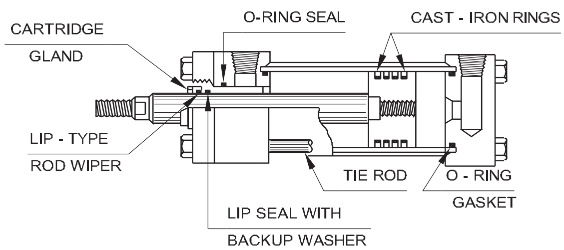
Leakage in between cylinder and head is prevented by O-rings made up of rubber as shown in the Fig. 3b. Better view of sealing arrangement can be seen in Figs 3b.

Fig 3



1 PISTON ROD
2 ROD WIPER
3 GUIDE BUSH
4 MOUNTING FLANGE
5 ROD SEAL
6 BUSH SEAL
7 OIL PORT
8 CYLINDER HEAD
9 TUBE SEAL
10 TUBE (BARREL)
11 GUIDE RING
12 PISTON
13 PISTON SEAL
14 LOCK NUT
15 CYLINDER CAP
16 TIE ROD

a. CONSTRUCTION - DOUBLE ACTING CYLINDER



b. NONCUSHIONED CYLINDER WITH CAST-IRON RINGS

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End cushioning

High pressure oil at the ends of the stroke will make the piston to impact on the ends of cylinder. To avoid this, end cushioning is generally provided. Springs find common application. But when the spring is compressed beyond its full home length, it is prone to damage. Hence cushioning is done by restricting the oil outlet as shown in the Fig 4a. This arrangement is provided in the end portion of cylinder heads.

As shown in Fig. 4b the other side of the piston is provided with a plunger or cushioning piston. In the cylinder head, the check valve connects the passage from outlet to the cylinder. Another passage is connected by a restricted orifice 'O'.

This orifice can be adjusted by a screw

As the piston travel to the left-hand side, the plunger or cushioning piston enters outlet port 'E'. Now oil can escape through limited passages C and O only. But the check-valve blocks the oil passage by means of a ball. Now the oil can pass through the passage 'O' only. Thus travel of the piston is slowed down at the ends.

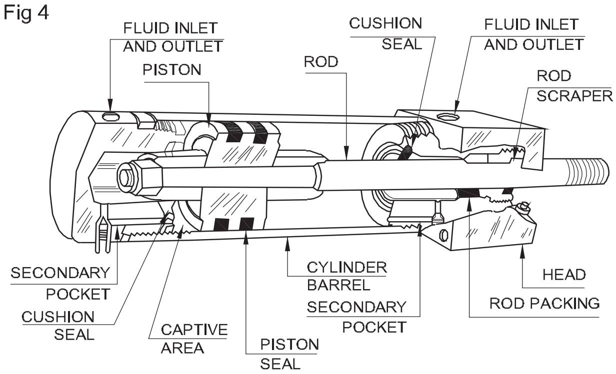
Pressure and speed of piston

Pressure exerted by the piston = Pressure (Kg/cm^2) x Area of cross section of piston (cm^2)

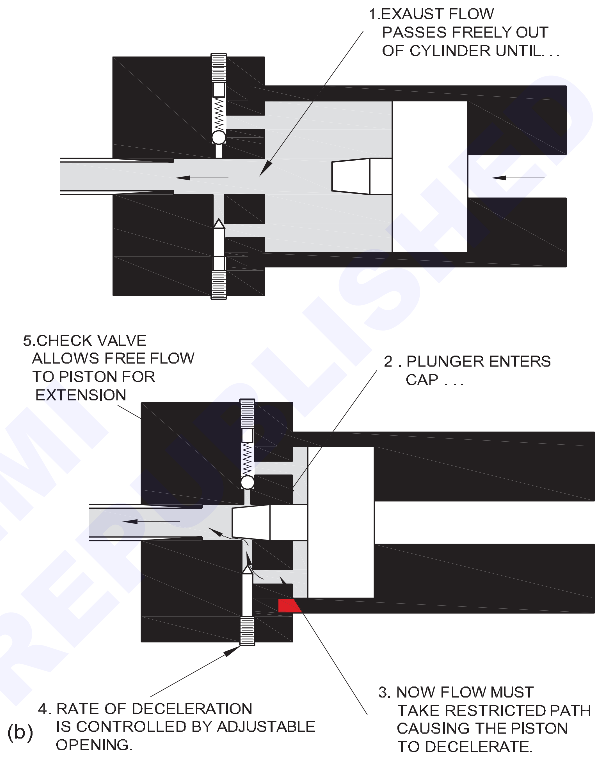
$$\text{Speed of the piston (cm/min)} = \frac{1000 \times \text{LPM}}{\text{Area of piston (cm}^2\text{)}}$$

Where LPM = Litres Per Minute.

Fig 4



(a) CUSHIONED CYLINDER



(b)

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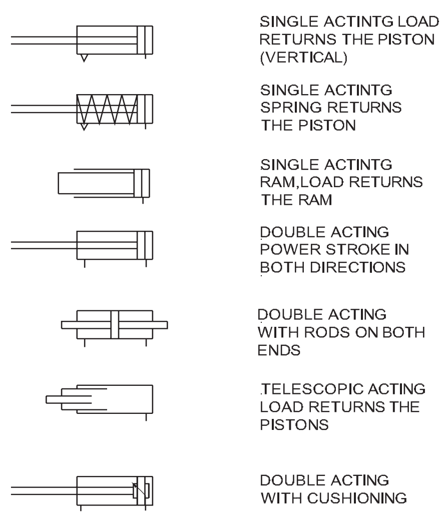
Symbol

The symbols for hydraulic cylinders resembles the symbols of pneumatic cylinders. The symbols for commonly used cylinders are given in Fig 5.

Fig 5



GRAPHIC SYMBOLS FOR THE MORE COMMONLY USED LINER ACTUATIONS

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Classification of cylinders

Two basic types of cylinders are

- Single acting cylinders
- Double acting cylinders

Single acting cylinders are further classified into

- Plunge type
- Piston type
- Ram type
- Telescopic type.

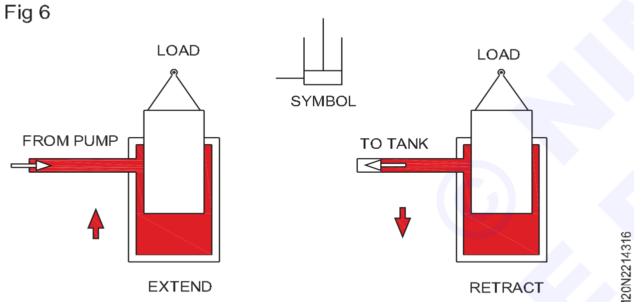
Double acting cylinders can be further classified into

- Single piston rod type
- Double sided piston rod
- D.A. cylinder with end cushioning
- Telescopic type
- Pressure intensifier
- Tandem cylinder.

Ram

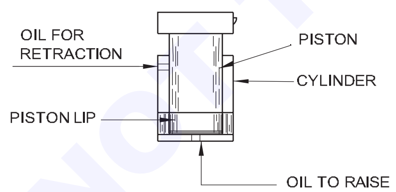
It is the simplest linear actuator as shown in Fig 6. It has only one chamber for oil. They are usually mounted vertical and ram descends down by its self weight. Rams are practically suitable for long strokes and used in elevators jacks and automobile.

Fig 6



Since the diameter of the Ram is throughout and there is no piston rod, if the Ram has to descends down at a faster rate than gravity, oil has to be supplied to the top as in the case of a double acting cylinder. (Fig 7)

Fig 7



DOUBLE-ACTING RAM

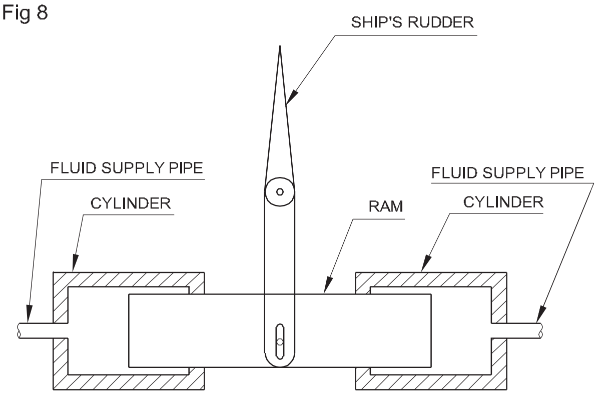
However, the diameter of the Ram can be reduced only to a little extent to have piston rod.

The application of a double sided or dual Ram in turning the rudder of a ship is shown in Fig 8.

Mountings of cylinders

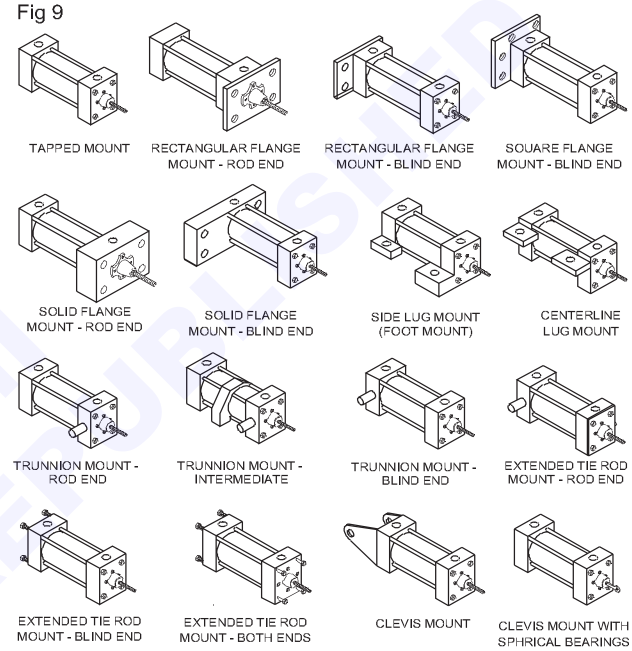
Cylinders are mounted on different points to have a desirable movement space limitations, severity of load, direction of actuation etc. Fig 9 shows the possible methods of mounting a hydraulic cylinder.

Fig 8



DUAL RAMS IN SHIP'S STEERING GEAR

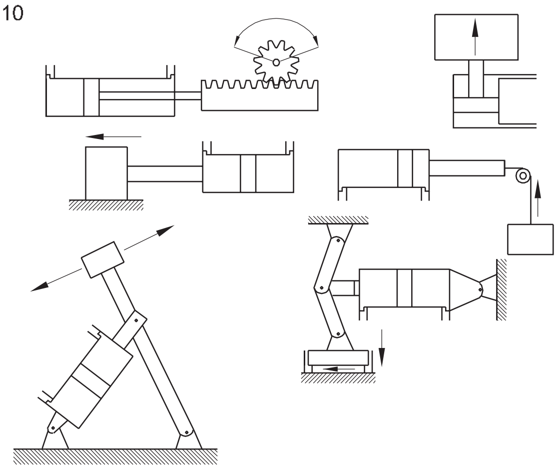
Fig 9



Actuation by linkages

Fig 10 shows the various methods of handling load, clamping, oscillation, lift, tilt and other kinds of applications of a cylinder along with mechanical linkages.

Fig 10



LINKAGES AND LOAD ATTACHED TO LINEAR ACTUATORS

Hydro motors (Rotary actuators)

Objectives: At the end of this lesson you will be able to
- **state the principle of working of hydromotor**
- **state various types of hydromotor**
- **state the specification of hydromotor**
- **calculate the efficiency of hydromotor**
- **name the parts of the hydromotor.**

Hydromotor

This is a rotary actuator used in hydraulics, also called as hydraulic motors. This is very useful when a rotary motion is required. (The rotary action is achieved by this hydromotors) Similar to linear actuators, this also can be controlled in terms of displacement, direction of rotation, pressure or torque requirement. Nearly all elements used in linear circuits are used in rotary circuits also.

Cylinders provide linear motion where as hydromotors provide rotary motion.

Various types of hydromotors

Hydromotors are classified according to their internal design. Hydromotors are of three types namely:

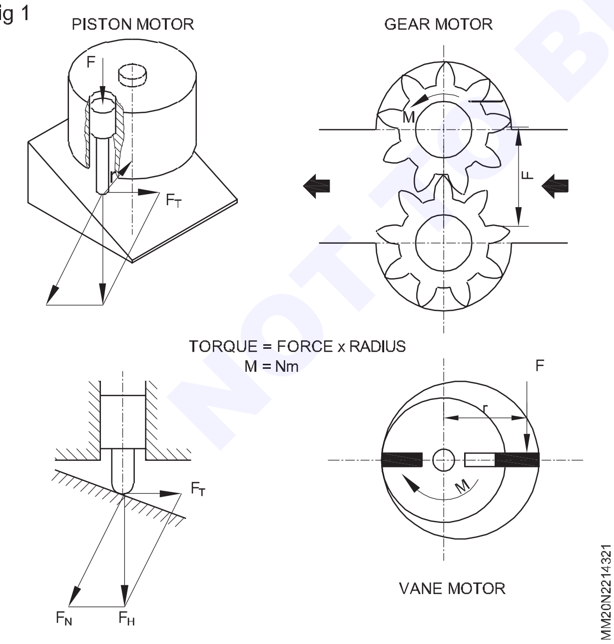
- Gear type
- Vane type
- Piston type.

All these types have the common principle of working. These almost resemble a hydraulic pump in construction.

Operation of hydraulic motor is opposite to that of hydraulic pump.

The principle of working is shown with a simple line sketch in Fig 1.

Fig 1



Gear type motors

Gear motors are designed either as

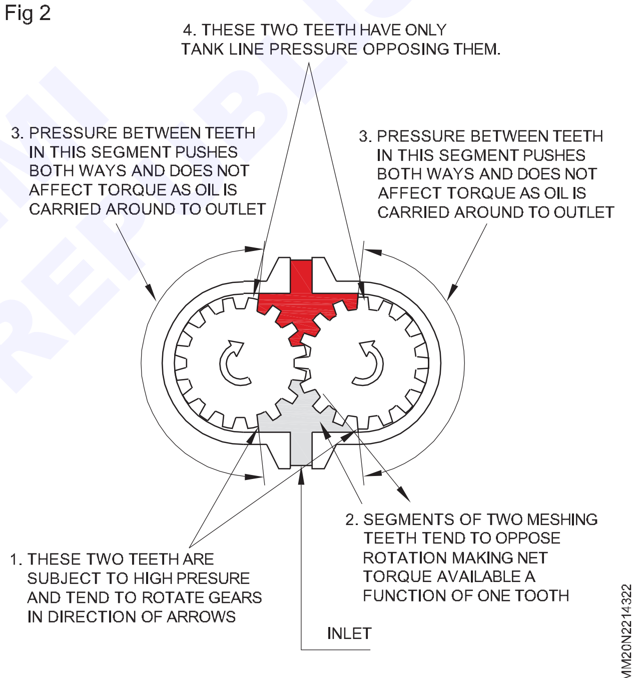
1 Gear on gear motor (external gear)

or

2 Gear in gear motor (internal gear).

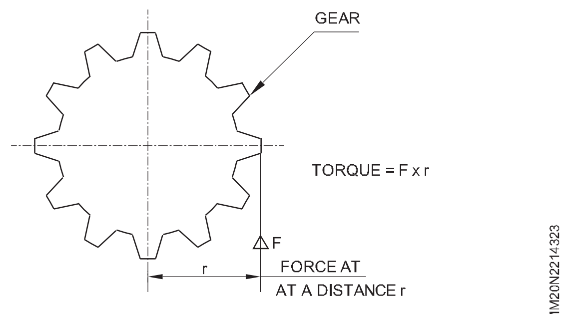
The Fig 2 shows the gear on gear motor, oil enters the inlet port with pressure, this oil forces the gears to rotate and the oil flow out of the outlet. The speed of the motor depends on the amount of flow/minute and the motor torque depends on the pressure of oil. These motors have the lowest volumetric efficiency of about 70 to 80%.

Fig 2



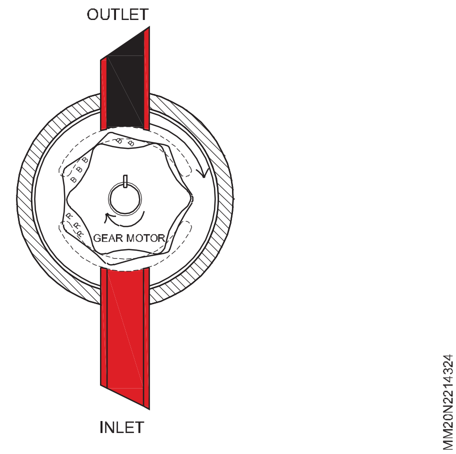
The pressure of oil creates the torque in the same way as that of on a lever. (Fig 3)

Fig 3



The internal gear motor usually of gear type shown in the Fig 4.

Fig 4



This is a motor which is very smooth in running and compact in design.

Vane type motors

This differs in the design when compared to gear motor. The simple line sketch in figure 5 shows the vane being moved along with the shaft by the oil flow. The prominent feature of the vane motor is the sliding vane. Each shaft will have more than one vane which ensures continuous rotation of the shaft. (Fig 6)

Fig 5

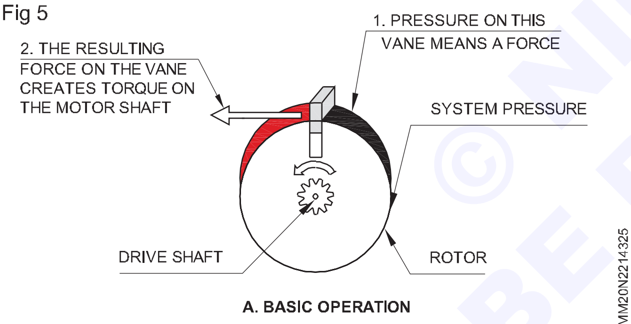
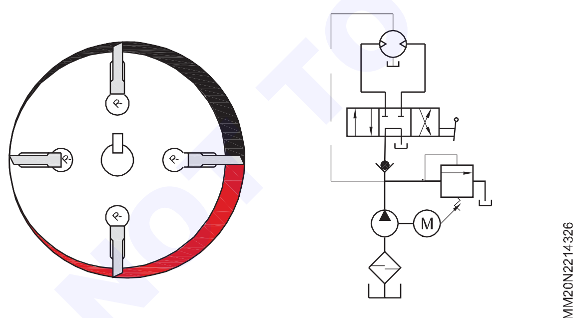


Fig 6



The vanes in the slots extent out by the action of centrifugal force and oil pressure. This has a high speed operating character.

Piston type motor

Piston motor is totally different from the other two types in its construction. Piston motors are of two types namely

1 Axial piston motors (Fig 7)

2 Radial piston motors (Fig 8)

Fig 7

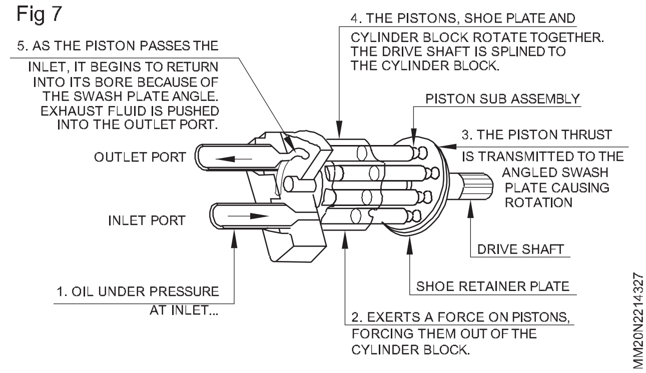
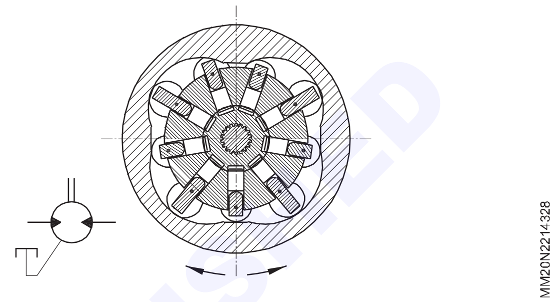


Fig 8



These motors are the most volumetrically efficient motors rating up to 95% efficiency.

The operating principle of these type of motors are shown in Fig 7&8. In a piston and barrel assembly when oil with pressure is allowed, it pushes the piston out.

This piston in turn in tune with the other pistons starts the rotary motion and continue the rotation.

Piston motors have the high volumetric efficiency and it is found its place in high efficiency, fast operating, high pressure circuitry.

Control of hydromotors

Hydromotors to perform effectively has to be controlled for it is speed and torque and direction.

Speed control of hydromotor

This is controlling the rpm of the hydromotor. This is usually done by controlling the quantity incoming fluid. This is also called as the displacement of the hydromotor. The control of flow of oil can be done by various methods which will be discussed in coming chapters.

Speed of a hydromotor depends on the quantity of oil passing through motor.

Torque control of hydromotor

Torque obtained in a hydromotor is the function of the fluid pressure. Thus by controlling the fluid pressure of the hydromotor the torque is also controlled.

Direction control of hydromotor

This is done by using a direction control valve in the circuit. This very much resembles the method of controlling the direction of movement of a double acting cylinder.

Direction of rotation of hydromotor depends on flow path of the oil.

Specification of a hydromotor

A hydromotor is usually designed and specified by the following parameters:

- max torque required
- max RPM required (outlet)
- max operating pressure
- efficiency.

Efficiency of hydromotor

Most of the times the hydromotor does not function as calculated. This is indicated by the various efficiencies of hydromotors. They are as follows

Volumetric efficiency

During operation same amount oil slip away without performing any work. This is a volumetric loss which is reflected in the volumetric efficiency

$$\eta_{\text{Vol}} \frac{\text{Theoreticl flow rate}}{\text{Actual flow rate}}$$

Mechanical efficiency

During operation, particularly at low rpm and at high pressure conditions, there is a lot of mechanical losses. This is given by mechanical efficiency.

$$\eta_{(\text{Mech})} \frac{\text{Actual flow rate}}{\text{Theoretical flow rate}}$$

Overall efficiency

This is used to calculate the power output of a hydraulic motor. It is expressed as the product of volumetric and mechanical efficiency.

$$\eta_{\text{o}} \frac{\eta_{\text{Vol}}\, \eta_{\text{Mech}}}{100}$$

Direction control valve

Objectives: At the end of this lesson you shall be able to
- **explain function of various direction control valves and non return valve**
- **interpret direction control valve function in a hydraulic circuit**
- **define meaning of by - pass circuit.**

Direction control valve are components which change, open or close flow path in hydraulics system. They are used to control the direction of motion of hydraulic actuator as well as responsible to stop the motion of actuator.

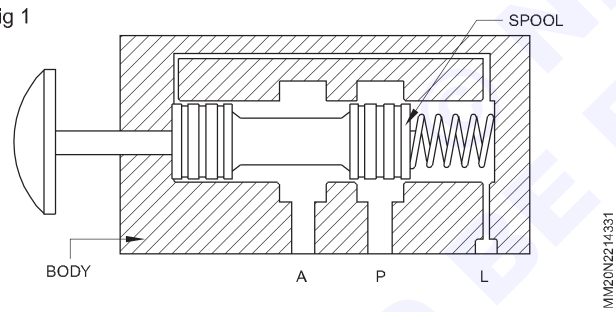
Direction control valves are classified as following according to the number of ports and positions:-

- 2/2- Way valve
- 3/2- Way valve
- 4/2-Way valve
- 4/3-Way valve

2/2 Way valve

The 2/2-way valve has a working port A, a supply port P and a leakage- oil port L. In the case of the valve shown here, of slide design, flow from P to A is closed in the normal position. (Fig 1)

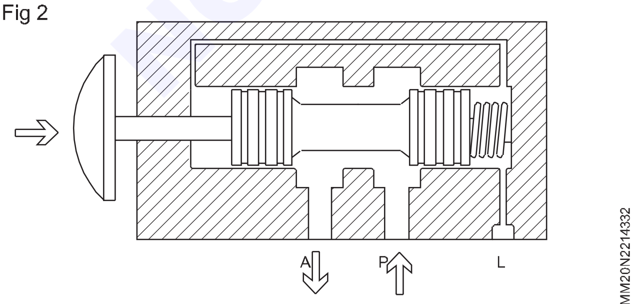
Fig 1



A relief line leading to the leakage - oil port is provided to prevent a build -up of pressure in the spring and piston chambers.

The 2/2-way valve is actuated and the passage from P to A is open. 2/2 -way valves are also available which are normally open from P to A. (Fig 2)

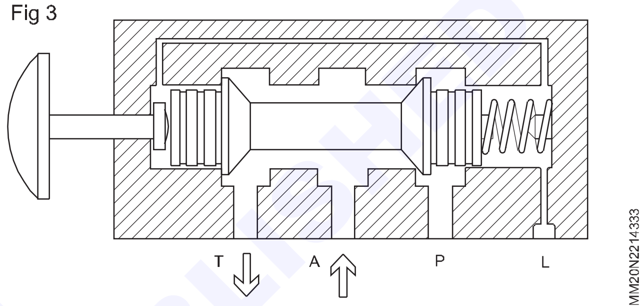
Fig 2



3/2-Way valve

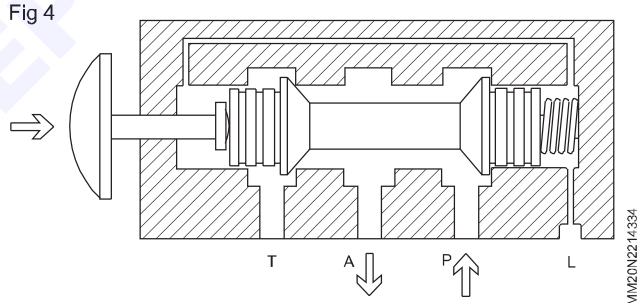
The 3/2-way valve has working port A, a supply port P and a tank port T. Volumetric flow can be routed from the supply port to the working port or from the working port to the tank port. The third port in each case is closed. In the normal position shown, P is closed and flow released from A to T. (Fig 3)

Fig 3



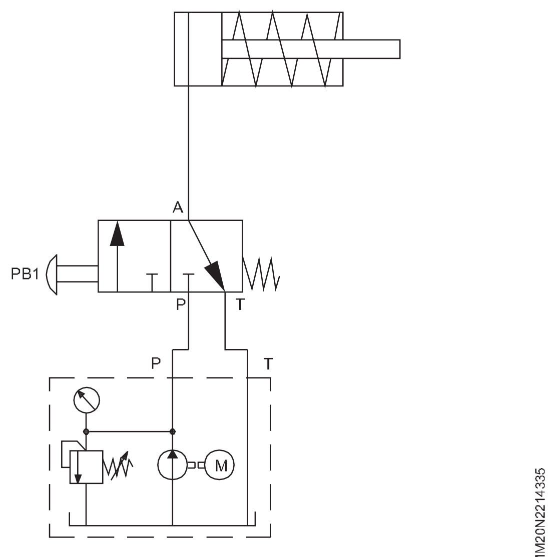
The 3/2-Way valve is actuated; flow is released from P to A, the outlet T is closed. 3/2-Way valves which are normally open from P to A and T closed are also available. (Fig 4)

Fig 4



Example of 3/2 way circuit with single acting cylinder. (Fig 5)

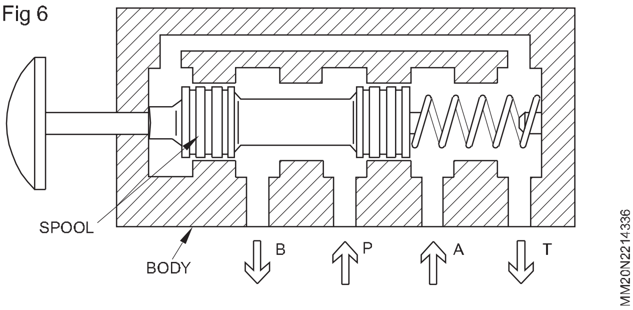
Fig 5



4/2 Way valve, two pistons

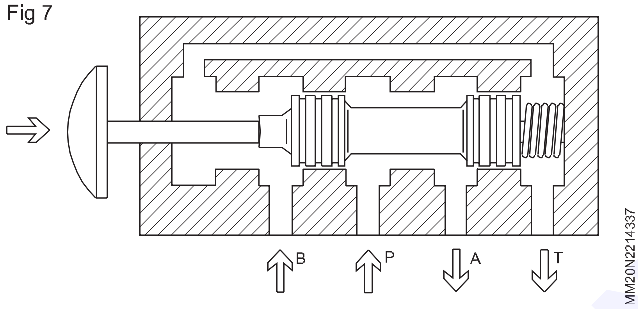
The 4/2-Way valve has two working ports A and B, a supply port P and a tank port T. The supply port is always connected to one of the working ports, while the second working port is routed to the tank. In the normal position, there is flow P to B and from A to T. (Fig 6)

Fig 6



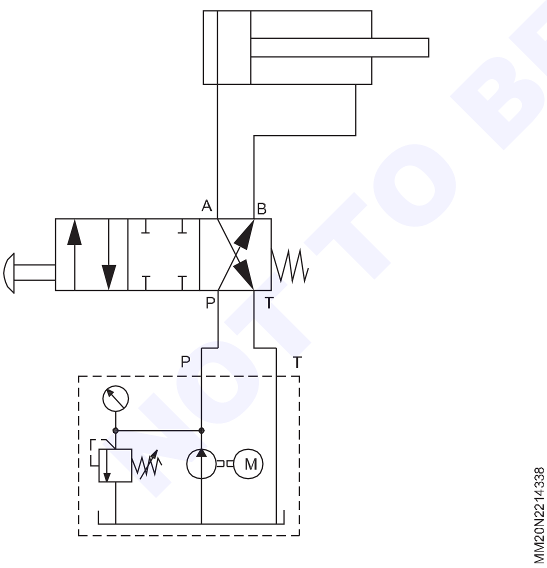
The 4/2-Way valve is actuated,and there is flow from P to A and from B to T. 4/2-way valves are also available which are normally open from P to A and from B to T. (Fig 7)

Fig 7



Example of 4/2 way circuit with double acting cylinder. (Fig 8)

Fig 8

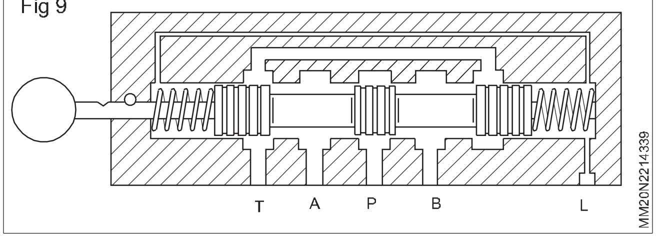


4/3- Way valve

From the logic point of view, 4/3-way valves are 4/2-way valves with an additional mid-position. There are various versions of this mid-position (in the mid-position in the example shown, the supply port P is directly connected to the tank T, see next illustration). In the switching position shown, there is flow from P to B and from A to T.

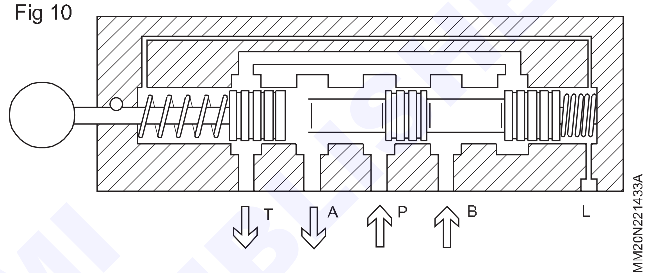
The 4/3-way valve is in its mid-position; there is flow from P to T, while A and B are closed. Since the output from the pump flows to the tank, this switching position is called pump bypass or also pump recirculation. In the case of pump bypass, the pump needs to operate only against the resistance of the valve, which has a favourable effect on the power balance. (Fig 9)

Fig 9



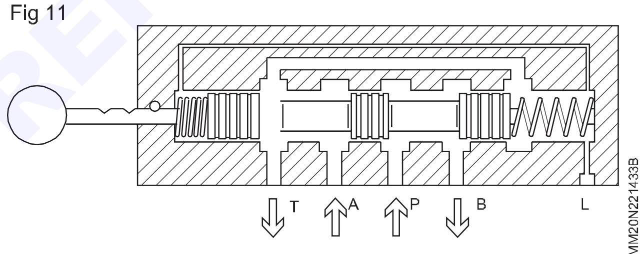
The valve is in its left-hand switching position; there is flow from P to A and from B to T. (Fig 10)

Fig 10



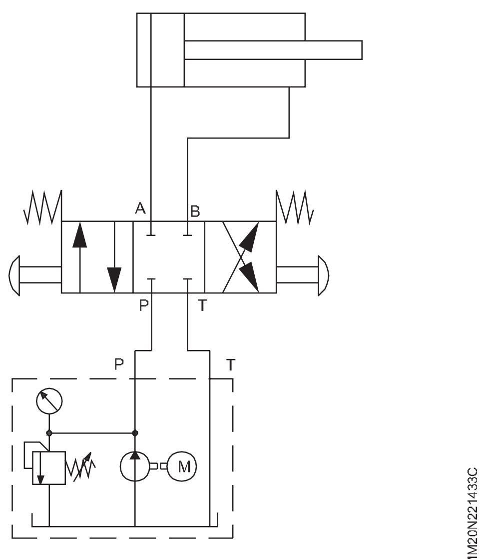
And the valve is in its right hand switching position there is flow from P to B and A to T. (Fig 11)

Fig 11



Example of 4/3 way circuit with double acting cylinder. (Fig 12)

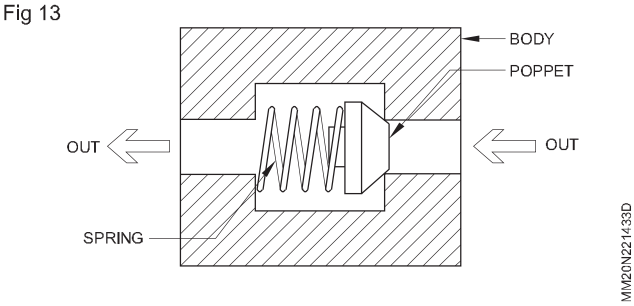
Fig 12



Non-return valve

Non-return valves block flow in one direction and allow free flow in the other. In the direction of flow shown, the sealing element is pressed against a seat by a spring and the hydraulic fluid. (Fig 13)

Fig 13



A spring loaded Non-return valve is shown in fig 13. If oil pressure is more on left side of NRV, poppet of valve will not open as well as it will not allow the flow of oil.

And when oil pressure is more on right side of valve then poppet of valve will move for opening and oil will flow through the valve. (Fig 14)

Fig 14

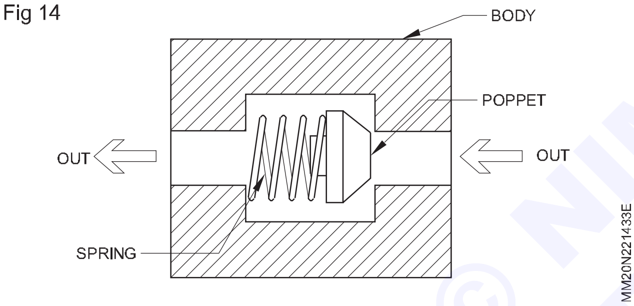
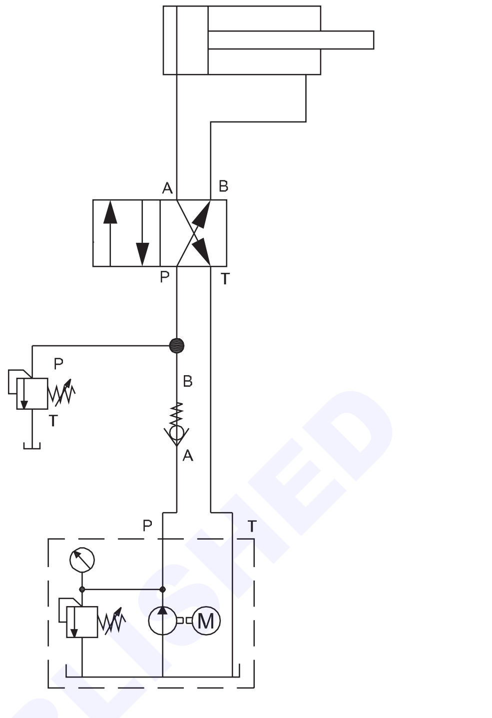


Fig 15 shows the application of non-return valve for pump protection. (Fig 15)

Fig 15



Study & working hydraulic presses along with its components

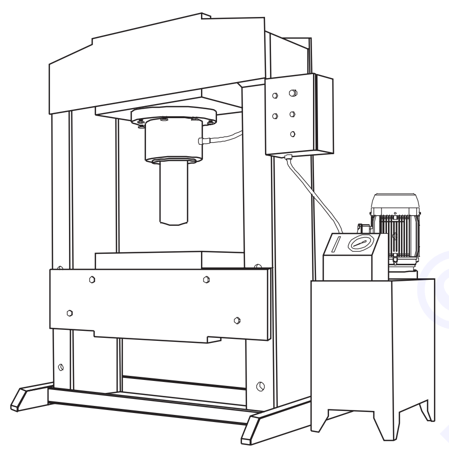
Objectives: At the end of this lesson you shall be able to
- **know general safety in hydraulic presses**
- **explain press safety devices and forbidden measures**
- **describe working of hydraulic press**
- **state the parts and advantages of hydraulic press.**

Hydraulics is topic in applied science and engineering dealing with the mechanical properties of liquids. Fluid mechanics provides the theoretical foundation for hydraulics, which focuses on the engineering uses of fluid properties, in fluid power, hydraulics is used for the generation, control, and transmission or power by the use of pressurized liquids.

Working of hydraulic press

A hydraulic press is a machine which is used for applying a large lifting or compressive force to perform various industrial processes. (Fig 1)

Fig 1



HYDRAULIC PRESS

Study of hydraulic press: The study of hydraulic presses encompasses various aspects related to the design, operation, applications, and principles of these versatile mechanical devices. Hydraulic presses use the power of pressurized hydraulic fluid to generate force and motion, making them essential tools in a wide range of industries. Here's an overview of the key areas in the study of hydraulic presses:

Basic Components and Operation: Understanding the fundamental components of a hydraulic press is the starting point of the study. This includes the hydraulic system, hydraulic fluid, pump, cylinders, pistons, valves, and control systems. Students learn how hydraulic pressure is used to create mechanical force and motion.

Principles of Hydraulics: The study of hydraulic presses delves into the principles of fluid dynamics, Pascal's law, and Bernoulli's principle. Trainees learn how hydraulic pressure is transmitted uniformly in all directions and how these principles underpin the operation of hydraulic systems.

Types of Hydraulic Presses Hydraulic presses come in various types, including single-acting, double- acting, and four-column presses Students learn about the differences in design, applications, and advantages of each type.

Applications: Hydraulic presses have a wide range of applications, from metal forming and stamping to plastic molding, forging, and vehicle assembly. Students explore the specific industries and processes where hydraulic presses are used and the benefits they offer in terms of precision and force.

Safety protocols: Given the immense force that hydraulic presses can generate, safety is of utmost importance. Students learn about the safety procedures, precautions,and protective measures required when operating or working near hydraulic presses.

Maintenance and troubleshooting: Maintaining hydraulic presses in optimal working condition is crucial. Students study maintenance procedures, including regular inspections oil, changes, and the identification and resolution of common issues and malfunctions.

Environmental considerations: As with any industrial machinery, the study may also cover the environmental impact and sustainability aspects of hydraulic presses, including energy efficiency and waste management.

Emerging technologies: The field of hydraulic presses is continuously evolving. Students may explore the latest advancements, such as the integration of sensors, data analytics, and automation in hydraulic systems.

A hydraulic press also referred to as a Bramah press, which works by either fluid pressure or hydraulic pressure Hydraulic presses works under the principle known as Pascal's law, which asserts that pressure that is built up throughout any closed system will exert equal force on all areas of the container. Hydraulic presses are the most common type of press used, primarily due to the fact that it is most efficient and dependable. The force achieved with hydraulic presses can't be achieved with either mechanical or Pneumatic Presses

There are different types of hydraulic presses are available to perform different tasks. Among which, Platen presses are designed to function by using a ram A good example would be a C-frame press, which can be used for various application and operations, including blanking, straightening, drawing, forming, Punching. bending, etc. On the other hand, vacuum and laminating presses possess several specialized capabilities, which encapsulating (making like a capsule) numerous layers of plastic maternal for certain application such as credit cards. Another type of press that has specialized capacity is a stamping press.

The hydraulic press usually corning under the category of power press. There are several power presses, which include hydraulic, mechanical and pneumatic. Pneumatic presses have similar applications to hydraulic presses, Including crimping, bending punching, metal working, and piercing, however, the distinction between the two types of presses is that pneumatic presses used compressed air to produce their dynamic movements, whereas hydraulic presses use some type of fluid to produce the pressure that facilitate the dynamic movements of the press

Hydraulic presses are generally differentiated by two primary elements such as desigri and application. C-frame presses have the capacity to be either manually or automatically. They also require less floor space than other types of hydraulic presses.

The H-frame press either from C-frame presses in shape as well as their capacity to facilities multiple operations.

As the name implies, hydraulic presses are powered through the use of hydraulic fluid, which is used to generated pressure. The hydraulic press consists of all of the primarily elements found is the common hydraulic system, such as pistons, hydraulic pipes, cylinders and a stationary die or anvil. The piston is designed to create a thrusting or plunging motion, using liquid that is under pressure to help it exert the force necessary to perform its purpose.

The hydraulic system is comprised of two primary cylinders. The fluid either oil or water, is generally poured into the smaller of the two cylinders. This smaller cylinder is commonly referred to as the slave cylinder while the larger cylinder is referred to as the master cylinder. As the pressure builds, it is exerted on to the piston in the larger cylinder, causing the larger piston in that cylinder to press in the master cylinder. This action cause the punch to come in contact with the die, subsequently deformin the metal into the desired shape. The vast majority of hydraulic presses are constructed from stainless steel for durability. When shear force is necessary, the hydraulic press remains the best choice.

Parts of hydraulic press

- Bed: The main foundation and supporting structure upon which all operating parts of the machine are mounted and guided.
- Bolster: A Bolster plate is attached to the top surface of the press bed for supporting the work:
- Cylinder: Cylinder assembly consists of a cylinder, piston, ram, packing and seals. Piston diameter and oil pressure determine the force (tonnage) that a press can deliver
- Frame: The main structure of the press containing the Cylinder and the working surfaces
- Stroke: Stroke length can be set for any distance within the stroke limits of the Cylinder
- Throat Clearance The distance from the vertical centerline of the ram to the frame member behind the bed. This distance determines the largest diameter piece that can be positioned.
- Moving plate: A plate which is mounted on the cylinder Ram and moves whent the cylinder extended
- Dual push buttons A most common mehtod of actuating hydraulic presses considering the safety of the operator
- Work Height The distance from the floor to the top of the bed.

Advantages of hydraulic presses

The following are the important advantages of hydraulic press

- **Full power throughout the stroke**

  A hydraulic press can develop and deliver full or maximum power throughout its entire stroke length.
- **Lower operating costs**

  Comparatively a lower operating cost while using hydraulic presses
- **More capacity at lower cost**
- **More control flexibility**

  It is possible to control different pressure depending upon applications.
- **More flexibility**

  It can impart a varity of motions for locating, clamping, driving, feeding, etc
- **Better controls of speed and force**
- **Silent operation**
- **More compact**
- **Low maintenance**

Common causes of hydraulic press breakdowns

- **Oil contamination:** Contaminants like dirt, debris, or water in the hydraulic fluid can damage the sysem, leading to component failiures and reduced efficiency.
- **Oil Leaks:** Damaged seals or connections can result in hydraulic components like seals, O-rings, and hoses can deteriorate, causing loss of pressure, slow operation, or complete failiure.
- **Worn-out components:** Over time, hydraulic components like seals, O-rings, and hoses can deteriorate, causing loss of pressure, slow operation, or complete failiure.
- **Overheating:** Excessive heat can damage hydraulic fluid and components, leading to decreased performance and potential sustem shutdown.
- **Misalignment:** Improper installation, alignment, or adjustment of hydraulic press components can result in unnecessary stress, wear, and eventual breakdown.

- **Lack of lubrication:** Components that require lubrication, such as guides and bearings, can fail when not properly maintained.

Preventive maintenance for Hydraulic press

- **Regular inspections:**Implement a schedule for routine inspections, during which you should check for oil leaks, worn or damaged components, and any visible signs of wear or damage. Inspect hydraulic hoses, fittings, and seals for any signs of deterioration.
- **Fluid analysis:** Periodically test and analyze the hydraulic fluid for contamination, temperature and viscosity. Replace or filter the fluid as needed to maintain its quality.
- **Filter maintenance:** Ensure the hydraulic press has properly fuctioning filters to remove contaminants. Regularly replace or clean filters to prevent contamination.
- **Lubrication:** Porperly lubricate all moving parts, including guides, bearings, and sliding surfaces, to reduce friction adn wear.
- **Thightening and alignnment**: Check and tighten all bolts and connections to ensure proper alignment and prevent mislignment-related issues.
- **Seals and O-rings:** Inspect and replace worn-outseals, O- rings, and gaskets as needed to prevent oil leaks.
- Cooling system: Maintain the cooling system to prevent overheating. clean or replace the cooling components, such as radiators or fans, to ensure efficient heat dissipation.
- Pressure and control settings: Periodically check and adjust pressure and control settings to ensure thery are within the manufacturer's recommended range for optimal operation.
- Training and Documentation: Ensure that personnel operating and maintaining the hydraulic press are adequately trained and that proper maintenance procedures and records are in place.
- Emergency response plan: Develop an emergency response plan in case of breakdown or system failure. This includes having spare parts on hand knowing how to troubleshoot common issues.

Proximity sensors

Objectives: At the end of this lesson you shall be able to
- **define proximity switches**
- **explain the different types of proximity switches**
- **describe the selection, advantages and disadvantages.**

Proximity sensors

Proximity sensors detect the presence of objects without physical contact.It detects the presence or absence of objects using electromagnetic fields, light, and sound. There are many types, each suited to specific applications and environments.

Types of proximity

1 Capacitive

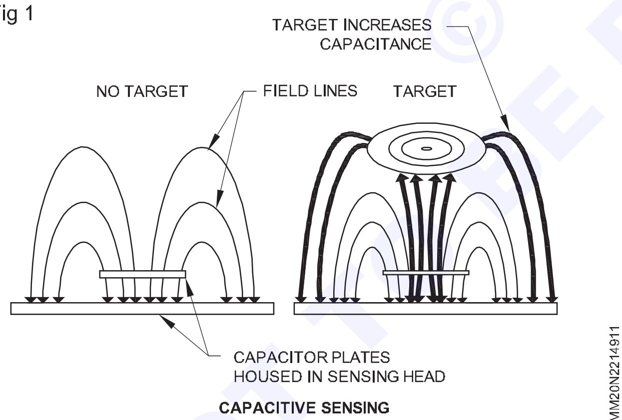
2 Inductive

3 Photo electric

Capacitive Transducers

It is important to know the basics of a parallel plate capacitor. Being the simplest form of a capacitor, it has two parallel conducting plates that are separated to each other by a dielectric or insulator with a permittivity of E (for air). Other than paper, vacuum, and semi-conductor depletion region, the most commonly used dielectric is air. as shown in Fig 1.

Fig 1



CAPACITIVE SENSING

Due to a potential difference across the conductors, an electric field develops across the insulator. This causes the positive charges to accumulate on one plate and the negative charges to accumulate on the other. The capacitor value is usually denoted by its capacitance, which is measured in Farads. It can be defined as the ratio of the electric charge on each conductor to the voltage difference between them.

The capacitance is denoted by C. In a parallel plate capacitor, C = [A*Îr*9.85*1012 F/M]/d

A - Area of each plate (m)

d - Distance between both the plates (m)

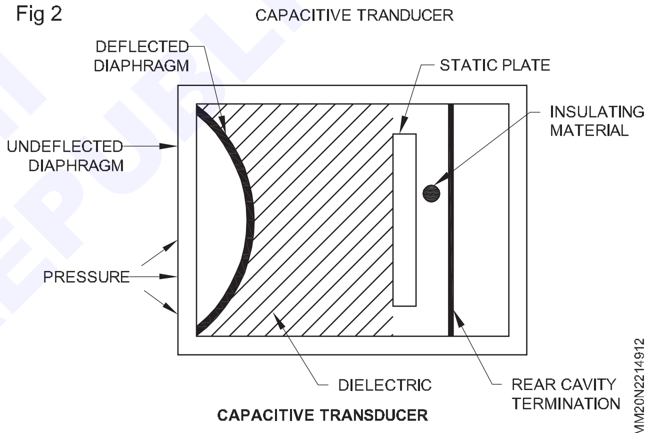
∈r- Relative Dielectric Constant

The value 9.85*1012 F/M is a constant denoted by Î0 and is called the dielectric constant of free space.

From the equation it is clear that the value of capacitance C and the distance between the parallel plates,d are inversely proportional to each other. An increase of distance between the parallel plates will decrease the capacitance value correspondingly. The same theory is used in a capacitive transducer. This transducer is used to convert the value of displacement or change in pressure in terms of frequency.

Parts of Capacitance Transducer (Fig 2)

Fig 2



CAPACITIVE TRANSDUCER

As shown in the figure 2, a capacitive transducer has a static plate and a deflected flexible diaphragm with a dielectric in between. When a force is exerted to the outer side of the diaphragm the distance between the diaphragm and the static plate changes. This produces a capacitance which is measured using an alternating current bridge or a tank circuit.

A tank circuit is more preferred because it produces a change in frequency according to the change in capacitance. This value of frequency will be corresponding to the displacement or force given to the input.

Advantages

- It produces an accurate frequency response to both static and dynamic measurements.

Disadvantages

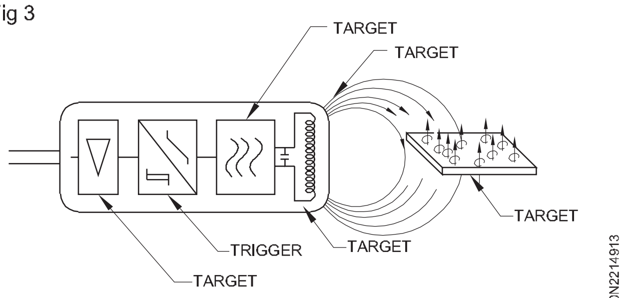
- An increase or decrease in temperature to a high level will change the accuracy of the device.
- As the lead is lengthy it can cause errors or distortion in signals.

Inductance Type Inductive Transducers

The inductance type of the inductive transducers simple single coil is used as the transducer. When the mechanical element whose displacement is to be measured is moved, it changes the permeance of the flux path generated by the circuit, which changes the inductance of the circuit and the corresponding output. The output from the circuit is calibrated directly against the value of the input, thus it directly gives the valve of the parameter to be measured.

The Fig 3 shows the single coil inductive circuit. Here the magnetic material is connected to the electric circuit and it is excited by the alternating current. At the bottom there is another magnetic material that acts as the armature. As the armature is moved, the air gap between the two magnetic material changes and the permeance of the flux generated by the circuit changes that changes the inductance of the circuit and its output. The output meter directly gives the valve of the input mechanical quantity.

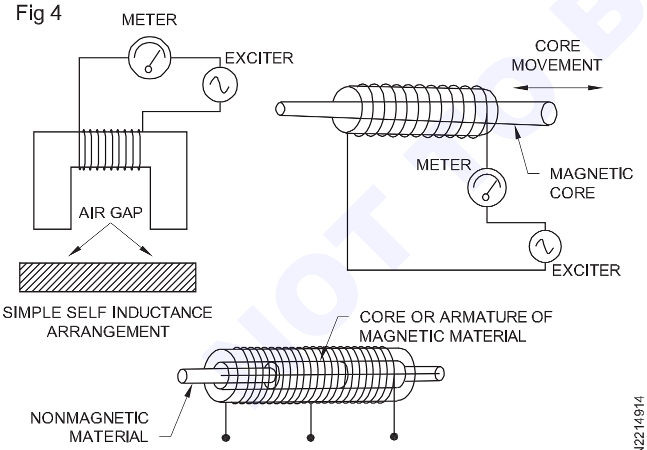
Fig 3



INDUCTANCE TYPE INDUCTIVE TRANSDUCERS

In the Fig 4, coil is wound around the round hollow magnetic material and there is magnetic core that moves inside hollow magnetic material. In the above circuits the change in the air gap or the change in the amount of the magnetic material in the circuit can be used to produce the output proportional to the input.

Fig 4



INDUCTANCE TYPE INDUCTIVE TRANSDUCERS

Another arrangement of the coils is shown in Fig 3, where two coils are used. In this circuit the movement of the core changes the relative inductance of the two coils and over all inductance of the circuit. This system is used in the devices along with the inductive bridge circuit. In this circuit the change in the induction ratio of the two coils provides the output proportional to the mechanical input.

In the above arrangements the supply of the current and the output is obtained from the same coil or circuit.

Advantages

1 Non contact type

2 Maintenance free

3 pnp or npn type

4 360°-viewable output indicators for easy operation and maintenance

5 Electrical protections against short circuits, overload, transient noise, false pulses and reverse polarity (DC models) to help reduce downtime and maintenance costs.

Disadvantages

Virtually nil but following may be noted

1 Cannot be repaired

2 Must be free from oil and dust

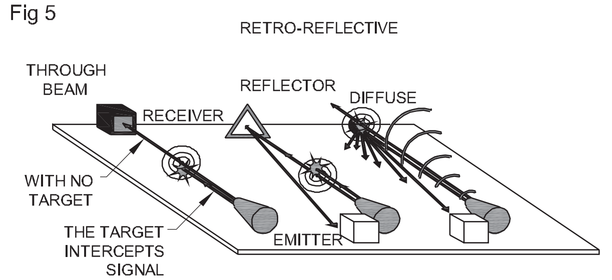
3 Cable connections to be checked regularly

Photoelectric sensors

Photoelectric sensors are so versatile that they solve the bulk of problems put to industrial sensing. Because photoelectric technology has so rapidly advanced, they now commonly detect targets less than 1 mm in diameter, or from 60 m away. Classified by the method in which light is emitted and delivered to the receiver, many photoelectric configurations are available. However, all photoelectric sensors consist of a few of basic components: each has an emitter light source (Light Emitting Diode, laser diode), a photodiode or phototransistor receiver to detect emitted light, and supporting electronics designed to amplify the receiver signal. The emitter, sometimes called the sender, transmits a beam of either visible or infrared light to the detecting receiver.

All photoelectric sensors operate under similar principles as shown in Fig 5. Identifying their output is thus made easy; dark-on and light-on classifications refer to light reception and sensor output activity. If output is produced when no light is received, the sensor is dark-on. Output from light received, and it's light-on. Either way, deciding on light-on or dark-on prior to purchasing is required unless the sensor is user adjustable. (In that case, output style can be specified during installation by flipping a switch or wiring the sensor accordingly.)

Fig 5



LASERS OF SOUND WAVES SERVE AS THE SIGNAL IN THREE SETUPS. IN THROUGH BEAM AND RETRO-REFLECTIVE, THE SIGNAL SHOOTS FROM THE EMITTER TO RECEIVER UNTIL THE TARGET CUTS IT OFF. IN DIFFUSE SENSING, THE SIGNAL DIVERGES UNTIL A TARGET MOVES IN AND REFLECTS SOME BACK TO THE RECEIVER.

PHOTOELECTRIC / ULTRASONIC SENSING SETUPS

Through-beam

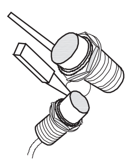
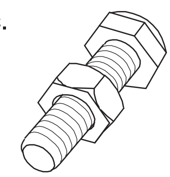
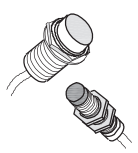
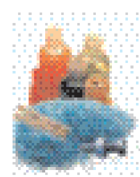
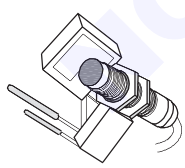
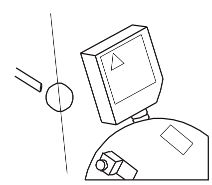
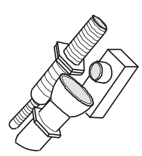
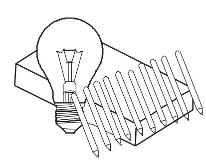
The most reliable photoelectric sensing is with through-beam sensors. Separated from the receiver by a separate housing, the emitter provides a constant beam of light; detection occurs when an object passing between the two breaks the beam. Despite its reliability, through-beam is the least popular photoelectric setup. The purchase, installation, and alignment of the emitter and receiver in two opposing locations, which may be quite a distance apart, are costly and laborious. With newly developed designs, through-beam photoelectric sensors typically offer the longest sensing distance of photoelectric sensors - 25 m and over is now commonplace. New laser diode emitter models can transmit a well-collimated beam 60 m for increased accuracy and detection. At these distances, some through-beam laser sensors are capable of detecting an object the size of a fly; at close range, that becomes 0.01 mm. But while these laser sensors increase precision, response speed is the same as with non-laser sensors - typically around 500 Hz.

One ability unique to through-beam photoelectric sensors is effective sensing in the presence of thick airborne contaminants. If pollutants build up directly on the emitter or receiver, there is a higher probability of false triggering. However, some manufacturers now incorporate alarm outputs into the sensor's circuitry that monitor the amount of light hitting the receiver. If detected light decreases to a specified level without a target in place, the sensor sends a warning by means of a builtin LED or output wire.

Through-beam photoelectric sensors have commercial and industrial applications. At home, for example, they detect obstructions in the path of garage doors; the sensors have saved many a bicycle and car from being smashed. Objects on industrial conveyors, on the other hand, can be detected anywhere between the emitter and receiver, as long as there are gaps between the monitored objects, and sensor light does not "burn through" them. (Burn-through might happen with thin or lightly colored objects that allow emitted light to pass through to the receiver.)

Application and selection of proximity sensor:

Proximity Sensor comparison table -1

Technology	Sensing Range	Applications	Target Materials
Inductive 	<4-40 mm	Any close - range detection of errous material	Iron Steel Aluminum Copper etc. 
Capacitive 	<3-60 mm	Close - range detection of non - ferrous material	Liquids Wood Granulates Plastic Glass etc 
Photoelectric 	<1mm - 60 mm	Long - range small or large target detection	Silicon Plastic Paper Metal etc. 
Ultrasonic 	<30 mm - 3 mm	Long - range detection of targets with difficult surface properties. Color/ reflectivity insensitive.	Cellophane Foam Glass liquid Powder etc 

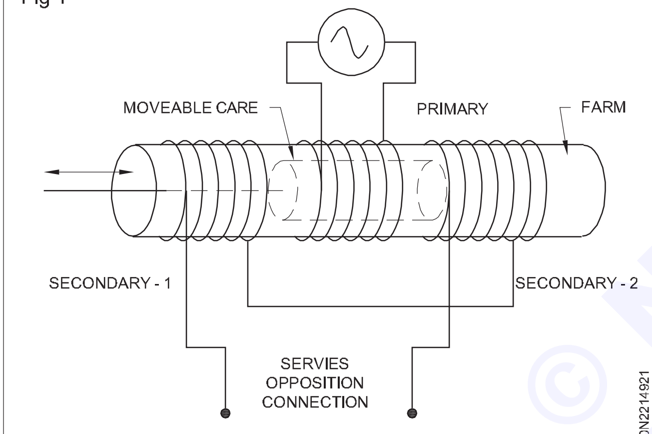
Displacement measurement using LVDT

Objectives : At the end of this lesson you shall be able to
- **define LVDT**
- **explain the working principle and operation of LVDT**
- **state the advantages, disadvantages and application of LVDT.**

Details of LVDT and its construction

Linear variable differential transformers (LVDT) are used to measure displacement. LVDTs operate on the principle of a transformer. As shown in Figure 1, an LVDT consists of a coil assembly and a core. The coil assembly is typically mounted to a stationary form, while the core is secured to the object whose position is being measured. The coil assembly consists of three coils of wire wound on the hollow form. A core of permeable material can slide freely through the center of the form. The inner coil is the primary, which is excited by an AC source as shown. Magnetic flux produced by the primary is coupled to the two secondary coils, inducing an AC voltage in each coil.

Fig 1



GENERAL LVDT ASSEMBLY

LVDTs Working principle

The LVDT or Linear Variable Differential Transformer is a well established transducer design which has been used throughout many decades for the accurate measurement of displacement and within closed loops for the control of positioning. So, how does an LVDT work? In its simplest form, the design consists of a cylindrical array of a primary and secondary windings with a separate cylindrical core which passes through the centre. (Fig 2a).

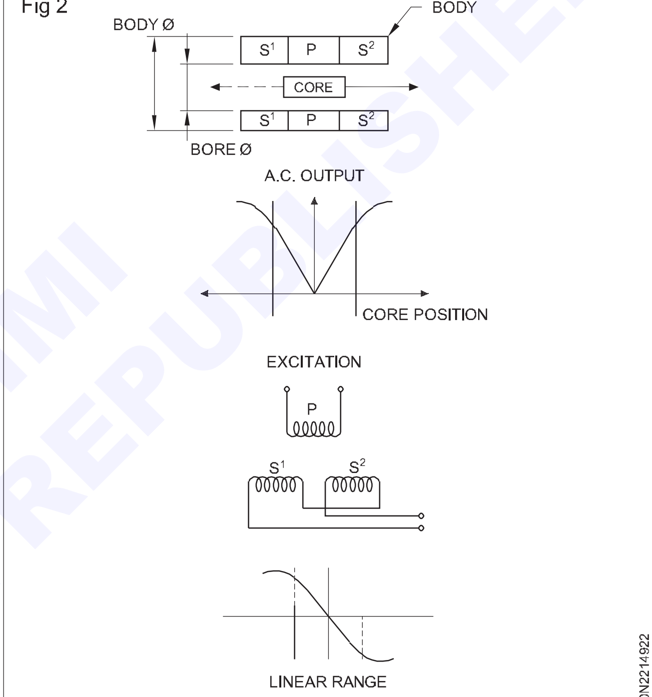
The primary windings (P) are energized with a constant amplitude A.C. supply at a frequency of 1 to 10 kHz. This produces an alternating magnetic field in the centre of the transducer which induces a signal into the secondary windings (S &S) depending on the position of the core.

Movement of the core within this area causes the secondary signal to change (Fig 2b). As the two secondary windings are positioned and connected in a set arrangement (push-pull mode), when the core is positioned at the centre, a zero signal is derived.

Movement of the core from this point in either direction causes the signal to increase (Fig 2c). As the windings are wound in a particular precise manner, the signal output has a linear relationship with the actual mechanical movement of the core.

The secondary output signal is then processed by a phase-sensitive demodulator which is switched at the same frequency as the primary energising supply. This results in a final output which, after rectification and filtering, gives D.C. or 4-20mA output proportional to the core movement and also indicates its direction, positive or negative from the central zero point (Fig 2d).

Fig 2



LVDTs WORKING PRINCIPLE

Advantage:

The distinct advantage of using an LVDT displacement transducer is that the moving core does not make contact with other electrical components of the assembly, as with resistive types, as so offers high reliability and long life. Further, the core can be so aligned that an air gap exists around it, ideal for applications where minimum mechanical friction is required.

The LVDT design lends itself for easy modification to fulfill a whole range of different applications in both research and industry.

Disadvantages of LVDT

- Very high displacement is required for generating high voltages.
- Shielding is required since it is sensitive to magnetic field.

- The performance of the transducer gets affected by vibrations
- Its is greatly affected by temperature changes.
- Internally non contact but externally has to be connected where the measurement has to be made
- Not feasible for very long range measurements

Applications of LVDT

LVDT is used to measure displacement ranging from fraction millimeter to centimeter.

Acting as a secondary transducer, LVDT can be used as a device to measure force, weight and pressure, etc.

Pipes and pipe fittings

Objectives : At the end of this lesson you shall be able to
- **state the uses of pipes**
- **name the common types of pipes**
- **identify the standard pipe fittings and state their uses.**

Various types of pipes and tubes are used for the following purposes.

- Domestic hot and cold water supplies.
- Waste water outlets.
- High pressure steam supplies.
- Hydraulic oil supplies.
- Lubricating oil supplies.
- Special fluid and gases for industrial processes.
- Pneumatic systems.
- Refrigeration systems.
- Fuel oil supplies.

The common types of pipes classified according to material are:

- galvanized iron pipes
- mild steel pipes
- cast iron pipes
- C.I. soil pipes
- copper pipes
- aluminium pipes
- brass pipes
- lead pipes
- P.V.C. pipes
- rubber pipes
- plastic pipes
- stoneware pipes.

Standard pipe fitting

'Pipe fittings' are those fittings that may be attached to water pipes in order to:

- change the direction of the pipe
- connect a branch with a main water supply pipe
- connect two or more pipes of different sizes
- close the pipe ends.

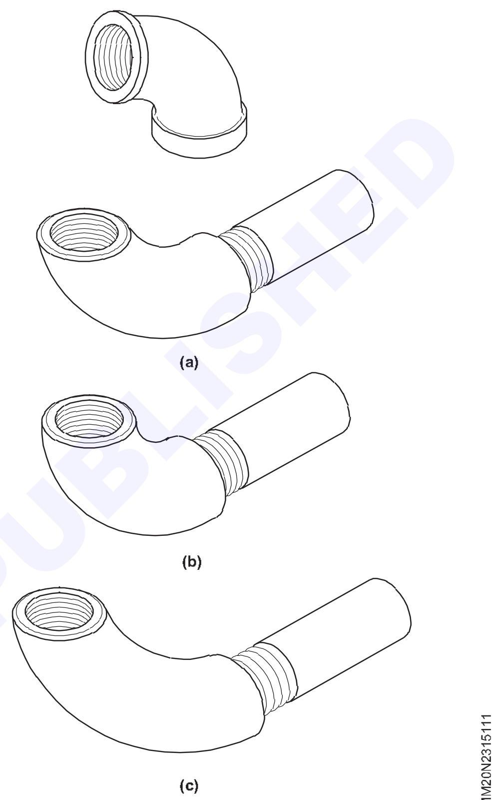
Standard pipe fittings

Elbow (Fig 1)

Elbows and bends provide deviations of 90˚ and 45˚ in pipe work systems.

Long radius elbows have a radius equal to 1 1/2 times the bore of the pipe. (Fig 1a)

Fig 1



Short radius elbows have a radius equal to the bore of the pipe.(Fig 1b)

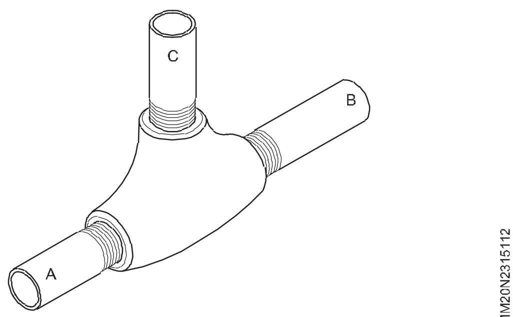
The 45˚ elbows allow pipe deviation of 45˚. (Fig 1c)

Tee branch

A tee joint helps the pipe line to branch off at 90˚. The branches may be equal in diameter or there may be one reducing branch.

The dimensions of a branch are always quoted as A x B x C. (Fig 2)

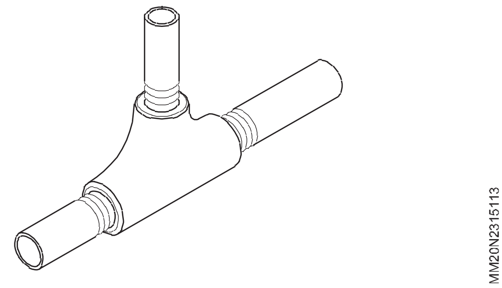
Fig 2



Reducing tee branch

Reducers are fitted where a change in pipe diameter is required.(Fig 3)

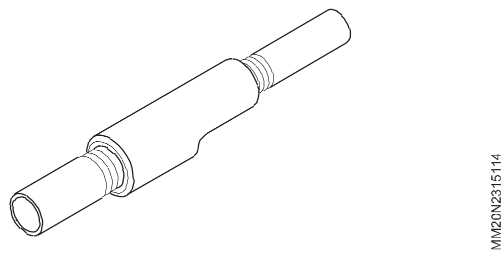
Fig 3



Eccentric reducer

Used mainly in horizontal position.(Fig 4)

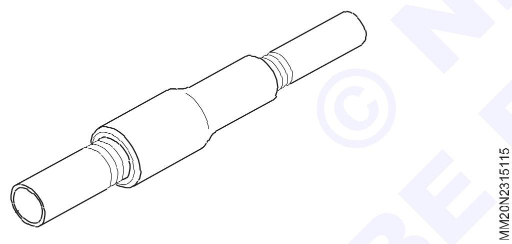
Fig 4



Concentric reducer

Used mainly in vertical position. (Fig 5)

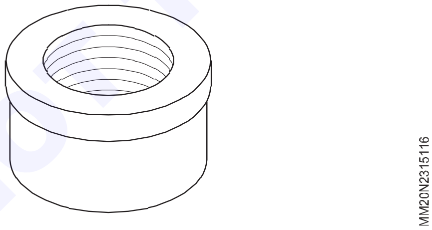
Fig 5



Cap

Caps are used for closing the end of a pipe or fitting which has an external thread. (Fig 6)

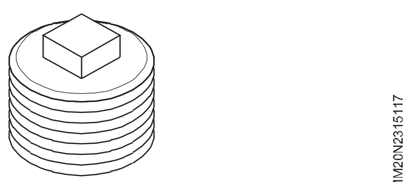
Fig 6



Plug

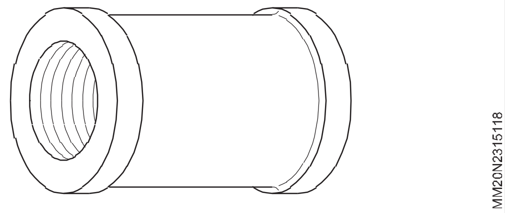
A plug is used for closing a pipeline which has an internal thread.(Fig 7)

Fig 7



Coupling (Fig 8)

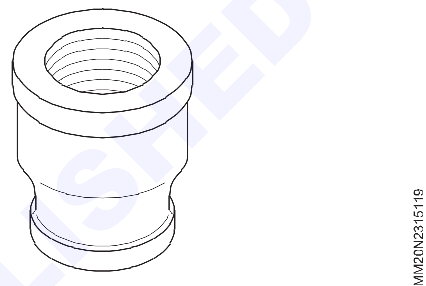
Fig 8



A coupling is used to connect two pipes. Couplings have internal threads at both ends to fit the external threads on pipes.

Reducer (Fig 9)

Fig 9



A reducer coupling is used to connect two pipes with different diameters.

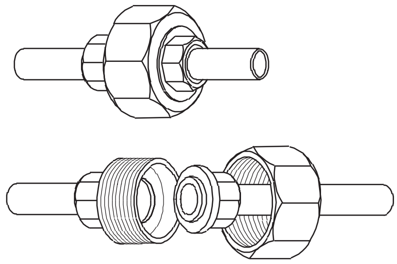
Pipe fitting symbols are listed in table 1

FITTING	SYMBOL
BEND, 90 DEGREES	
BEND, 45 DEGREES	
CROSS	
ELBOW, 90 DEGREES	
ELBOW, 45 DEGREES	
TEE	
REDUCER,CONCENTRIC	
UNION,SCREWED	
PLUG OR CAP	
JOINT/SOCKET	

Union

A device used to connect pipes. Unions are inserted in a pipe-line to permit connections with little change to the position of the pipe. (Fig 10)

Fig 10

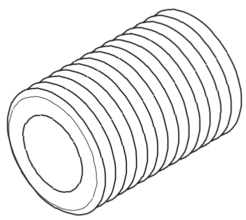


Pipe nipples

Pipe nipples are tubular pipe fittings used to connect two or more pipes of different sizes.

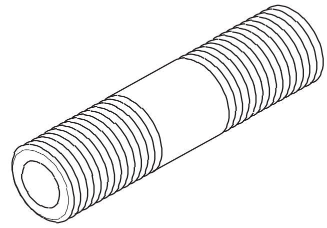
Pipe nipples insert here (Fig 11)

Fig 11



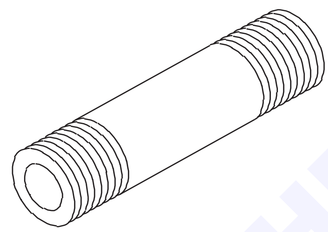
Short nipple (Fig 12)

Fig 12



Long nipple (Fig 13)

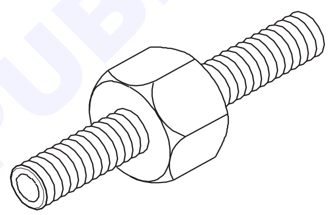
Fig 13



Hexagonal nut

Hexagonal nut in the centre of the nipple is for tightening with a spanner or wrench.(Fig 14)

Fig 14



Pipes and Valves

Objective : At the end of this lesson you shall be able to
- **use pipe schedule for real time project.**

Pipe schedule

Pipe schedule (SCH) is how the wall thickness of a pipe is described. It is not an actual measurement, but a guide number based on a wall thickness formula.

Two pipes the same diameter may have different schedules, which means they have a different wall thickness. So somebody specifying a pipe for a high pressure application will select a bigger number which represents a bigger schedule (wall thickness).

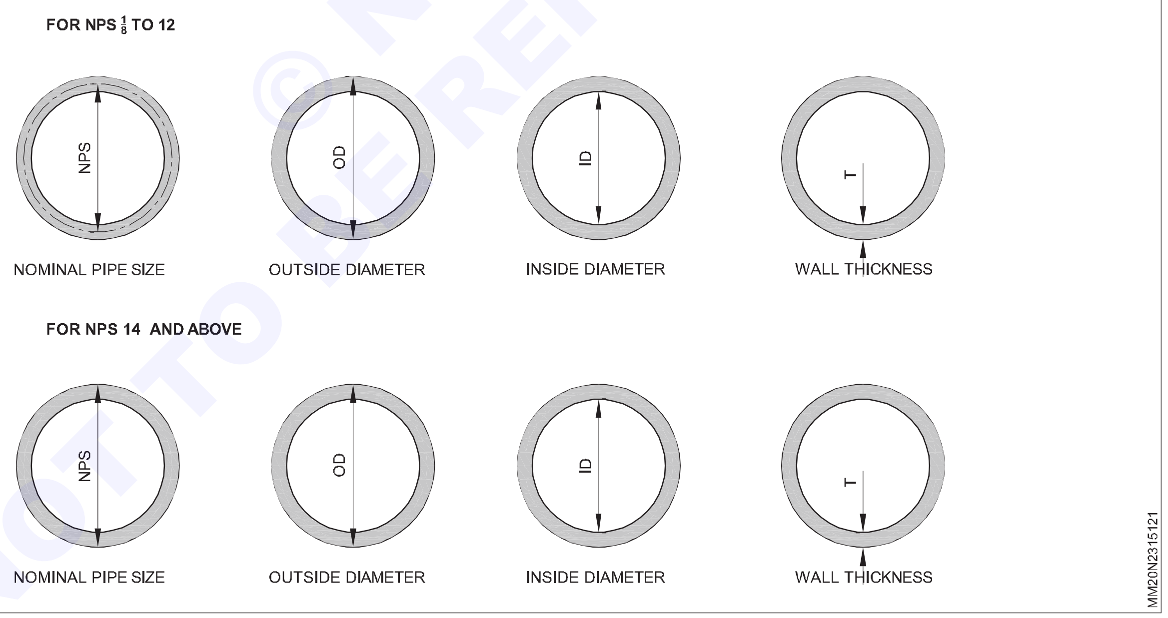
Additionally, in the case of stainless steel, piping schedules are specified with a letter ‘s’ as a suffix after the number . An example to illustrate is an NPS 14 pipe with a schedule of 40s shown in the table below.

NPS Nominal Pipe Size	40 Schedule	40s Schedule
14	0.438” wall thickness	0.375” wall thickness

The list of pipe schedules used today are as follows; 5,5S,10,10S, 20, 30, 40, 40S, 60,80, 80S, 100, 120, 140, 160, STD, XS and XXS.

		PIPE SCHEDULES & WEIGHTS			
		SCHEDULES 40		SCHEDULES 80	
NORMAL PIPE SIZE	**OUTSIDE DIAMETER**	**Wall Thick**	**Wt. per Ft.**	**Wall Thick**	**Weight per Ft.**
1/8	0.405	0.068	0.245	0.095	0.315
1/4	0.540	0.088	0.425	0.119	0.535
3/8	.675	0.091	0.568	0.126	0.739
1/2	0.840	0.109	0.851	0.147	1.088
3/4	1.050	0.113	1.131	0.154	1.474
1	1.315	0.133	1.679	0.179	2.172
1-1/4	1.660	0.140	2.273	0.191	2.997
1-1/2	1.900	0.145	2.718	0.200	3.631
2	2.375	0.154	3.653	0.218	5.022
2-1/2	2.875	0.203	5.793	0.275	7.661
3	3.500	0.216	7.576	0.300	10.250
3-1/2	4.000	0.226	9.109	0.318	12.510
4	4.500	0.237	10.790	0.337	14.980
5	5.563	0.258	14.620	0.375	20.780
6	6.625	0.280	18.970	0.432	28.570
8	8.625	0.322	28.550	0.500	43.390
10	10.750	0.365	40.480	0.500	54.740
12	12.750	0.375	49.560	0.500	65.420

Fig 1



Bending of pipes by hot and cold process

Objective: At the end of the lesson you shall be able to
- **state the bending of pipes by cold and hot process.**

Tube or pipes are bent at different angles, in different planes and shapes. Bent tubing is widely used for fuel pipes, oil, air conduits, and plumbing works etc.

The bending of the tubes can be done by hand or mechanized methods, in cold and hot conditions, with or without fillers. The choice of bending method depends in the tube diameter material of tube and the angle of bend.

Cold bending: Simplest method for bending tubes of 1 to 15 mm in diameter is done by the simple device. This device comprises a plate with holes and radius pins, which are inserted into suitable holes.

Pipes upto 40 mm dia. in cold condition are bend to large radius by means of simple bender. The pipes after fixing in clamp at the end of the radius collar are bend around the groove of the collar.

Pipes upto 20 mm dia. bent by the radius-collar bending unit. This unit is fixed at the top of the work bench through its base plate by means of bolts. Radius collar and the clamp are mounted on the base. Movable roller is fixed in yoke with hand lever. Now the pipe is inserted in between the roller and the collar. So that its end is hold by the clamp. Now the hand lever is turned with yoke and roller around the radius collar, until the pipe is bend as per requirement.

Hot bending: Hot bending is used for pipes over 100 mm diameter. In hot bending with a filter, the tube is annealed, layed out and one end is closed with wooden or metal plug. For preventing the tube from crushing, bulging or cracking, it is filled with dry sand, shifted through a sieve with 2 mm makes. Hammers or vibrators are used for proper filling and compacting the sand in the pipes. After filling sand the pipe is snugly fitted with plug.

Pipes are heated red-hot with blow lamps in furnaces or with gas burners, before bending. The pipes are bend in the required shape in hot condition in proper bending devices.

After bending the plugs are extracted or burnt out and the sand is removed. Poor compaction of sand and inadequate or non-uniform heating may cause the formation of folds or even cracking of the pipe.

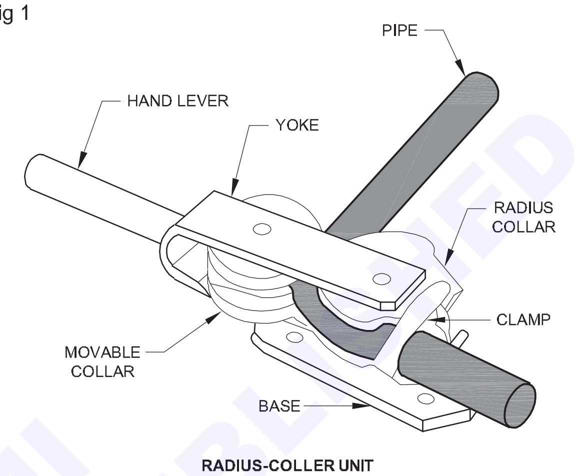
The most common pipe benders are listed here.

Portable hand operated pipe bender (Fig 1, 2 & 3)

The portable hand-operated pipe bender consists of the following parts.

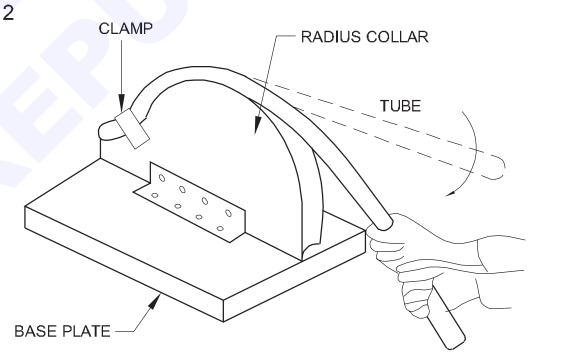
Method of bending galvanized and heavy pipes: The most effective way to bend a galvanized pipe is to use a pipe bender. Both automated and manual pipe benders are designed to give you leverage while working on a pipe. In short, these tools lend you the strength you need to safely create a bend in galvanized steel without hurting yourself or damaging the pipe.

Fig 1



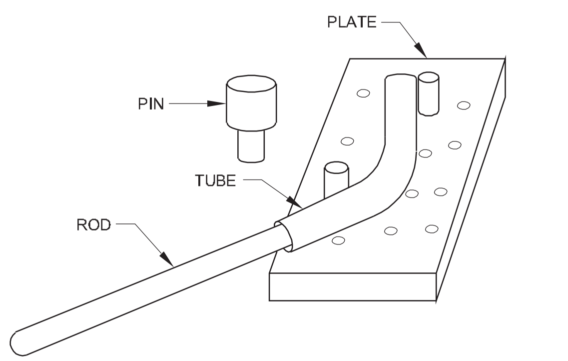
RADIUS-COLLER UNIT

Fig 2



METHOD OF BENDING TUBE AROUND RADIUS COLLAR

Fig 3



METHOD OF PIPE BENDING AROUND RADIUS COLLAR

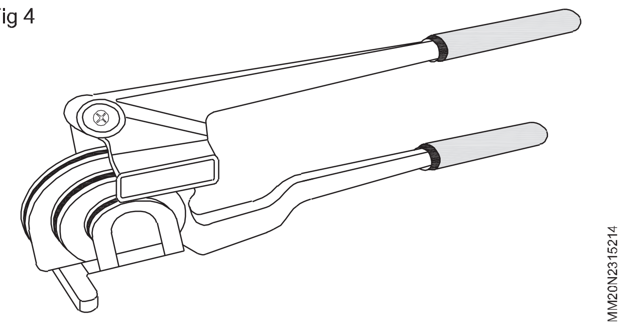
Handheld: Comparatively, handheld pipe benders tend to be less expensive but more difficult to use. You'll need to do a lot of your own math ahead of time if you want your handheld bender to serve you well. (Fig 4).

Induction Bending: To induction bend galvanized pipe, you can wrap a heating coil around your pipe. Make sure the coil fits the part of the pipe you wish to bend. As soon as the pipe has effectively softened, you can use your hands or a tool to bend it to your preferred degree.

Hot Bending: Hot bending works similarly to induction bending. Instead of fitting your pipe with an induction coil, though, you can instead heat your preferred bend with a blow torch or similar tool. Once the mental is softened, you can fit it with a clamp to ensure an effective bend.

Easy bending of Galvanized pipe: Galvanized pipe is protected by a layer of zinc. This layer keeps the pipe from rusting. While the layer may suffer damage over time, it ensures the pipes' longevity, saving you money and keeping your water and gas running for years at a time.

Fig 4



Pipe Bending machines

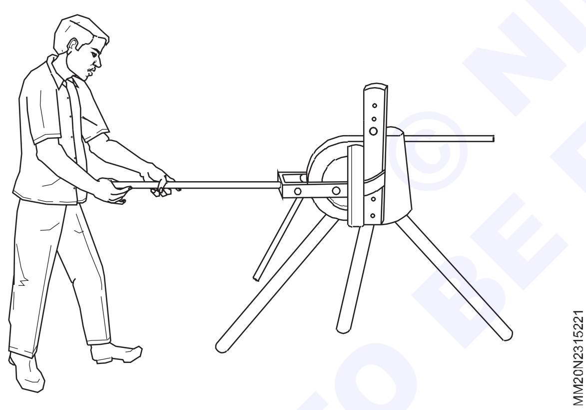
Objectives : At the end of this lesson you shall be able to
- **identify the three most common pipe benders**
- **differentiate their constructional features**
- **name the parts of bending machines**
- **state the uses of bending machines.**

There are some situations in plumbing jobs, where it is preferable to bend a pipe rather than use a pipe fitting.

The most common pipe benders are listed here.

Portable hand operated pipe bender (Fig 1)

Fig 1



The portable hand-operated pipe bender consists of the following parts

1 Tripod stand

2 Pipe stop lever

3 Handle or lever

4 Inside former

Bench type hand operated pipe bender (Fig 2)

This consists of the following parts. It is used for bending galvanized iron and steel pipes.

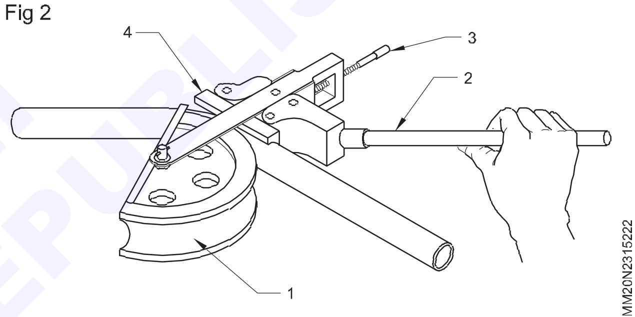
1 Inner former

2 Lever or handle

3 Adjusting screw with lock nut

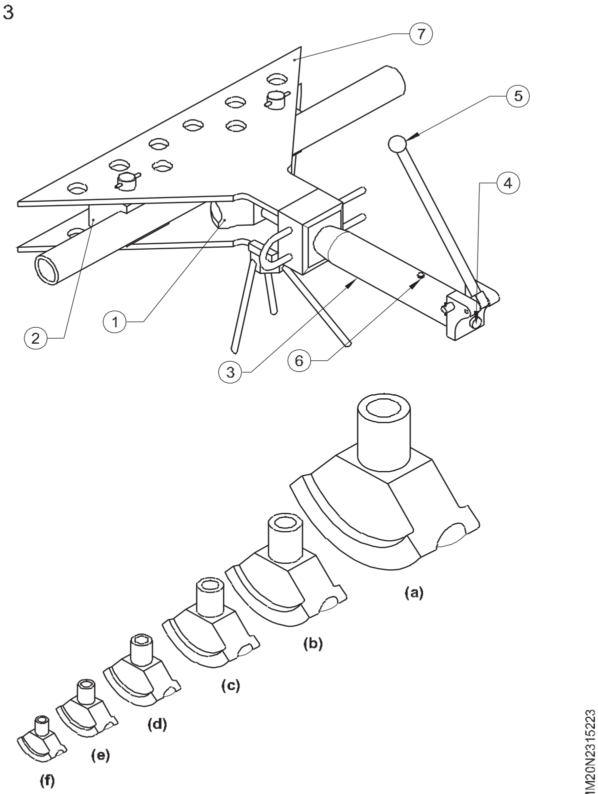
4 Pipe guide

Fig 2



Hydraulic bending machine (Fig 3)

Fig 3



This machine can be used for bending G.I and M.S. pipes without sand filling to any direction.

It consists of the following the parts.

1 Inner former

2 Back former

3 Hydraulic ram

4 Pressure release valve

5 Operating lever

6 Bleed screw

7 Base plate

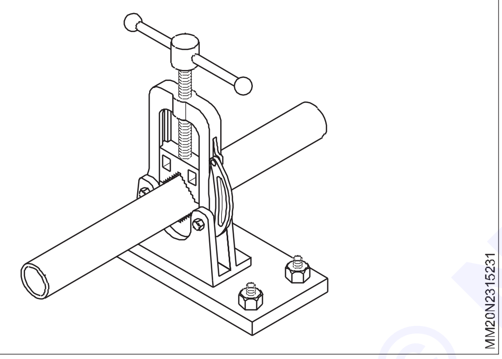
Inner formers are interchangeable and are able to bend pipes up to 75 mm diameters. (Figs 3a, b, c, d, e & f)

Pipe vices and pipe cutters

Objectives : At the end of this lesson you shall be able to
- **name the different types of pipe vices**
- **state the uses of pipe vices**
- **name the parts of a pipe cutter**
- **compare the constructional features of a pipe**
- **cutter and a multi-wheel chain pipe cutter**
- **state the care and maintenance aspects**
- **concerning pipe cutters.**

Pipe vice (Fig 1)

Fig 1



The pipe to be cut/bent/threaded must be held steadily and it must be prevented from rotating by holding it in a pipe vice.

It is a device used for holding and locating pipes. It can be used to hold pipes up to 63 mm diameter.

Portable folding pipe vice (Fig 2)

This vice can be folded and carried easily to any working place. This is similar to the quick-releasing type pipe vice.

Chain pipe vice (Fig 3)

This vice is used to hold larger diameter pipes up to 200 mm diameter. The pipe is gripped by means of a chain and the serrations provided on the vice jaws.

Fig 2

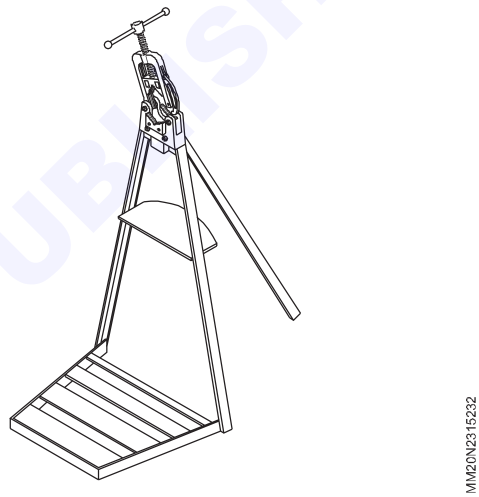
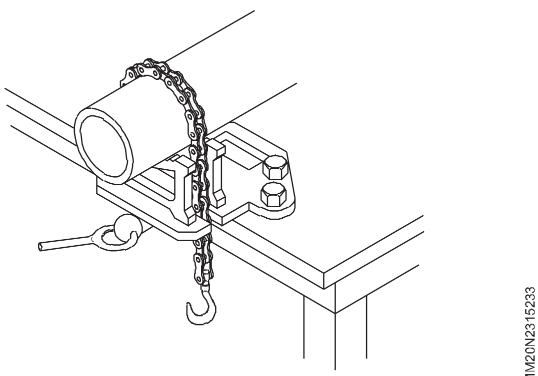


Fig 3



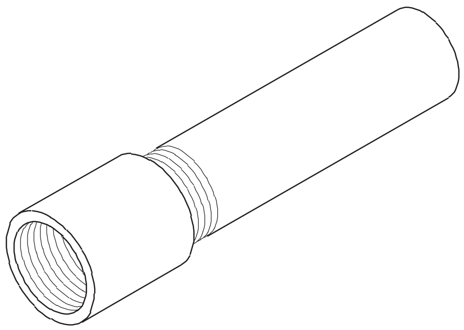
Pipe die, die stock and tap

Objectives : At the end of this lesson you shall be able to
- **identify die sets, die stocks and pipe taps**
- **name the parts of a die stock**
- **state the method of checking pipe threads.**

Pipe die

Most of the G.I. pipes that plumbers install are threaded at both ends. The pipes are available in lengths of 6 metres and it will be necessary to cut the pipe to the required length and thread it. (Fig 1)

Fig 1



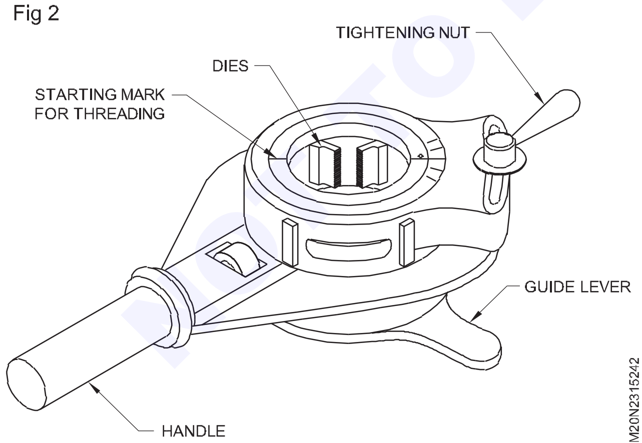
The threads on G.I. pipes and fittings for water supply systems are the standard pipe threads. External pipe threads are cut by pipe dies available in sizes from 1/4” to 4”.

The dies must be sharp so that they will cut metal rather than push it around. Dies which push the metal around instead of cutting freely cause threads to break.

Die stock

Die stock are required to turn the dies. The ratchet type die stock is preferred because it permits the operator to use his body weight to rotate the die while standing to one side of the pipe. (Fig 2) Die stock are adjustable.

Fig 2

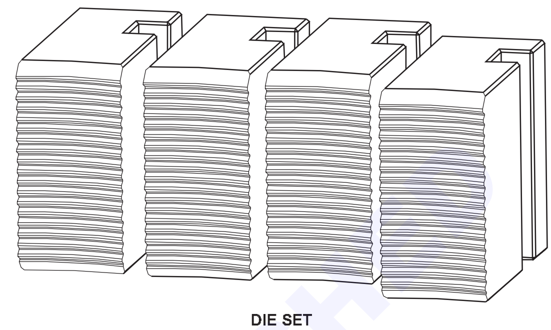


Die sets

Each die is clearly marked with its type of thread and range of pipe for which it is suitable. Each die has an identification number, that is 1 to 4. Die sets are available in various sizes.

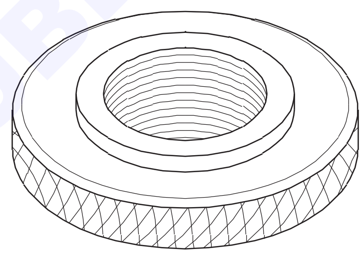
These dies must always be used and stored as a set. (Fig 3)

Fig 3



Pipe threads are usually cut with threading dies and can be checked by using the pipe ring gauge.(Fig 4)

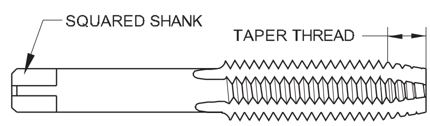
Fig 4



Pipe tap

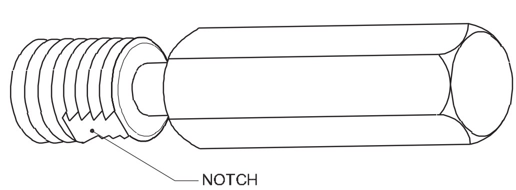
Internal pipe threads are usually cut with standard taper pipe taps. (Fig 5)

Fig 5



In gauging internal pipe threads, the pipe plug thread gauge should be screwed tight by hand into the pipe until the notch on the gauge is flush with the face. When the thread is chamferred the notch should be flushed with the bottom of the chamfer.(Fig 6)

Fig 6

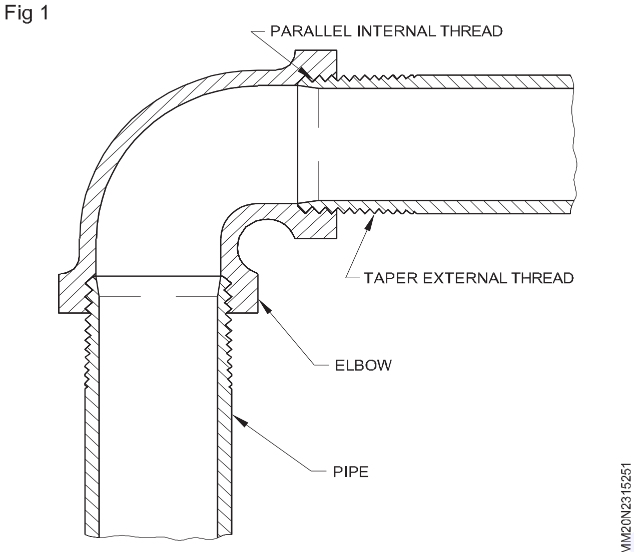


British standard pipe threads

Objectives : At the end of this lesson you shall be able to
- **state parallel and taper pipe threads**
- **determine the wall thickness and threads per inch TPI of BSP threads**
- **state the method of sealing pipe joints**
- **determine blank sizes for threading as per B.S 21 - 1973 and I.S. 2643-1964**.

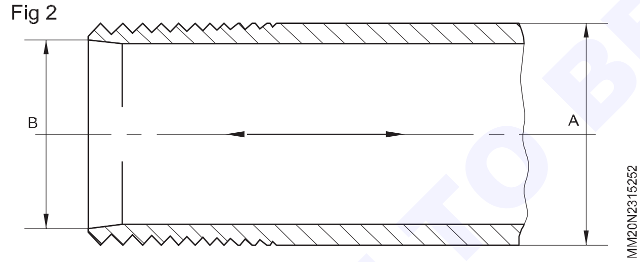
Pipe threads : The standard pipe fittings are threaded to British Standard pipe gauge (BSP). The internal pipe threads have parallel threads whereas the external pipes have tapered threads as shown in Fig 1.

Fig 1



B.S.P. threads : Galvanized iron pipes are available in sizes ranging from 1/2” to 6” in several different wall thicknesses. The table shows outside diameters and threads per inch from 1/2” to 4”. (Fig 2)

Fig 2

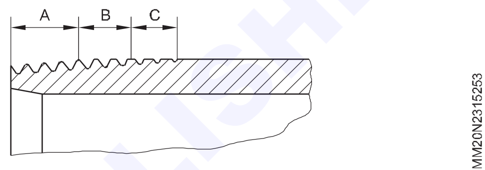


Sealing pipe joint : Fig 3 shows that the pipe has several fully formed threads at the end. (A).

The next two threads have fully formed bottoms but flat tops. (B)

BSP - Pipe sizes or DIN 2999 (inside) (B) +	Threads/ inch	Outside diameter/ mm of the pipe (A) +
1/2”	14	20.955 mm
3/4”	14	26.441
1”	11	33.249
11/4”	11	41.910
11/2”	11	47.803
2”	11	59.614
2^{1}/2”	8	75.184
3”	8	87.884
4”	8	113.030

Fig 3



The last four threads have flat tops and bottoms. (C)

The pipe joint shown in Fig 4 consists of the following.

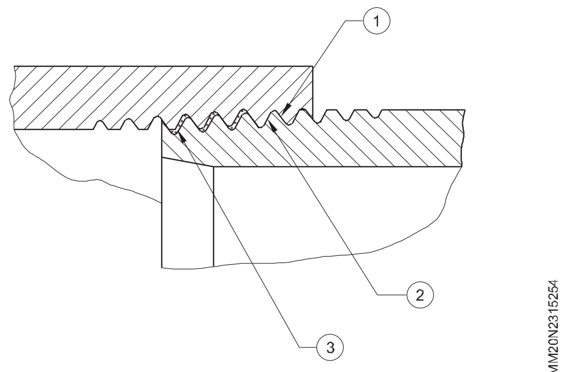
1 Parallel female thread

2 Tapered male thread

3 Hemp packing

The hemp packing is used to ensure that any small space between two metal threads (male and female threads) is sealed to prevent any leakage.

Fig 4



Types of fittings for different joints in different pipes

Objectives: At the end of this lesson you shall be able to
- **state the different fittings used for different pipe joints and their uses**
- **state the method adopted for flange joint, socket joint with lead**
- **state the method of detachable joint stone ware socket and spigot cement mortar joint**
- **state the method of ductile iron pipe joint.**

Describe

Mainly pipes are used for handling & transporting the water in position.

Pipes are manufacturing in small length of 2 to 6 meters. These small pieces of pipes are then joined together after placing in position, to make one continuous length of pipe line. The design of these joints mainly depends on condition of the pipe.

The pipe joints are classified as follows

1 Spigot and socket joint

2 Expansion joint

3 Flanged joint

4 Screwed joint

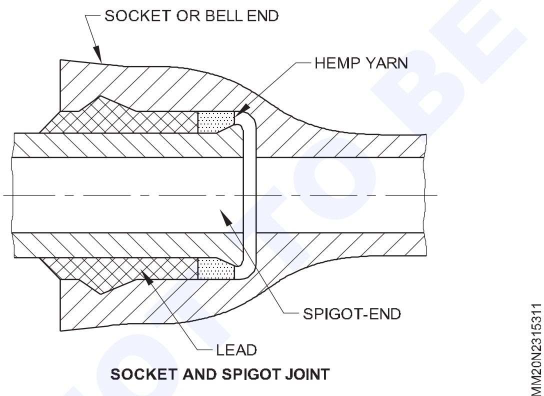
5 Collar joint

6 A.C pipe joint

7 Solvent cement joint

1 Socket and spigot joint (Fig 1)

Fig 1

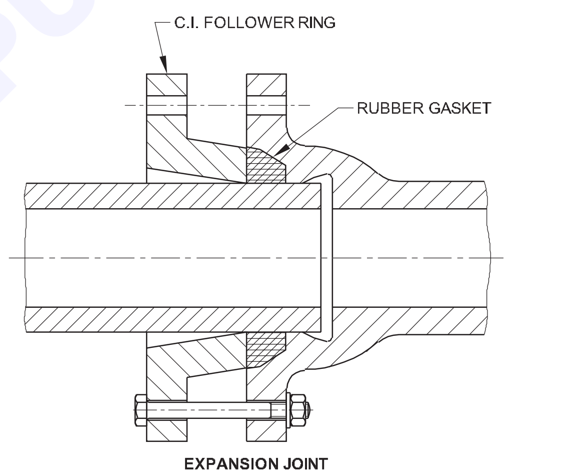


This type of joints are mostly used for cast iron pipes. For the construction of this joint the spigot of normal end of one pipe is slipped in socket or bell end of the other pipe until contact is made at base of the bell. After this yarn of hemp is wrapped around the spigot end of the pipe and tightly filled in the joint by means of yarning iron upto 5 cm depth. The hemp is tightly packed to maintain regular annular space and for preventing jointing materials from falling inside the pipe. After packing of hemp, a gasket or joint runner is clamped in place round the joint so that it fits tightly against the outer edge of the bell. Sometimes wet clay is used to make light contact between the runner and pipe so that hot lead may not run out of the joints space. The molten lead is then poured into the “V” shaped opening left in the top by the clamped joint runner. The space between the hemp yarn and the clamp runner is filled with molten lead. When the lead has hardened, the runner is removed the lead which shrinks while cooling is again tightened by means of caulking tool and hammer.

2 Expansion joint (Fig 2)

This joint is used at such places where pipes contract due to change in atmospheric temperature and thus checks the setting of thermal stresses in the pipe. In this joint the socket end is flanged with cast iron follower ring, which can freely slide on the spigot end or plane and of other pipe. An elastic rubber gasket is tightly pressed between the annular space of socket and spigot by means of bolts as shown in the (Fig 2).

Fig 2

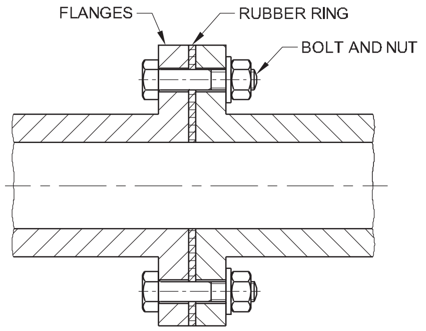


In the beginning while fixing the follower ring some space is left between the socket base and the spigot end for the free movement of the pipes under variation of temperature. In this way when the pipe expands the socket end moves forward and when pipes contract it moves backward in the space provided for it. The elastic rubber gasket in position keep the joint water tight.

3 Flanged joint (Fig 3)

This joint is mostly used for temporary pipe lines, because the pipe line can be dismantled and again assembled at other place. The pipe in this case has flanges on its both end welded or screwed with pipe. The two end of the pipes which are to be joined together are brought in perfect level near one another and after placing one hard rubber washer between flanges are bolted. Placing of washer or gasket of rubber, canvas, copper or lead between the two ends of flanges is very necessary for securing a perfect water tight joint. This joint cannot be used at such places where it has to bear vibration or deflection of pipes. (Fig 3)

Fig 3



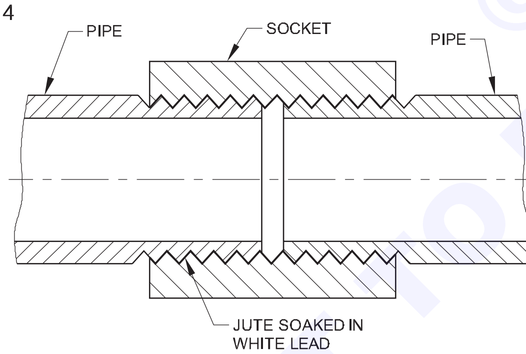
FLANGED JOINT

These joints are commonly used for joining pumping station, filter plants, hydraulic laboratory boiler, house etc. where it may be necessary occasionally to dismantle and reassemble the pipe line. If the steel pipes are to be jointed by these joints, it is better to screw the separately cast flanges on the pipe and then they are joined.

4 Screwed joint (Fig 4)

This joint is mostly used for connecting small dia. cast iron, wrought iron and galvanised pipes. The ends of the pipe have threads on outside while socket or coupling has threads on the inner side. The same socket is screwed on both the end of the pipe to join them, for making water tight joint zinc paint or hemp yarn should be placed in the threads of the pipe before screwing socket over it. (Fig 4)

Fig 4



SCREWED JOINT

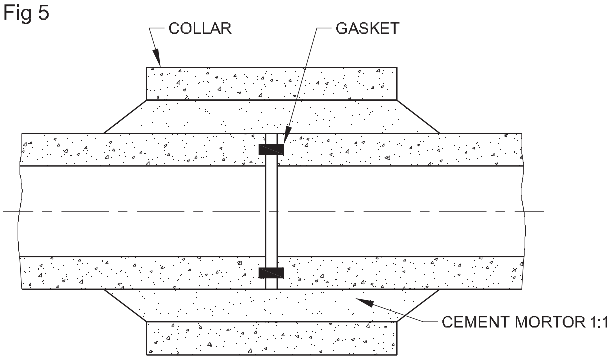
5 Collar joint (Fig 5)

This type of joints are mostly used for joining big diameter concrete and asbestos cement pipes. The end of the pipes are brought in one level before each other. The rubber gasket between steel rings and jute-rope soaked in cement is kept on the groove and the coller is placed at the joint so that it should have the same lap on both the pipes. Now 1:1 cement mortar is filled in the space between the pipes and the collar as shown in (Fig 5).

6 AC pipe Joint (Fig 6)

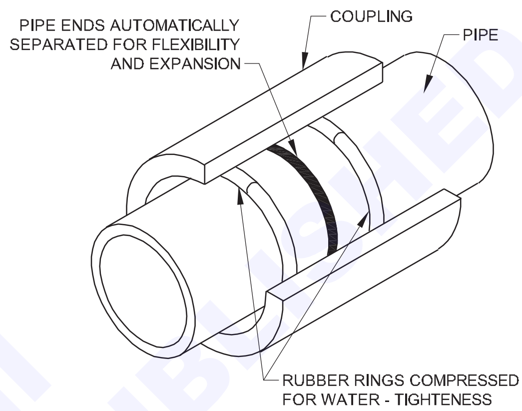
For joining small diameter AC pipe the two ends of pipes are butted against each other then two rubber ring will be slipped over the pipes and the coupling will be pushed over the rings as shown in (Fig 6).

Fig 5



COLLAR JOINT

Fig 6

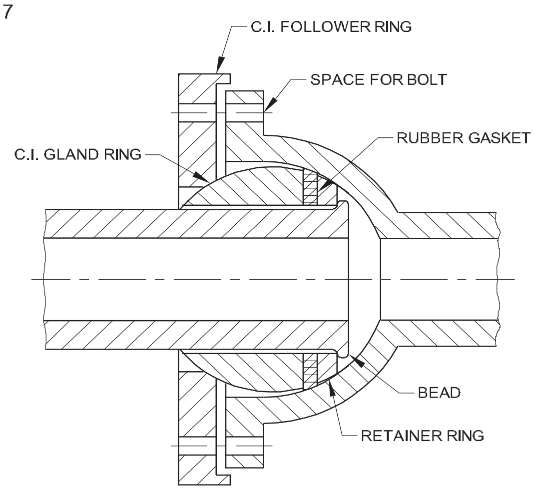


JOINT FOR A.C. PIPES

7 Flexible joint

Sometimes the joint is also called bolt and socket or universal joint. This joint is used at such places where settlement is likely to occur after the laying of the pipe. This joints can also be used for laying pipe on curves, because at the joints, the pipe can be laid at angle. This is a special type of joint. (Fig 7)

Fig 7



The socket end is cast in spherical shape as shown in (Fig 7). The spigot end is plain but has a bead at the end, for the assembling of the joint. The spigot end of one pipe is kept on the spherical end of the other pipe. After the retainer ring is slipped which is stretched over the bead. Then a rubber gasket is moved which touches the retainer ring. After its split cast iron gland ring is placed. The outer surface of which has the same shape as inner surface of socket end over this finally cast iron follower ring is moved and is fixed to the socket end by means of bolt as shown in figure. It is very clear that if one pipe is given any deflection the ball shaped portion will move inside the socket and the joint will remain water proof in all the positions.

8 Solvent cement joint

Clean the contacting surface of joint with a clean cloth- Abrace these area with emery paper and again clean it. Apply an even coat of solvent adhesive with a clean dry brush having sufficient width for quick application. Immediately after applying solvent cement, insert the pipe in the socket to its full depth and turn it through 90^0 angle. Leave joint undisturbed till the joint sets.

Special care should be taken while jointing large diameter or higher class pipe (6 kg/cm^2 and above). Always use heavy duty solvent cement for such pipes. (Requirement of solvent cement & lubricants are as under)

For small breakage of pipe i.e. less than 300mm ∅ a piece of pipe bigger than damaged portion can be cut vertically into unequal half. After applying thin coat of PVC solvent cement around the damaged portion and inside the bigger half cut pipe piece, stick it over the damaged portion. If the damage portion is more than 300mm ∅ remove the damaged portion by cutting a length of damaged portion plus two times the diameter of pipe. Cut a good piece of pipe equal to length of damaged pipe removed and chamfered ends. Slide one repair coupler to the upper line and one in lower. Place the cut pipe into the gap. Slide the repair coupler at top to down and bottom one up and joint the line.

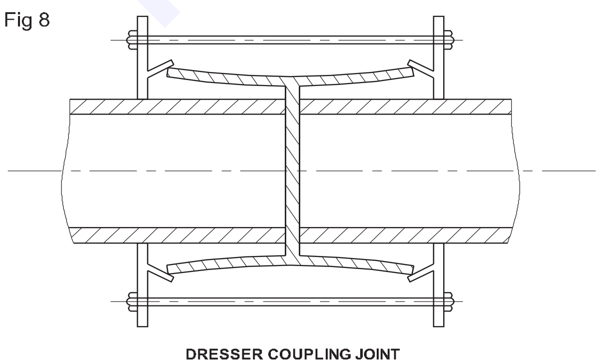
9 Mechanical Joints

The type of joint is used for jointing cast iron, steel or wrought iron pipes, when both the ends of the pipes are plain or spigot. There are two types of mechanical joints.

a **Dresser-coupling:** It essentially consists of one middle ring, two follower rings and two rubber gaskets. The two follower rings are connected together by bolts, and when they are tightened they press both the gaskets tightly below the ends of the middle ring. In this way the joint remains watertight.

These joints are very strong and rigid, and can withstand vibration and shocks upto certain limit. These joints are most suitable for carrying water lines over bridges, where it has to bear vibrations. (Fig 8)

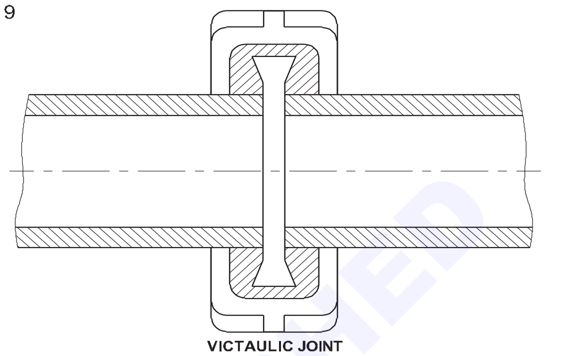
Fig 8



DRESSER COUPLING JOINT

b **Victaulic-Joint:** In this type of joint a gasket or leak proof ring is slipped over both the ends of the pipes as shown in the (Fig 9). This gasket is pressed from all sides on both the pipes by means of half iron coupling by bolts. The ends of pipes are kept sufficient apart to allow for free expansion, contraction and deflection. This joints can bear shocks, vibrations etc. and is used for cast-iron, steel or wrought iron pipes line in expose places. (Fig 9)

Fig 9



VICTAULIC JOINT

SW pipes

These pipes are manufactured from good quality clay. These clay is moulded in the shape of pipe and then heated in the kiln. Ther interior and exterior surface of pipes which remain exposed after jointing are glazed. The glazes are obtained by the action of fumes of volatized common salt on the material of the pipes during the process of burning. Glazing helps to get smooth inside surface.

Stone ware pipe will have spigot and socket (Fig 1). There will be grooves inside the socket and outside the spigot. Pipes are available for lengths of 600mm and diameter varying from 100 to 600 mm. Stoneware concentric taper pipes, tee, junctions bends of 90˚, 45˚, 22½^0 etc., are available. Hence jointing is easy.

Stone ware pipe joint (Fig 10)

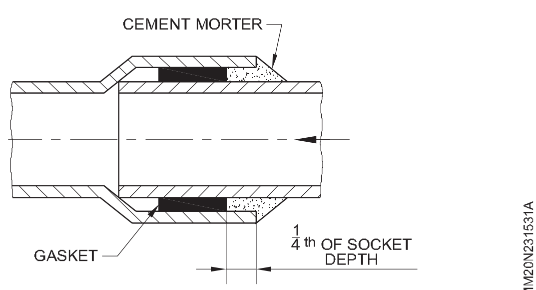
This type of joint is called socket and spigot joint. For this joint spigot end is inserted to the socket end and hempyam (or) gasket soaked in thick cement slyrry is placed in the gaps. This hempyarn is caulked tightly by the spunyarn caulling chisel.

Cement mortar of ratio 1:1 is filled in the socket for the 45° angle this is mostly used for under ground drainage.

Tests to be conducted on SW pipe is

- Hydraulic test

Fig 10



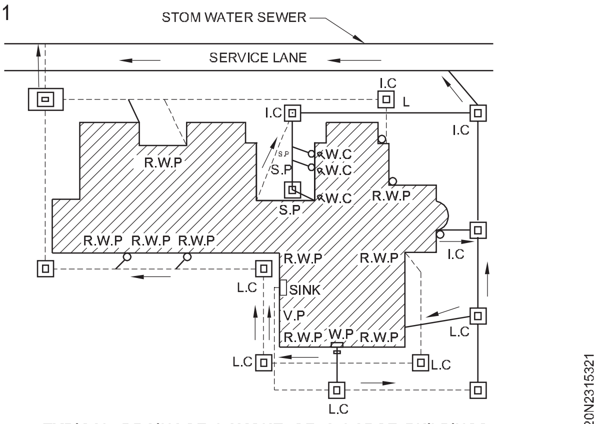
Layout of drainage system

Objectives: At the end of this lesson you shall be able to
- **state the necessity and pre-planning of drainage system**
- **state the factors considered to prepare layout of drainage system.**

Before starting the plumbing work it is most essential first to prepare the drainage plans. In the same way as detailed drawings are required before the starting of the construction of building the detailed plans should be prepared.

The following points should be kept in mind while preparing the layout of drainage system: (Fig 1)

Fig 1



TYPICAL DRAINAGE LAYOUT OF A LARGE BUILDINGS

1 The drains should be laid in such a way so as to remove the sewage quickly from the building. The quick removal is governed by the falls of the pipes. The drains should be laid at such a slope that self-cleaning velocity is developed in them.

2 All the drainage system should be properly ventilated on the house side. The ventilation pipe should be carried sufficiently high above the buildings. All the inspection chambers should be provided with fresh air inlets.

3 All the drains should be laid in such a way so as to ensure their safety in future.

4 The drain should be laid in such a way that in future extension can be done easily if desired.

5 All the rain water pipes, sweeping from house and bath water should discharge over gully traps.

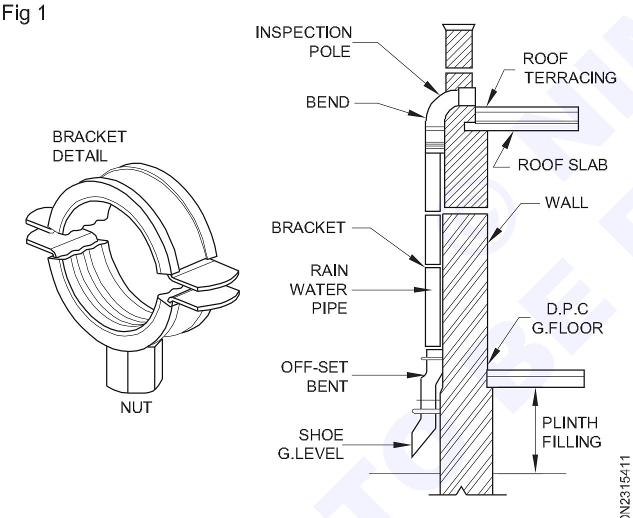
6 All soil pipes should be carried direct to the manholes without gully traps.

Erecting rain water and drainage pipe system

Objectives: At the end of this lesson you shall be able to
- **state the installation of rain water pipe from roof to ground**
- **state the rain water harvesting**
- **state the type of rain water harvesting**
- **state the rain water gutter with rain water pipe**
- **state the types of drainage pipe system.**

Erecting rain water pipe: The pipe laid to collect the rain water from the roofs is known as rain water pipe. The water from the flat as well as sloppy roofs is to be connected and brought on the ground level, from where it is allowed to flow in open drains. Rain water pipes for drainage of roofs (Fig 1). The roofs of a building shall be so constructed or framed as to permit effectual drainage of the rain water there from by means of a sufficient number of rain water pipes of adequate size so arranged, jointed and fixed as to ensure that the rain water is carried away from the building without causing dampness in any part of the walls or foundations of the building or those of an adjacent building.

Fig 1



PLUMBING WORK OF RAIN WATER PIPE FOR FLAT ROOF

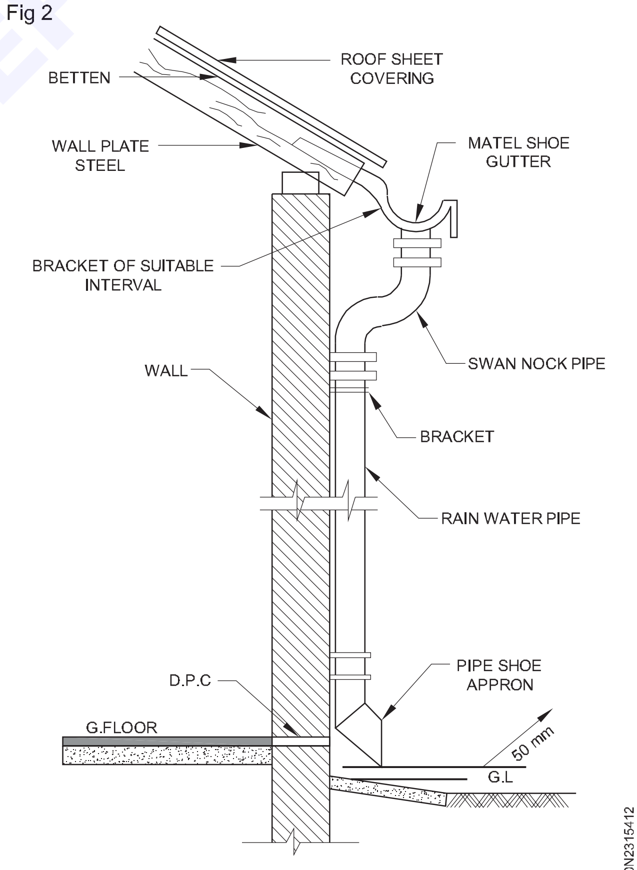
The rain water pipes shall be fixed to the outside of the external walls of the building or in recesses or chase cut or framed in such external walls or in such other manner as may be approved by the administrative authority.

(A rain water pipe conveying rain water shall discharge directly or by means of a channel into or over an inlet to a surface drain or shall discharge freely in a compound, drained to surface drain or shall discharge freely in a compound, drained to surface drain but in no case shall it discharge directly into any closed drain.

Whenever it is not possible to discharge a rain water pipe into or over an inlet to a surface drain or in a compound, drain to surface drain or in a street drain within 30 m from the boundary of the premises, such rain water pipe shall discharge into a gully trap which shall be connected with the street drain. Such a gully trap shall have a screen and a silt catcher incorporated in its design.

Rain water pipes shall be constructed of cast iron, asbestos cement, galvanized sheet or other equally suitable material and shall be securely fixed. The latest practice, however, is not to use the pipes made from galvanized sheets for rain water services. Cast iron rain water pipes and fittings shall conform to IS: 1230 -1979. Asbestos cement building pipes and gutters and fittings (Fig 2) (spigot and socket type) shall conform to IS: 1626 (Part 1) 1980, IS 1626 (Part 2) 1980 and IS: 1626 (Part 3) 1981. Sizing of rain water pipes for roof drainage: Rain water pipes shall be normally sized on the basis of roof areas according to Table 1 as under. A bell mouth inlet at the roof surface is found to give better drainage effect, provided proper slopes are given to the roof surface.

Fig 2



RAIN WATER CUTTER FOR ROOFS

The spacing of pipes depends on the position of the windows and arc openings but 6 m apart is a convenient distance. The strainer fixed to the bell mouth inlet shall have an area 1½ to 2 times the area of pipe which it connects.

Table 1

Sl. No.	Dia. of pipe mm	Average rate of rainfall in mm					
		50	75	100	125	150	200
		Roof area in square metres					
1	50	13.4	8.9	6.6	5.3	4.4	3.3
2	65	24.4	16.0	12.0	9.6	8.0	6.0
3	75	40.8	27.0	20.4	16.3	13.6	10.2
4	100	85.4	57.0	42.7	34.2	28.5	21.3
5	125			80.5	64.3	53.5	40.0
6	150					83.6	62.7

Laying of rainwater pipe

1 Only the required size whole should be made in the wall for fixing of pegs, brackets etc. de-shape the pipe and make it oval in section.

2 While bending the pipes on the bending machines, care should be taken otherwise it may also press the pipe and give more bend than desired.

3 The cutting of the pipes should be done properly, it should be at right angle to the axis of the pipe.

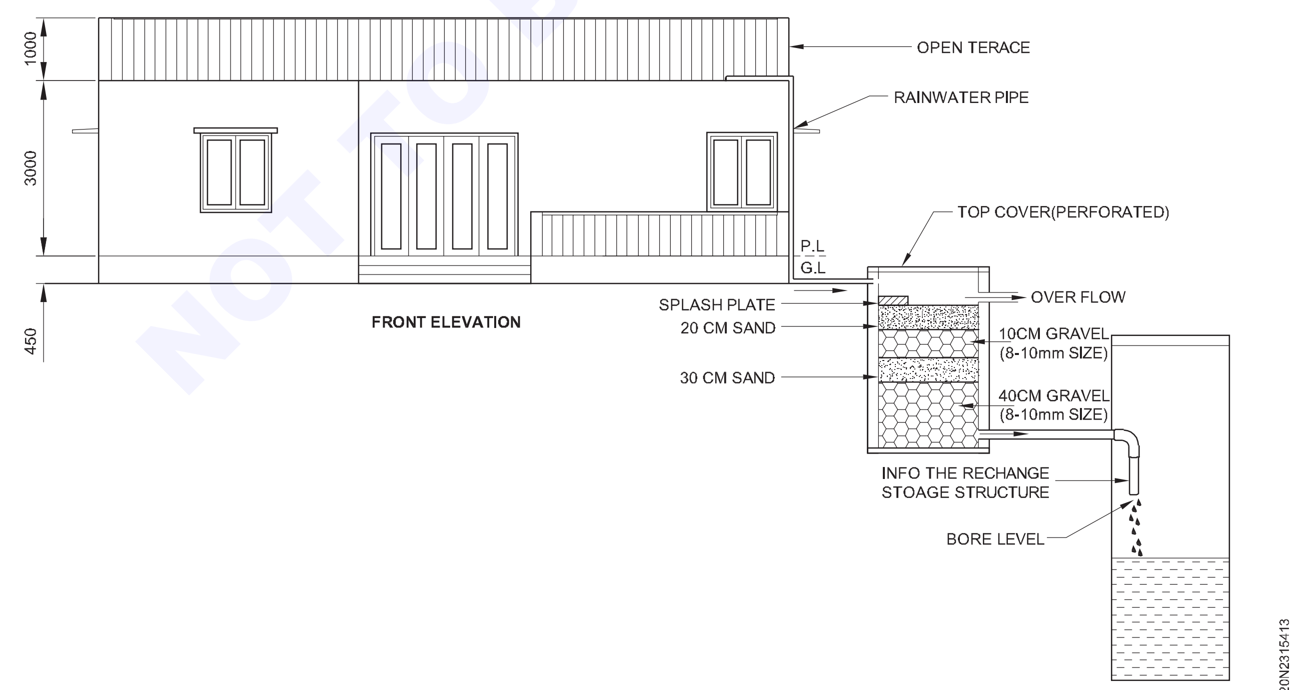
4 The pipes should be fixed with pipe-hooks art proper place. These hooks should be driven in the masonary joints.

5 In case of accidents first-aid facilities should be available.

Rain water harvesting (Fig 3)

Collection of rain water when it rains for use during non monsoon months is called rain water harvesting. When rainfall occurs in heavy during a short spell if it is not collected it floods the area or run off to sea. It is quite possible to put all the water into soil below with little effort and less expenditure so that rain water is not lost but goes to recharge ground water table.

Fig 3



SAND FILTER

Method of testing drainage lines

Objectives: At the end of this lesson you shall be able to
- **state the testing of drainage lines**
- **explain various types of testing in drainage lines.**

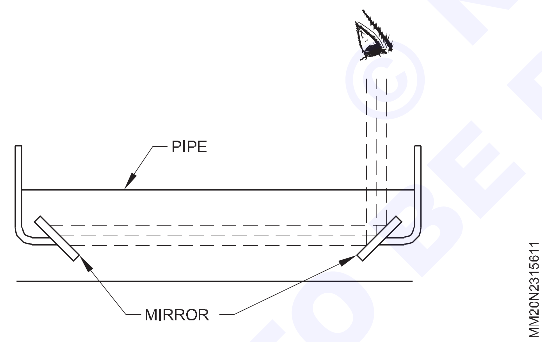
A wide ranges of testing equipment's are available therefore we should select the equipment required for inspection and testing as per local by law requirements.

The principle methods of soil stack and drain testing are

- Mirror test
- Ball test
- Hydrostatic or water test
- Smoke test
- Pneumatic or air test
- Chemical smell test or odour test

Mirror test: This test is applied to check the alignment and condition of the inside of the pipes. Two mirrors are used for the test. They are placed in position through across points and by looking at one of the mirror the condition of the bore of the pipe can be seen as the light is reflected along the pipe. (Fig 1).

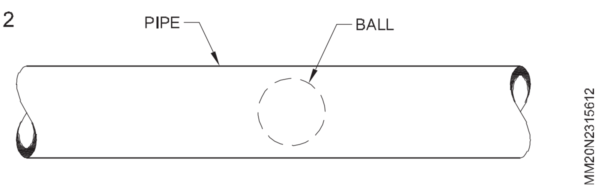
Fig 1



Ball test: In situations where it is not possible to use a mirror test such as bend in the pipe, a brass ball 13 mm smaller than the inside of pipe is inserted in the top end and should roll freely along the bottom or invert of the pipe. If there is an obstruction or pipe is out of alignment the ball will stop, the point where it stops is marked on a rod so that the exact position can be measured off along the pipe. (Fig 2)

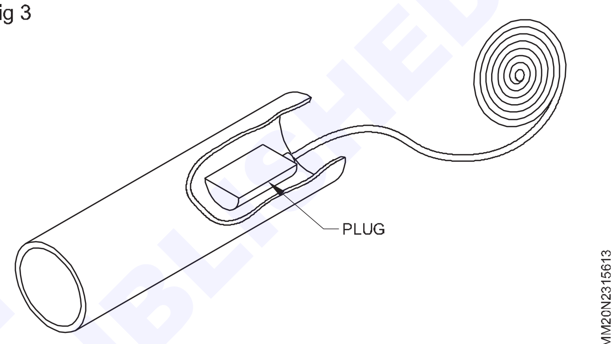
- realignment the pipe to the correct fall or
- removing the obstruction.

Fig 2



A lead slide or plug: A lead slide or plug can also be used to test for obstruction. A lead plug is attached to a spring steel tape and the plug is then carefully pushed along the pipe until resistance is felt. The tap is then markes and plug withdrawn. This will show exactly where the obstruction is (Fig 3).

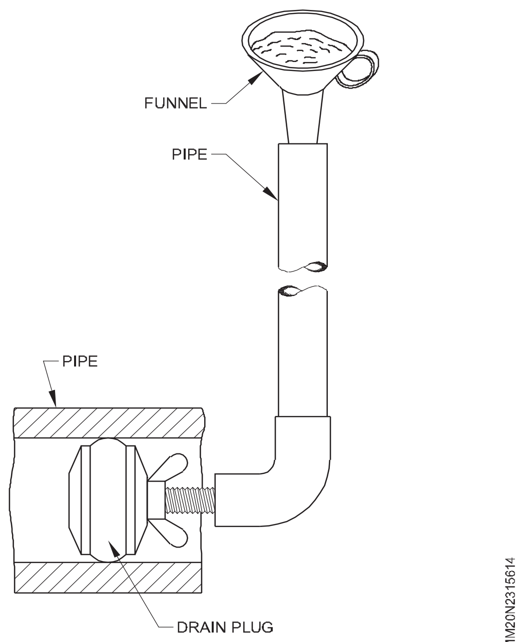
Fig 3



Hydrostatic or water test: The equipment required to conduct this test is drain plug/air bag stopper extrusion tubes, funnel and sight gauge.

Vertical pipes are temporarily installed on the top end of the installation to provide pressure or head on horizontal pipe and to record level of water. Colored water test is similar to this except that a soluble dye such as fluorescene is mixed with water to easily locate the leak. (Fig 4)

Fig 4



Smoke test: This test is less severe than the water test and is generally carried out where water is not available for apply hydrostatic test. Plug one ends of pipe, other end for testing smoke. After inserting the smoke rocket in pipe the touch paper is producing dense clouds of smoke which travel throughout this pipe work or smoke generator can be used to force the smoke under pressure to pipe. Check the installation for sign of smoke leaking from the joint, plugged end. (Fig 5, 6)

Fig 5

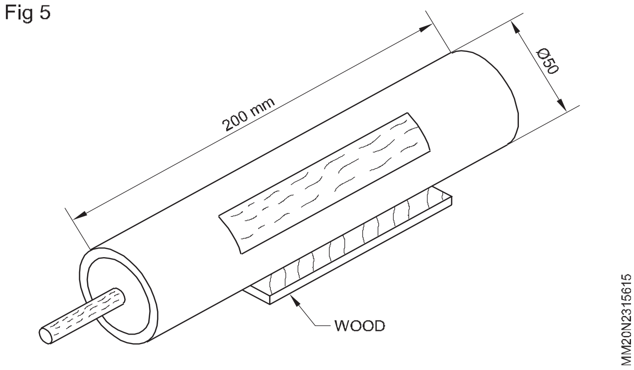
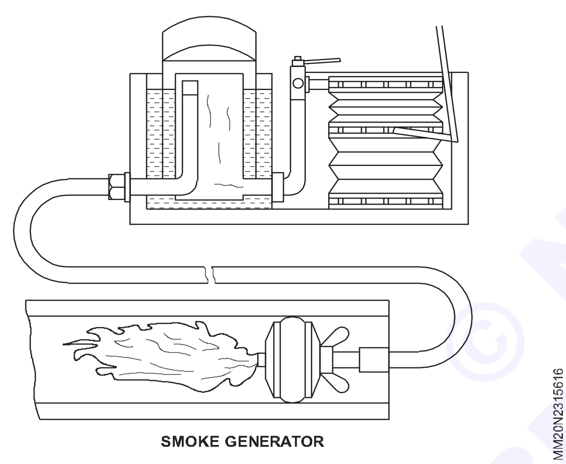
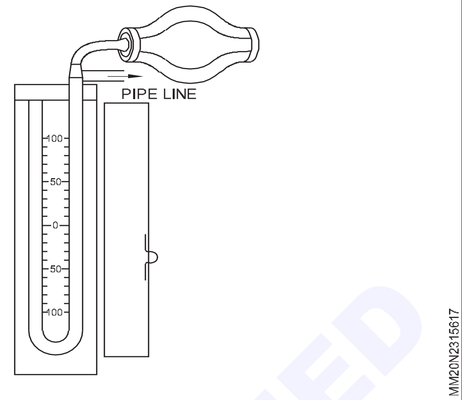


Fig 6



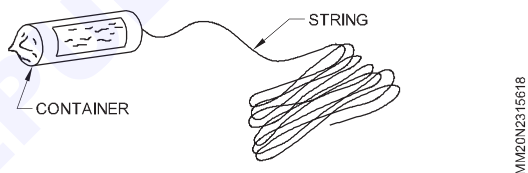
Pneumatic or air test: Air test into the pipe line is similar to smoke test. Connect manometer to pipe line. The hand ballon are pumped to pressure air with the pipe work This should be maintained for a period without dropping back. If the level falls, the leak has to be found and this can be done by applying soap solution on joints. (Fig 7).

Fig 7



Chemical smell test or odour test: A small container filled with strong pungent chemical such as crude oil of peper minit is attached to a long length of string and flushed through a trap into the pipe work pulling on the string opens the container leak is detected by smell. (Fig 8)

Fig 8



Testing of existing connection

Objectives: At the end of this lesson you shall be able to
- **state the purpose of drain testing**
- **state the method of drain testing**
- **explain the drain testing.**

Drain testing: After the drain has been laid and before backfilling, or pouring concretor or granular material round the pipes, it should be tested.

The three main methods of testing underground drains for soundness are:

1 Water tests

2 Air tests

3 Smoke tests

If any leak occurs, the defective pipe or joint should be rectified and the drain again tested. Wherever possible, testing should be carried out between the manholes and short branch drains tested along with the main drainage system. The test before backfilling should be carried out the pipe should be supported to prevent any movement.

Water Tests

1 The drain should be filled with water, to give a test pressure equal to 1.5 m of water. Steeply grade drains should be tested in stages, so that the head of water at the lower end does not exceed 4 m.

2 The pipeline should be allowed to stand for two hours and topped up with water.

3 After two hours the loss of water from the pipeline should be measured by noting the quantity of water needed to maintain the test head for 30 minutes.

Pipe colour codes

Objectives : At the end of this lesson you shall be able to
- **define colour code**
- **state the colour codes for different mediums.**

Colour code : Pipes are coated with different colour to identify the type of medium transferred/converted through the pipe line. The table of shows the pipe line colour codes for different medium. (Fig 1)

Fig 1

TYPE OF MEDIUM		COLOUR
• LUBRICATING OIL		YELLOW
• FUEL OIL		BROWN
• DIESEL OIL		PURPLE
• STEAM		GREY
• COMPRESSED AIR		WHITE
• SEA WATER		GREEN
• FRESH WATER		SKY BLUE
• FIRE MAIN LINE		RED

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1 Do Follow all safe work instructions
2 Do Follow suitable clothing for this job
3 Do use all personal protective equipment (PPE) as directed
4 Do practice good housekeeping.
5 Do know what to do in the event of emergency.
6 Do Follow manufactures recommended standards for the operation and care of tools and equipment.
7 Do Follow all safe procedures "When in doubt ask".
8 Do use air respirator While Working chemical pipe line.
9 Do avoid work inside a classed chamber if necessary provide correct veneration.
10 Don't try to work on a chemical contained pipe line remove chemical and clean properly and do work.
11 Don't enter a trech that is not sloped or supported as required by rejection.
12 Don't walk under suspended loads or between unsecured materials or equipment.

Safety precautions to be steered while working at pipeline

Working at pipelines, whether for maintenance, risks that require strict construction, or inspection, involves potential safety precautions to ensure the well-being of workers and the integrity of the pipeline. Here are some essential safety precautions to observe while working at pipelines

Pre-Work Planning

Conduct a thorough job and analysis (JHA or risk assessment before starting work.

Develop a comprehensive work plan that outlines racks, responsibilities, and safety measures.

Training and Competence:

Ensure that all workers an adequately trained and competent to perform their assigned tasks.

Provide specialized training for specific pipeline tasks, such as welding, trenching, or confined space entry.

Personal Protective Equipment (PPE):

Require all personnel to wear appropriate PPE, such as hard hats, safety glasses, gloves, hearing protection, and high-visibility clothing.

Ensure that workers have the necessary respiratory protection if dealing with hazardous materials.

Gas Detection and Ventilation:

Use gas detectors to monitor the atmosphere for hazardous gases like methane, hydrogen

Sulfide, or other flammable or toxic substances.

Implement proper ventilation or forced air exchange in confined spaces or areas with potentially harmful gases.

Trench Safety:

When working in excavations or trenches, follow OSHA guidelines for trench safety, including shoring, sloping, or using protective trench boxes.

Establish clearly marked and guarded areas around trenches.

Confined Space Entry:

Adhere to confined space entry procedures when working in or near confined spaces within the pipeline system.

Conduct proper atmospheric testing, and ensure workers are trained for confined space entry.

Hydro testing Safety:

When as inducting hydrostatic testing, ensure that all equipment is properly secured and regularly inspected for leaks.

Be prepared for unexpected releases of pressurized fluids.

Excavation and Ground Disturbance:

Contact the relevant authorities to locate and mark underground utilities before digging to prevent accidental damage to pipelines and other utilities Implement safe excavation practices, such as hand digging when close to pipelines.

Fire Safety:

Keep fire extinguishers and fire suppression equipment readily available at the worksite

Ensure that all personnel know the location of fire exits and emergency evacuation procedures

Communication and Emergency Response:

Establish clear communication protocols, including radios or other means, to ensure that workers can contact each other and emergency services

Develop and rehearse emergency response plans for pipeline incidents, including leaks or ruptures

Lockout/Tag out: Implement lockout/tag out procedures when working on pipelines to control hazardous energy sources and prevent accidental startup.

Hot Work Safety:

When conducting hot work like welding or cutting near pipelines, ensure proper fire prevention measures are in place, including fire-resistant barriers and fire watches. Use flame-resistant protective clothing and welding curtains

Environmental Protection:

Prevent spills and leaks by using appropriate containment measures like berms, absorbent materials, and spill kits.

Follow environmental regulations and guidelines to minimize the impact of your work on the surrounding ecosystem.

Pipeline Marking and Identification:

Clearly mark the location of pipelines and provide information on the type of material being transported and emergency contact numbers.

Quality Control and Inspection:

Conduct quality control and inspection of materials, equipment, and workmanship to prevent defects that could lead to failures in the pipeline.

Emergency Shutdown Procedures:

Ensure that workers are familiar with emergency shutdown procedures and can quickly stop the flow of material in case of a pipeline emergency

Documentation: Maintain thorough records of safety inspections, equipment maintenance, and emergency response drills.

Gate valve

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

- **identify a gate-valve**
- **state the constructional features of a gate-valve**
- **state the common defects in gate-valves, their causes and remedies**

Gate-valve

The gate-valve gets its name from the gate-like disc that slides across the path of the flow. This valve provides an unobstructed waterway when fully open. This feature makes the gate-valve useful in large piping installations. It is best suited for main supply lines and pump-lines. It should not be used to regulate flow. It should either be fully opened or completely closed.

It is one of the most common valves found in a water distribution system. (Figs 1 & 2)

Fig 1

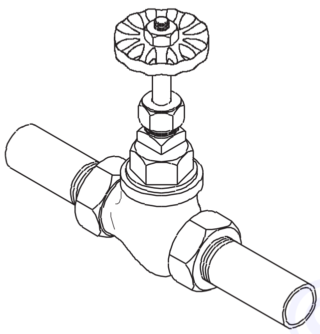
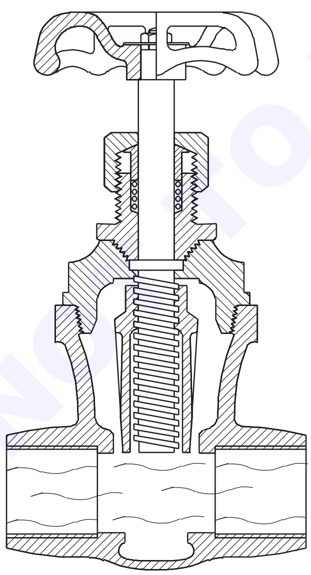
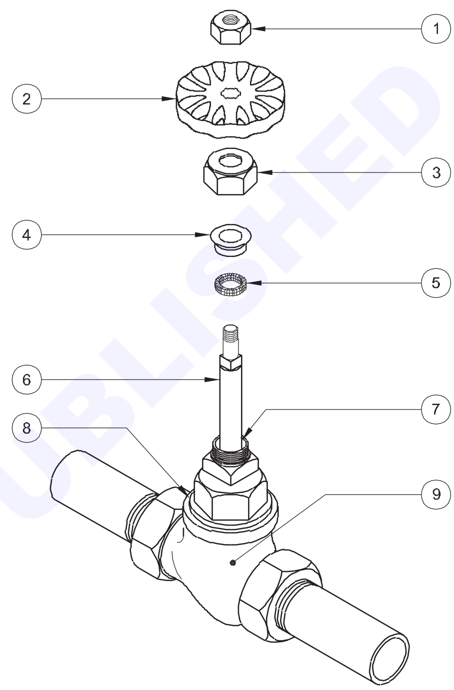


Fig 2



Parts of a gate-valve (Fig 3)

Fig 3



1 Hand wheel nut
2 Hand wheel
3 Gland nut
4 Stuffing gland
5 Packing
6 Shaft or spindle
7 Stuffing box
8 Bonnet
9 Gate-valve body

Common in the working of gate valves, their causes and remedies

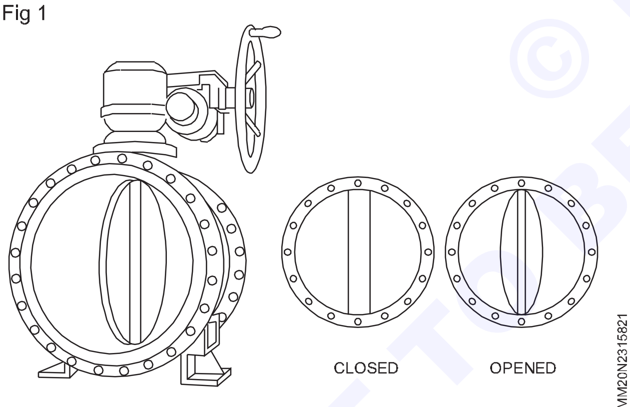
Defects	Causes	Remedies
Water flowing from around Stuffing box screw.	Defective packing in the Stuffing box.	Renew packing with Asbestos hemp and water Pump grease.
	Gland nut loose.	Tighten the gland nut.
Valve hard to turn on and off.	Stuffing box packing is dry.	Renew packing or drop a Little oil into the stuffing box.
	Spindle is bent.	Replace the spindle.
Spindle rotates continuously when Turned so that the gate-valve does not close.	Spindle thread badly worn out.	Replace the worn out part.

Butterfly valves

Objectives : At end of the lesson you shall be able to
- **identify the butterfly valves**
- **state the constructional features of a butterfly valve.**

In butterfly valves, the flow is regulated through a disc-type element held in place in the centre of the valve by a rod. Similar to ball valves, valve operation time is short because the valving element is simply rotated a quarter turn (90°)to open or close the passage way (Fig 1).

Fig 1



Butterfly valves are characterized by their simple constructing, lightness in weight, and compact design. Their face-to-face dimension is often extremely small, making the pressure drop across a butterfly valve much smaller than globe valves (see below). Materials used for the valving element and sealing can limit their applications at higher temperature or with certain types of fluids. Butterfly valves are oftern used on applications for water and air, and in applications with large pipe diameters.

Globe valves

In this type of valve, flow rate control is determined not by the size of the opening in the valve seat, but rather by the lift of the valve plug (the distance the valve plug is form the valve seat). One feature of globe valves is that even if used in the partially open position, there is a less risk of damage to the valve seat or valve plug by the fluid than with other types of manual valves. Among the various configurations available, needle type of globe valves are particularly well suited for flow rate control.

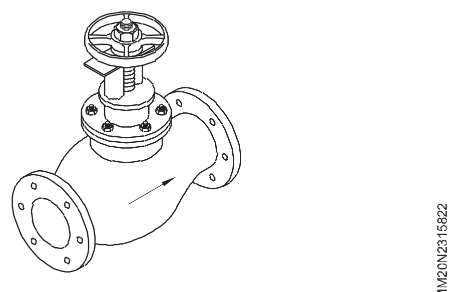
Other points to consider about globe valves is that the pressure drop across the valve is greater than that of many other types of valves because the passageway is S-shaped. Valve operation time is also longer because the valve stem must be turned several times in order to open and close the valve, and this may eventually cause leakage of the gland seal(packing). Furthermore, care must be taken not to turn the valve shaft too far because there is a possibility it could damage the seating surface.

Systems for controlling air, steam and water. The globe shaped body of the valve has a partition in it. This partition closes off the inlet side of the valve from the outlet side. (Fig 2)

The upper side of the opening is ground smooth.

A rubber disc or metallic disc is attached to the end of the stem which presses down against the smooth opening when the handle is turned clockwise. This closes the valve and stops the flow.

Fig 2



The top of the housing is hollowed out to receive some packing material. This packing should be replaced if the valve begins to leak between the packing nut and the valve stem.

Advantages: The major advantages of the globe valves are as follows.

- The critical parts such as washer, seat and packing can be replaced.
- The valve permits accurate control of the flow of water.
- The valve can be used repeatedly, because it can be repaired easily.

The globe valve consists of the following parts. (Fig 3)

1 Hand wheel

2 Shaft or spindle

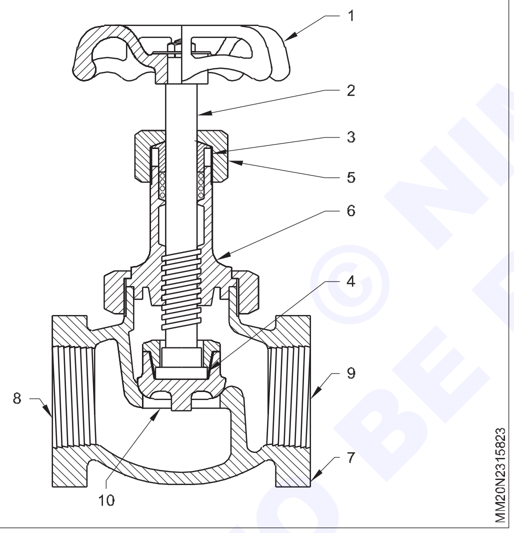
3 Gland nut

4 Stuffing box with packing

5 Bonnet

6 Threaded portion of spindle

Fig 3



7 Metal valve or disk holder with rubberwasher

8 Inlet

9 Outlet

10 Valve seat

Reseating tool (Fig 4): The parts of a reseating tool are as follows.

1 Hand wheel

2 Shaft or stem cone

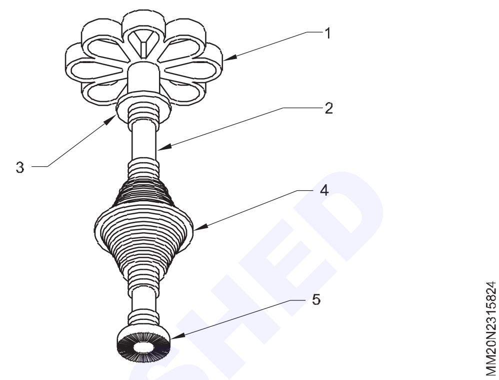
3 Feed screw or collar

4 Tapered adapter

5 Cutters (inter- changeable)

This is used to level and clean the valve seat area. The reseating tool has a steel shaft with a round handle on one end and a cutter on the other.

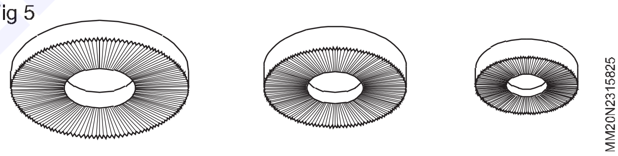
Fig 4



The cutter can be changed to the size required and is held down to the seat by a feed screw.

The tapered adapter cone has threads on both sides and is reversible. The threads on one side of the adapter are from 3/8" to 1 1/4". The reseating tool has three or four different cutters having sizes 3/8", 1/2", 3/4" and 1". (Fig 5)

Fig 5



Non-return valve/check valve

Non-return valve: Water supply piping systems are used several mechanical devices to control and regulate the fluids and gases flowing through them.

The non-return valve allows one-way flow in water supply or drainage lines. It is also called a check valve. Valves are made of cast iron, brass, bronze or plastic.

Sometimes two or more different kinds of materials are used on a single valve. There are many types of check valves available in the market.

The swing check valve consists of the following parts.

Diaphragm valve

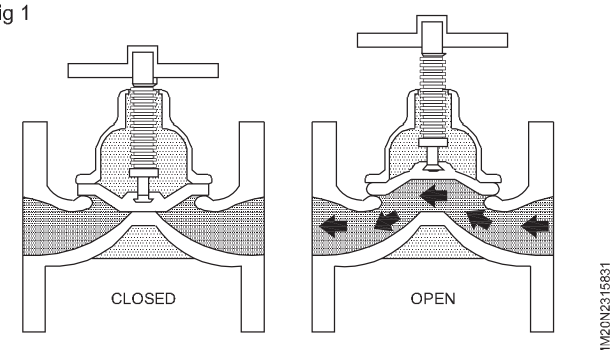
Objective : At the end of this lesson you shall be able to

- **explain the working of a diaphragm valve**

Diaphragm valve use a pinching method to stop the valve flow using a flexible diaphragm. They are available in two types weir and straight way. The most commonly seen of the two is the weir-type. This is because the straight-way type requires additional stretching of the diaphragm, which can shorten the diaphragm's life-span. (Fig 1)

One of the major advantages of using diaphragm valves is that the valve components can be isolated from the process fluid. Similarly, this construction helps prevent leakage of the fluid without the use of a gland seal(packing)as seen in other types of valves. On the other hand, the diaphragm becomes worn more easily and regular maintenance is necessary if the valve is used on a regular basis. These types of valves are generally not suited for very high temperature fluids and are mainly used on liquid systems.

Fig 1



Preventive and breakdown maintenance of milling machine

Objectives : At the end of this lesson you shall be able to
- **list preventive maintenance schedule of milling machine**
- **explain various problems causes and their remedies related to milling machine.**

Preventive maintenance

Daily

- Clean all exposed surface of limit switches and trip dogs
- Lubricate points as specified in the manual under heading instructions for lubrications
- Use correct grade of oil as mentioned in the manual under heading "Recommended Lubricants".

Weekly

- Wipe clean the entire machine
- Lubricate oil nipple for the hand wheel of vertical milling head as per instructions in the manual under heading "Instruction for Lubricants".
- Refill the reservior of feed box and distribution box to level marked on oil sight glass to compensate the lost oil.
- Check coolant level in the base plate & fill if necessary
- Check all flexible conduits for any damage

Monthly

- Refill the reservoir of column and overarm bearing brackets to level marked on oil sight glass to compensate the lost oil.
- Fill anti-friction bearing grease in bearings of vertical milling head and smear grease on bevel gear as per instructions in the manual under heading "Instructions for lubricants".
- Clean the coolant sump and fill fresh coolant.
- Clean the inter of electrical cabinet preferably with a vacuum cleaner.

Discounted before attempting to cleaning.

Six monthly

- Drain out oil from column feed box and distribution box, flush the sumps and refill fresh oil.
- All terminal connections to be inspected and tightened, if necessary. All electrical elements to be properly cleaned.
- Electromagnetic clutches to be checked for proper functioning.
- Climb milling attachment to be adjustment if required.

Yearly

- Check the machine level
- Check machine adjustment and slide shakes.
- Proper tightening of all fasteners and fitting of pins to be done, if required.
- Fill antification bearing greases in motor bearings.

Causes and remedies related to milling machine break down are listed in Table 1.

Table 1

Problems	Causes	Remedies
Column and main drive a Excessive heating of main spindle.	Improper adjustment of axial and radial plays of the spindle bearings. Less or excessive quantity of lubricants	Adjust the play of the spindle taper roller bearings. Check the pipe connection from pump to the bearing housing Proper greasing of V.M. Head spindle bearings for 'V' machine.
b Lubrication pump noisy or does not pump sufficient quantity of oil.	Pump plunger loose in the bore. Choking of suction filter	Replace worn-out parts if necessary. Clean filter
c Too much instantaneous noise near main motor at starting.	Flexible coupling rubber bushes might have failed.	Replace rubber bushes of the coupling
d Main spindle does not stop quickly after switching off the main	Brake not functioning Excessive Armature play of the elctro magnetic brake	Check all the relevant electrical connections & tighten them Adjust the Armature play to the recommended value.
Knee a Knee movement jerky	Knee gib screws may be too loose or too tight Improper lubrication.	Adjust the screws for easy movement. Ensure correct lubrication.
b Vertical feed screw heats up or sizes when the knee is taken up or down.	Insufficient lubrication	Ensure correct lubrication. Check for proper lubrication.
c Power feed movements occur when the crank handle is in vertical or cross cranking dia	Interlocking limit switches in front cover of knee not fixed or connected properly	Check the connection
d Vertical power drive engaging lever does not stay in engaged in horizontal position.	The spring loaded locating bush does not have sufficient force.	Replace compression spring if required
e Loud noise in knee at starting the vertical power drive or rapid.	Improper backlash setting of feed box to knee dive spur gear pair	Adjust the play with two screws at the top of feed box after taking out the taper pin lock with larger dia taper pin.
Feed box a Lubrication pump noisy or does not pump sufficient quantity of oil.	Pump plunger loose in the bore .	Replace worn out parts, if necessary.
b To much instantaneous noise near feed motor at starting.	Flexible coupling rubber bushes might have failed.	Replace rubber bushses of the coupling.
c Feed/rapid electromagnetic clutch not engaging to give feed/rapid.	Faulty electrical connections	Check all the relevant connection of clutches, contactor, limit switches and push buttons etc.
d The feed drive is not being braked properly when switched off	Faulty electrical connections The two clutches in feed box, which should energise simultaneously for braking action, are not functioning as desired	Check all the relevant connection of clutches, contactor, limit switches and push buttons etc

Problems	Causes	Remedies
Distribution box and saddle		
a Longitudinal or cross motion not occurring inspite of the feed box output shaft rotation and selector lever being in engaged position	Safety sheer pin broken	Replace the shear pin.
b Too frequent shearing off of the safety shear pin.	Excessive resistance to free movement of the machine	Check the easy movement of slides by hand and remove the cause of overloading before operating on power drive.
c Saddle hand movement very tight or jerky movement in power feed	Too less a clearance in gib	Adjust the gib
	Cross feed screw driving gear keyway is blocked by dirt or small chips.	Clean the parts and assemble back
	Improper lubrication	Ensure proper lubrication.
		Check the lubrication pump in distribution box and all pipe connections.
Table and over arm		
a Chatter when heavy cut is given	Excessive axial and radial play in main spindle.	Adjust axial and radial play
	Gibs of table,saddle or knee may be loose.	Adjust the gibs properly.
	Arbor support bushes running loose in the bronze bearings of the over arm bracket	Adjust ring nut on bronze bearing
	Clamping of knee saddle or table not effective	Check and improve clamping
	Improper foundation and bad levelling.	Follow the instructions on foundation, level the machine as per chart & tighten all grouting bolts.
	Excessive backlash in screw feed drive.	Replace worn out parts.
b Overarm support bracket too tight on the guideways	Nuts may be tight	Loosen the nuts

Problems	Causes	Remedies
a Lubrication distribution not effective	Dirt in the sump	Clean the sump and filter
b Coolant not flowing.	Coolant motor running in opposite direction. Dirt in the sump Dirt clogged in the mesh Low voltage supply	Interchange any two phases in the electrical connection of coolant motor. Clean the sump Clean the mesh Check voltage supply
c Electrical motors do not start	Blown out fuse. Loose contact in circuit Defective contact points in the contactor.	Replace fuse Tighten all screws and electrical contacts. Clean or replace contacts if necessary
d Indicating light on electrical cabinet do not light up inspite of switch being in 'ON' position	Loose connections Defective light bulb	Check and tighten the electrical connections Replace the bulb
e Excessive noise of electric motor/ and excessive drive vibrations.	Faulty motor/s	Replace the motor/s.

Name of the machine : Location of the machine :

Machine Number :

Model No & Make :

CHECK - LIST FOR MACHINE INSPECTION (Milling machine)

Inspect the following items and tick in the appropriate column and list the remedial measures for the defective items.

Item to be checked	Good working/Satisfactory/Status	Defective	Remedial measures
Level of the machine			
Belt and its tension			
Bearing sound			
Driving clutch a			
Working in all the speeds			
Working in all the feeds			
Lubrication system			
Coolant system			
Table travel			
Cross - slide & its movement			
Saddle & its travels			
Knee up & down movement			
Electrical controls			
Safety guards			

Inspected by

Signature

Name :

Date : Signature of in-charge

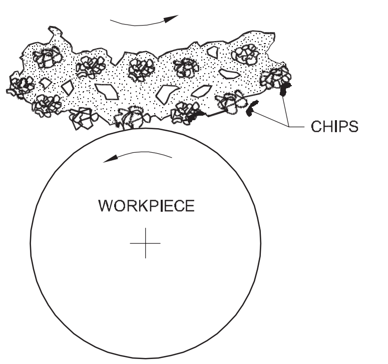
Introduction to grinding process

Objectives : At the end of this lesson you shall be able to
- **state the importance of the grinding operation**
- **state the three basic kinds of precision grinding and their working principles**
- **state the purpose of a grinding machine**
- **name the common types of precision grinders.**

Introduction

Grinding is a metal cutting operation performed by means of a rotating abrasive wheel that acts as a cutting tool. (Fig 1) Mostly, grinding is a finishing operation because it removes comparatively less metal (0.25 to 0.50 mm) in most operations.

Fig 1



Grinding has three advantages over other metal cutting methods.

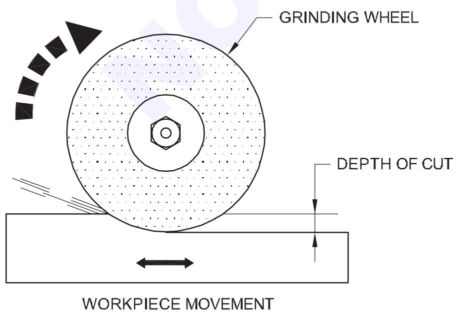
- It is the only economical method of cutting hard materials like hardened steel.
- It produces very smooth surfaces up to N4, suitable for bearing surface.
- Surface pressure is minimum in grinding. It is suitable for light work, which will spring away from the cutting tool in the other machining processes.

Types of grinding operations

There are four main grinding operations.

Surface grinding (Fig 2)

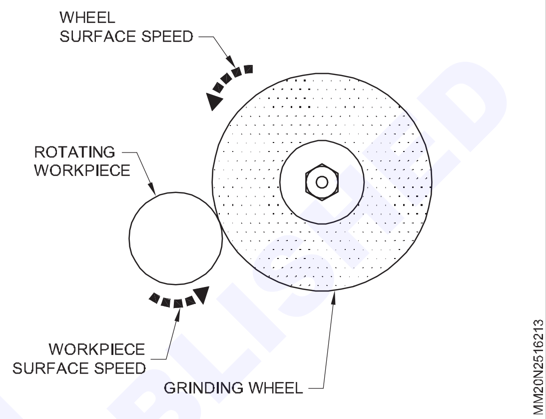
Fig 2



It is the operation of using precision grinding machines to produce flat or plain surfaces on workpieces. The workpiece is at a constant speed below the grinding wheel.

External cylindrical grinding (Fig 3)

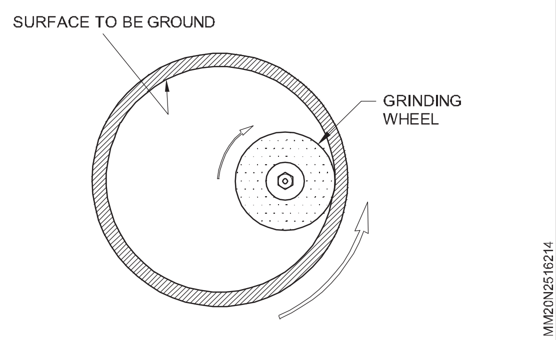
Fig 3



It produces a straight or tapered cylindrical surface. The workpiece is rotated about its own axis between centres as it passes lengthwise across the face of a revolving grinding wheel.

Internal cylindrical grinding (Fig 4)

Fig 4



It produces internal cylindrical holes straight or taper sided.

The workpieces are held in the chuck and rotated precisely about their axis. A revolving grinding wheel, smaller than the dia. of the hole to be ground, is set against the rotation of the workpiece and traverses along the surface of the hole.

Form grinding

It produces formed surfaces. Specially shaped grinding wheels grind the formed surfaces as is the case in grinding gear teeth, threads, splined shafts etc.

Grinding Machines

Grinding machines are precision machine tools, designed to remove metal from a workpiece to close tolerances (up to 0.0025 mm) and to produce high quality surface finish (up to N4).

The common types of precision grinders are: (Fig 5)

- surface grinders
- cylindrical grinders
- tool and cutter grinders.

There are two major groups of grinding machines.

- Off hand or rough grinders (Fig 6)
- Precision grinders

Surface grinders

Surface grinders are used to grind flat, parallel surfaces or stepped surfaces. The surface produced by a surface grinder is more economical and more accurate than the surface obtained by filing or scraping.

Cylindrical grinder

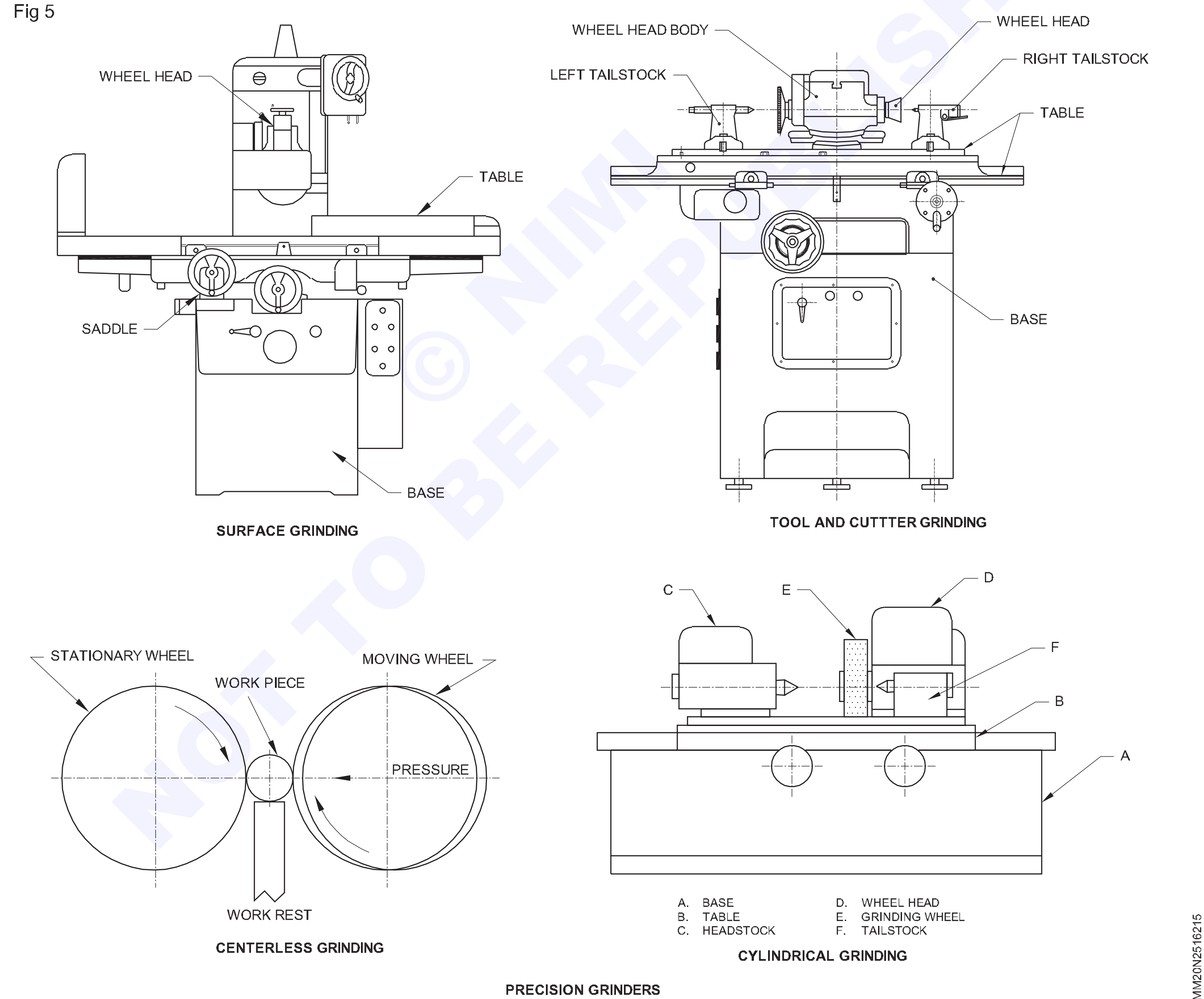
Cylindrical grinders are used to grind external and internal cylindrical surfaces. The cylindrical surfaces produced may be plain, tapered or stepped.

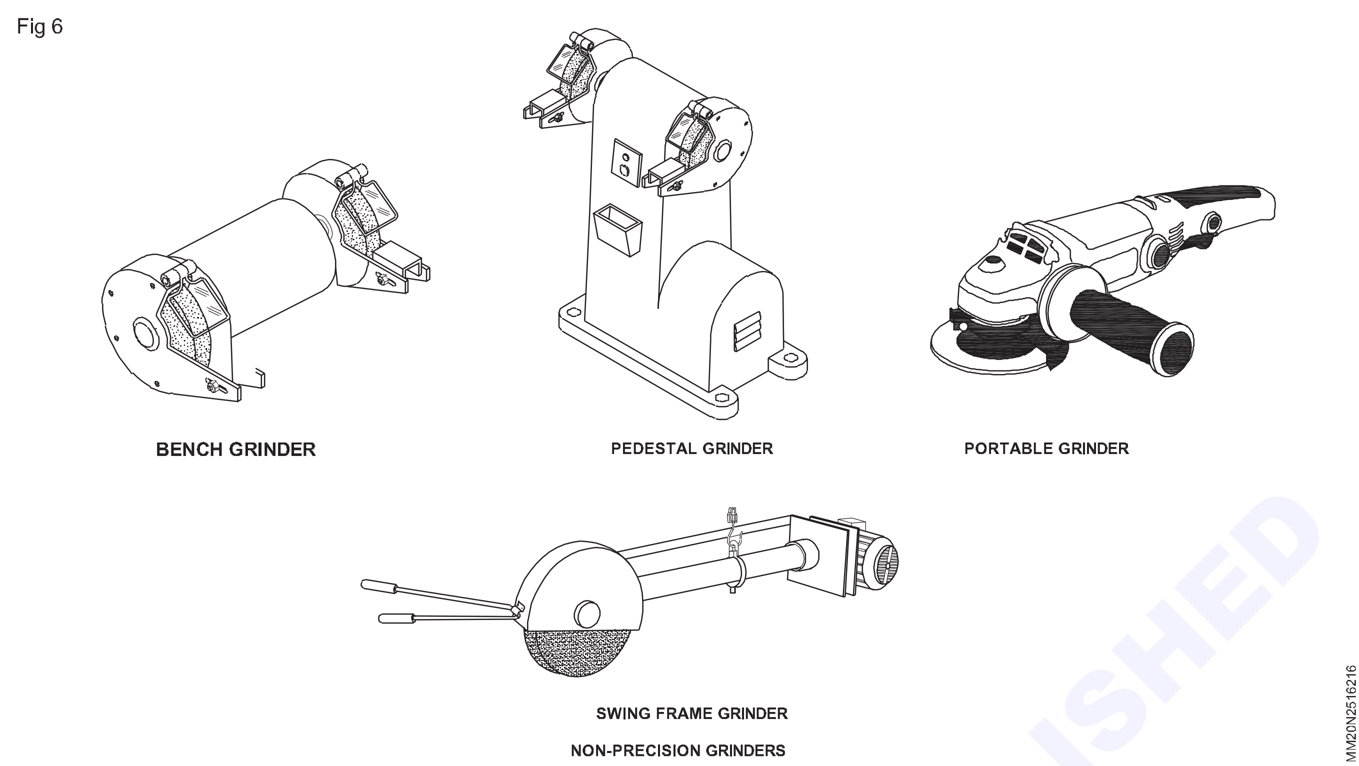
Tool and cutter grinder

A tool and cutter grinder is mainly used to sharpen single point cutting tools, milling cutters etc. It also can be used as a surface and cylindrical grinder along with some attachments.

Different types of grinding machines

Fig 5





Surface grinder

Objectives: At the end of this lesson you shall be able to
- **state the types and parts of surface grinding**
- **describe the construction of surface grinder**

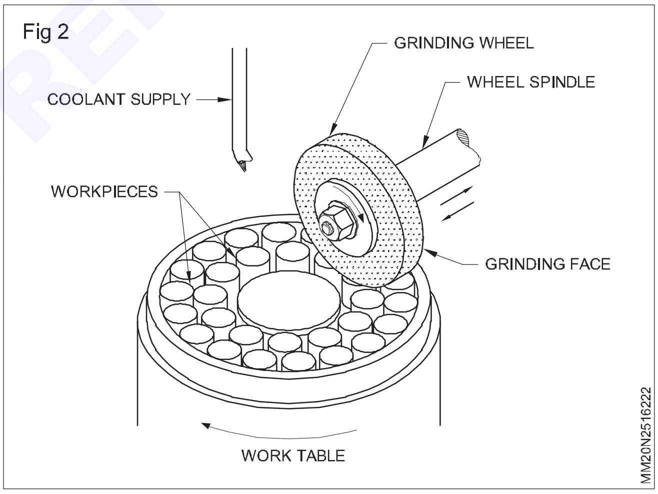
Surface grinding machine

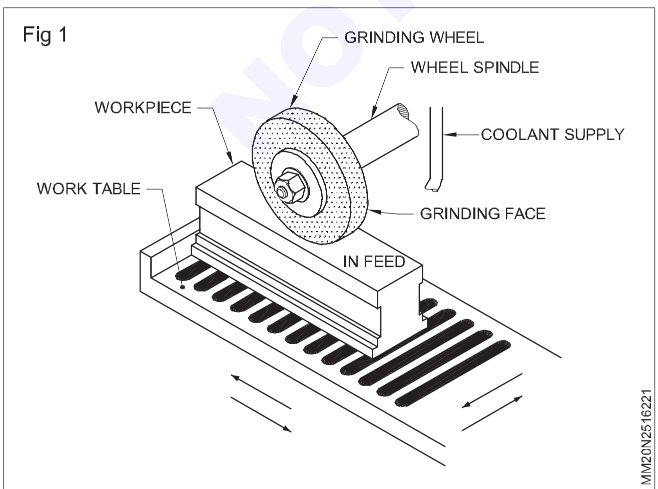
It is a precision grinding machine to produce flat surfaces on a workpiece. It is a more economical and more practical method of accurately finishing flat surfaces than filing and scraping.

Types of surface grinders

There are four types of surface grinders.

- Horizontal spindle reciprocating table (Fig 1)
- Horizontal spindle rotary table (Fig 2)
- Vertical spindle reciprocating table (Fig 3)
- Vertical spindle rotary table (Fig 4)





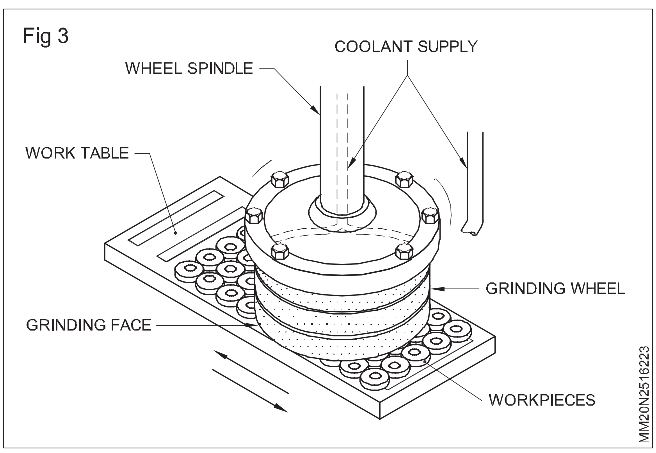
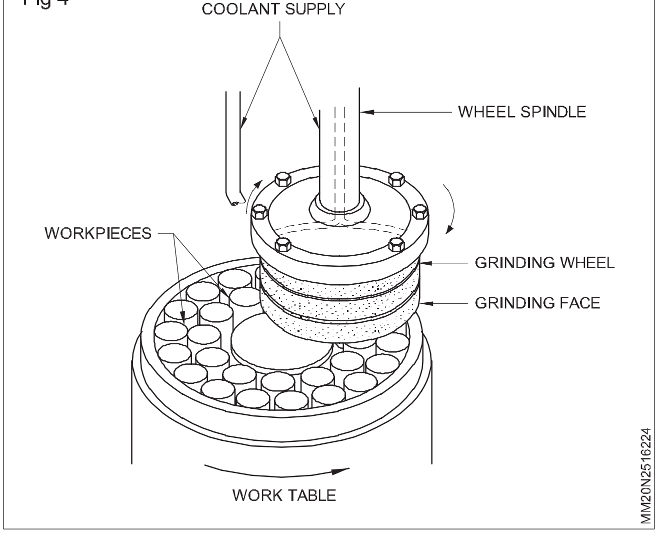


Fig 4



Parts

Horizontal spindle reciprocating table surface grinder main parts (Fig 5).

- Base
- Saddle
- Table
- Wheel head

Base

It is a rigid rectangular box contains the driving mechanism (hydraulic device tank and motor). It has a column at the back for supporting the wheel head on the top of the base provide precision guide ways for moving saddle.

Saddle

It is a frame. It contains the table in its cross wise movement. It is used to give cross feed to the work. It can be removed by hand or auto feed.

Table

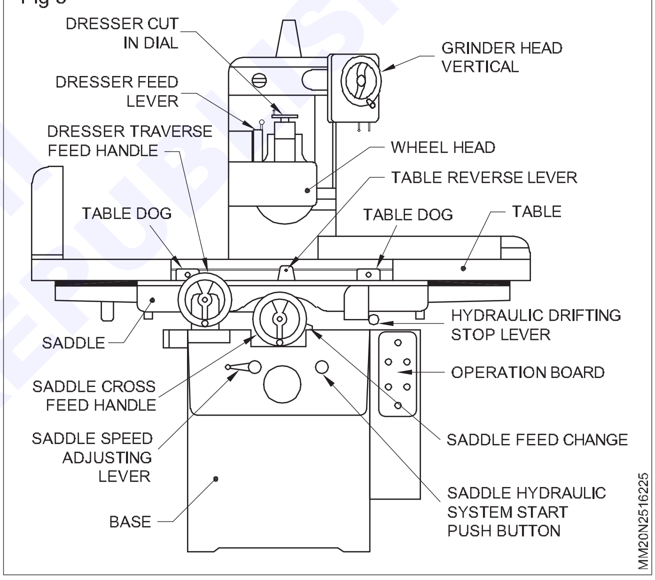
It is fitted on the saddle. It is reciprocating along the guide ways to provide the longitudinal feed to the work. The surface is accurately machined and T-slots are provided for clamping of workpieces directly on the table or for clamping magnetic chuck and grinding fixtures. It is moved by hand or auto feed.

Wheel head

It is mounted on the column secured to the base. It can be moved vertically up and down to by rotating a hand wheel accommodate work piece of different height and set the wheel for depth of cut. The wheel rotates at a constant wheel speed. (1500 rpm)

Some surface grinding machines the dressing unit mounted on the top of the wheel head and slide for dressing the wheel with help of rotating micrometer collar handle. Dress the wheel 0.015 mm to 0.025 mm giving feed.

Fig 5



Cylindrical grinders

Objectives: At the end of this lesson you shall be able to
- **state the purpose of a cylindrical grinder**
- **state the types of cylindrical grinders**
- **list the parts and functions of a plain centre type cylindrical grinder**
- **state the specification of a cylindrical grinder.**

Cylindrical grinders are used to grind the external or internal surfaces of a cylindrical workpiece.

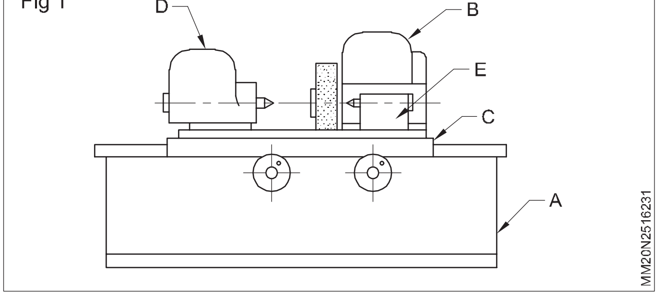
By cylindrical grinding the diameter of a workpiece can be maintained to a close tolerance (upto 0.0025 mm), and high quality surface finish can be obtained (upto N4).

The four types of cylindrical grinders are:

- external cylindrical grinders
- internal cylindrical grinders
- universal cylindrical grinders
- centreless grinders

Plain centre type cylindrical grinder (Fig 1)

Fig 1



It is mainly intended to produce plain, stepped or tapered

Parts

The main parts of this type of a cylindrical grinder are the:

Base

Wheel head

Table

Headstock

Foot-stock

Functions

Base (A) is made out of cast iron. It is heavy and provides rigidity to the machine. The top surface is machined to form guideway to the table.

The wheel head (B) is mounted on the cross-slide. It moves perpendicular to give depth of cut.

The table (C) is mounted on the bed-ways. It reciprocates past the wheel. It can be swivelled to grind taper. Trip dogs are provided to control reciprocation.

The headstock (D) is mounted on the table at the left end. It has a motor with 2 or 4 speed steps to drive the work. A dead centre is mounted in the spindle of this head to support the workpiece between centres.

The foot-stock (E) is mounted on the table at the right hand side. It can be moved and locked at any place along the table is spring-loaded and carries a dead centre to support the work.

The spring tension provides even, stiff support

Specification of cylindrical grinder

Maximum diameter of workpiece which can be held

The breadth of the table

Maximum table traverse movement

Maximum diameters of the grinding wheel

H.P of the spindle motor

Weight of the machine

Safety

Always wear safety goggles

Ensure the safety guards properly placed

Before starting the machine the wheel must be inspected

Ensure the holding devices are sufficiently tightened

Be sure to allowable clearance between hand and grinding wheel

Before starting of hydraulic system don't hold the job in between centre.

If the work is heavy shut the machine down when placing the work between centres.

Safety to be observed while working on grinding machine

Objective: At the end of this lesson you shall be able to
- **state the precautions to be observed while on grinding.**

Safety precautions

All grinding machines have parts that move at high speed. The machines are fitted with guards to protect the operator form injury and to make operation of the machine as safe as possible

Despite this, accidents still happen

These accidents are usually caused by:

- Ignorance
- Thoughtlessness
- Carelessness

Lack of consideration for the safety of others.

These accidents can be prevented by thinking before doing

Various unsafe conditions and procedure are mentioned throughout this manual. Learn to recognize them and gain a clear understanding of what should be done in each case

The safety precautions to be taken when using grinding machines may be divided into four areas.

- General
- Machine
- Personal

General safety precautions

- Key the work area around machines free of obstacles and waste a material.
- Immediately clean up any oil, grease or coolant spilled on the floor
- Place cleaning cloths and waste materials in the proper containers after use
- Store hand tools and accessories away from machines after use
- Do not handle work pieces which may be hot as a result of grinding operations.
- Use the correct hand tool for the job in hand.
- Seek assistance when handling heavy machine accessories, grinding wheels or work pieces.
- Learn the location of the nearest fire alarm.
- Learn where fire extinguishers are located and how to use them.
- Stop, look and think before starting any new operation Ensure lighting is adequate
- Always be courteous, considerate an obliging to others

Machine safety precautions

- Operation machines only when you are authorized by your instructor to do so
- Follow your instructor's directions carefully
- Keep your fingers away from the moving parts of the machine
- Do not start a machine unless all machine guards are correctly fitted
- Make sure the workpiece is securely fitted to the work table before starting a grinding operation.
- Do not handle the surface of the workpiece while the machine is operating
- Do not use your hand to stop movement of any part of the machine.
- Use a brush, not your hand to clean ground material from the workpiece and machine.
- Keep the machine free of tools, accessories and parts not being used at the time.
- When setting the work table for automatic traverse, allow the wheel to over travel the workpiece in each direction.
- Do not clamp hardend workpiece too tightly in the jaws of a vice
- Whenever possible, use a coolant during a grinding operation
- If a grit exhaust system is fitted to the machine, use it all times during grinding
- Stop the machine before cleaning or oiling it or before making any adjustments to the accessories or to the workpiece.
- Dot not leave a machine while it is still running
- Do not touch or lean on a machine someone else is using
- Do not divert the attention of someone else using a machine.

Personal safety precautions

- Wear goggles at all times when using a grinding machine.

- Report any injuries, however slight, to your instructor or supervisor
- Wear close-fitting clothes.
- Avoid wearing a tie and long sleeves If necessary. Truck your tie carefully inside your shirt or keep in inside of outer clothing buttoned or zipped up high and rollup your sleeves.
- If your hair is long, wear a protective head covering and make sure your hair is completely enclosed in side it
- Do not wear a watch, rings or other loose ornaments
- Do not wear gloves
- Wipe your hands clean before operating a machine adjusting accessories or handing a workpiece.

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Surface Grinder Safety

Make sure you are wearing your safety glasses before operating the machine.

Be familiar with the machine before attempting to operate it on your own. Ask the instructor if you are unsure about what to do.

Know where the emergency off switch is located in case of an emergency and be sure you can reach it.

Before cleaning the chuck, loading parts or working around the wheel it, must be OFF.

When you first turn on the grinding wheel do not stand directly in line with it, always stand to one side. Make sure the guard is in place. The guard should cover at least half of the wheel. If supplementary guards are available position them before starting to grind.

Let the wheel run for about a minute at operating speed before starting to work. If a wheel is going to fail it usually does so within the first minute.

Do not grind on the side of the wheel unless the wheel is made for that purpose. Straight wheels are not designed for side grinding. Be sure to use the correct grade of wheel.

File off any burrs on the workpiece before it is placed on the magnetic chuck. Make sure it is as clean as possible

Clean the magnetic chuck with a cloth and then wipe it with your hand before putting the piece down. This secures the best possible holding situation. Turn on the magnet.

Makes sure the magnet is turned on so the workpiece is secure. This means that any parts you want to grind need to be magnetic. If they are not magnetic you need to find another way to hold them (between two magnetic parts for example). Check that the part is securely fastened by trying to move it with your hand.

When finished grinding make sure the wheel has stopped before removing the workpiece(s), cleaning or making adjustments. Do not reach near or around the wheel while it is running.

Never wear a wristwatch while surface grinding. This is a general safety rule but in addition the magnetism may ruin the watch mechanisms.

Do NOT use a chuck that is not magnetizing properly.

Check that the work clears the wheel before starting the machine.

Never jam the work into the grinding wheel. This means approaching the wheel to the work in a controlled why with the table reciprocating. The first contact with the wheel and work should be very light and produce minimal sparks.

If you are using coolant, turn off the coolant a minute or so before you turn off the wheel, This prevents coolant from collecting at the bottom of the wheel and drying there while the wheel is stopped. This dried coolant will throw the wheel out of balance.

Keep the face of the wheel evenly dressed.

Do not grind without proper ventilation. Make sure you turn on the ventilation system before starting to grind.

If you are changing a grinding wheel, there are a number of safety considerations to be aware of and implement. They are outside the scope of this project.

Grinding wheel

Objectives: At the end of this lesson you shall be able to
- **explain grinding wheel**
- **state the types of abrasives**
- **explain grain and grade**
- **state the types of bonds.**

Grinding wheel

A grinding wheel is multipoint cutting tool made up of many hard particles known as abrasive. The abrasive grains are held together with adhesive substance known as bond.

The wheel may consist of one piece or segments of abrasive blocks built up to a solid wheel.

Abrasives

An abrasives are hard, tough, sharp edge and resistance to fracture used for cutting other materials.

There are two types of abrasives

Natural abrasive

Artificial abrasive

Natural abrasives

The natural abrasives are emery, corundum, sandstone or solid quartz and diamond.

Emery is a natural aluminium oxide. It contains aluminium iron oxide and other impurities.

Corundum also natural aluminium oxide it contains upto 95% and remainder is impurities.

Sand stone or quartz is one of the natural abrasive stones from which grind stones are shaped.

Diamond is less than quality of gem are crushed to produce abrasive grains for making grinding wheels and lapping compound.

Artificial abrasive

The artificial abrasive are silicon carbide and aluminium oxide.

Silicon carbide (SiC)

Silicon carbide abrasives are manufactured from silica sand. Silicon carbide is hard and brittle. It is used for grinding low tensile material like brass, copper, grey cast iron, aluminium. Silicon carbide is represented by letter 'S'.

Aluminium oxide (Al_2O_3)

This is manufactured from mineral bauxite. Aluminium oxide is tough and less brittle. It is used for grinding high tensile strength material like steels. Carbon steels, malleable iron, high speed steel and wrought iron. Aluminium oxide is represented letter 'A'.

The abrasives are selected depending upon the material being ground.

'Green' silicon carbide is used for very hard materials with low tensile strength such as cemented carbides.

'Brown' aluminium oxide is used for general purpose grinding of tough materials.

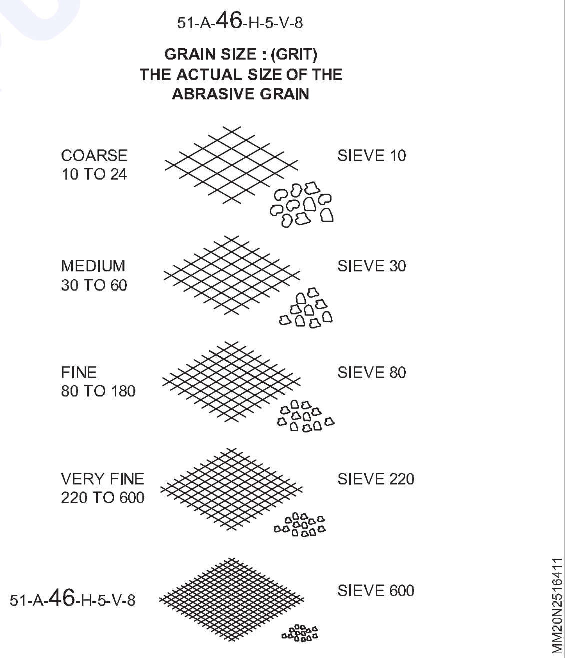
Aluminium oxide is used for grinding die steels.

Grain size (Grit size) (Fig 1)

The grit or grain size refer to the actual size of the abrasive particles. The grains size is denoted by a number. The sieve used to size the grain.

The larger the grit size number the finer the grit and the smaller the grit size number the large the grit.

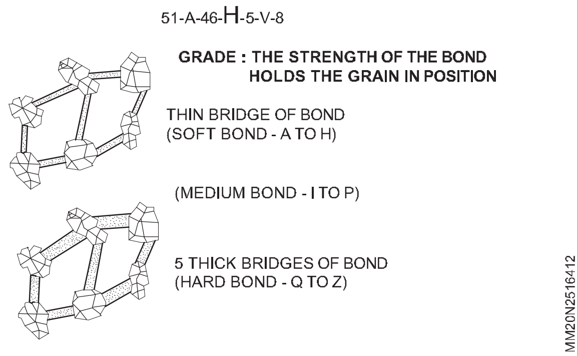
Fig 1



Grade (Fig 2)

Grade indicates the strength of the bond and, therefore, the 'hardness' of the wheel. In a hard wheel the bond is strong and it securely another the grit in place, and therefore, reduce the rate of wear. In a soft wheel, the bond is weak and the grit is easily detached resulting in a high rate of wear.

Fig 2



Alphate letters are used to indicate the grade of wheel

A to H - Soft

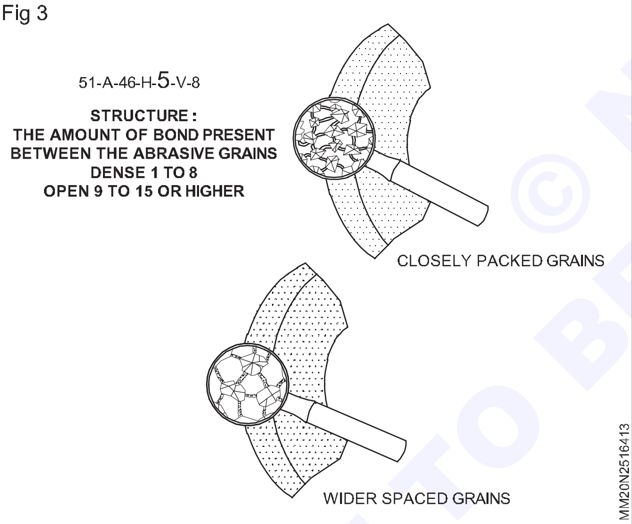
I to P - Medium

Q to Z - Hard

Structure (Fig 3)

This indicates the amount of bond present between the individual abrasive grains, and the closeness of the individual grains to each other. An open structured wheel will cut more freely. That is, it will remove more metal in a given time and produce less heat. It will not produce such a good finish as a close structured wheel.

Fig 3



The structure is specified by number from 1 to 15.1 is indicating dense structure 15 indicates most wider structure. 1 to 8 dense and 9 to 15 and above indicates open structure.

Open structure wheel is used for grinding soft tough and ductile metal and used rough grinding.

A closed structure wheel is used for finish grinding of hard and brittle metal.

Bond

The bond is the substance which, when mixed with abrasive grains, holds them together, enabling the mixture to be shaped to the form of the wheel, and after suitable treatment to take on the form of the wheel and the necessary mechanical strength for its work. The degree of hardness possessed by the bond is called the 'grade' of the wheel, and this indicates the ability of the bond to hold of bonding materials used for making wheels.

Types of bonds and their uses

Vitrified bond (V)

This is the most widely used bond. It has high porosity and strength which makes this type of wheel suitable for high rate of stock removal. It is not adversely affected by water, acid, oils at ordinary temperature conditions.

Silicate bond (S)

Silicate wheels have a milder action and cut with less harshness than vitrified wheels. For this reason they are suitable for grinding fine edge tools, cutlery etc. This bond is used for making large dia grinding wheels.

Shellac bond (E)

This is used for heavy duty, large diameter wheels where a fine finish is required. For example, the grinding of mill rolls.

Rubber bond (R)

This is used where a small degree of flexibility is required on the wheel as in the cutting of the cutting off wheels.

Resinoid bond (B)

This is used for high speed wheels. Such wheels are used in foundries for dressing castings. Resinoid bond wheels are also used for cutting off parts. They are strong enough to withstand considerable abuse.

Oxychloride bond (O)

The abrasive grains are mixed with magnesium chloride and magnesium oxide. This bond is used for making disc shaped wheels.

The bond ensures a cool cutting action so best for dry grinding operation. This bond is used for making segmented wheels.

Standard marking system for grinding wheels

Objectives: At the end of this lesson you shall be able to
- **interpret the marking on a grinding wheel**
- **specify a grinding wheel.**

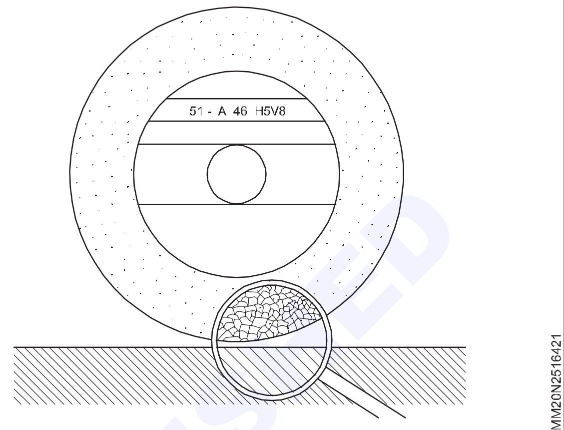
Introduction

Standard wheel markings specify all the important wheel characteristics. The marking system comprises of seven symbols which are arranged in the following order.

Position 0 - Manufactures code
Position 1 - Type of abrasive
Position 2 - Grain size or grit number
Position 3 - Grade of the wheel
Position 4 - Structure
Position 5 - Type of bond
Position 6 - Manufacture code

The Fig 1 is shows the standard marking system for grinding wheel.

Fig 1



Example 1

Marking system

51- A46H5V8

Table 1

Position 0	Position 1	Position 2	Position 3	Position 4	Position 5	Position 6
Manufacturers symbol for abrasive (optional)	Type of abra abrasive grit	Grain size	Grade	Structure (optional)	Type of bond (optional)	Manufacturers own mark
51	A Aluminium oxide	46 Medium	H Soft	5 Dense	V Vitrified	8

Example 2

Marking system

PA36J6V15

Table 2

Position 0	Position 1	Position 2	Position 3	Position 4	Position 5	Position 6
Manufacturers symbol for abrasive (optional)	Type of abrasive grit	Grain size	Grade	Structure (optional)	Type of bond (optional)	Manufacturers own mark
P	A Aluminium oxide	36 Medium	J Medium	6 Dense	V Vitrified	15

Specification of grinding wheels

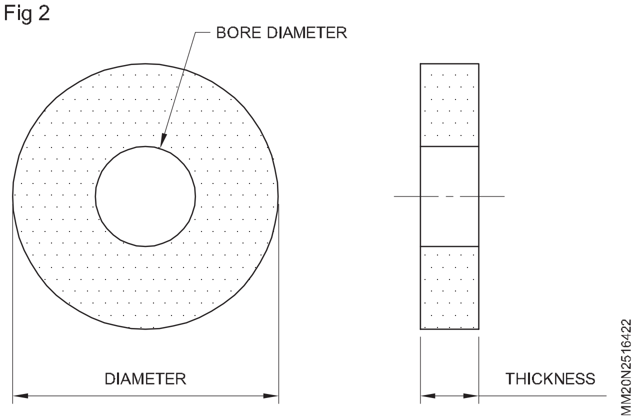
A grinding wheel is specified by the:

- standard wheel markings
- diameter of the wheel
- bore diameter of the wheel
- thickness of the wheel
- type (shape) of the wheel

Example

32 A46 H8V 250 x 20 x 32 straight wheel

Fig 2



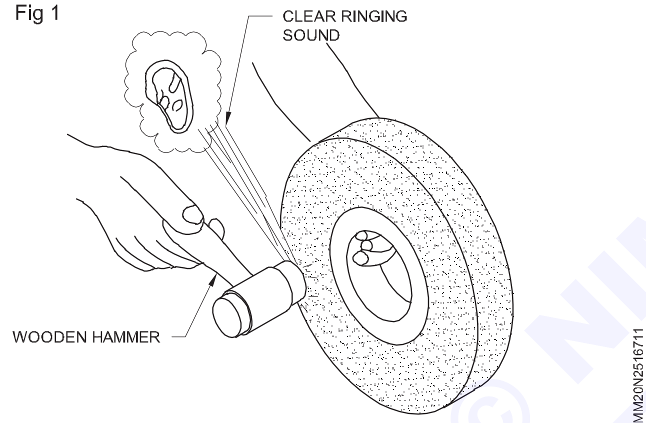
Mounting and balancing of grinding wheel

Objectives: At the end of this lesson you shall be able to
- **explain the method of mounting of grinding wheel**
- **brief the method of balancing of grinding wheel**
- **state the difference between static and dynamic balancing**
- **list the safety precaution to be taken for mounting and balancing of grinding wheel.**

Mounting the grinding wheel: Grinding wheels should be properly mounted upon suitably proportioned spindles and between properly designed flanges. This is one of the very important considerations in the use of grinding wheels.

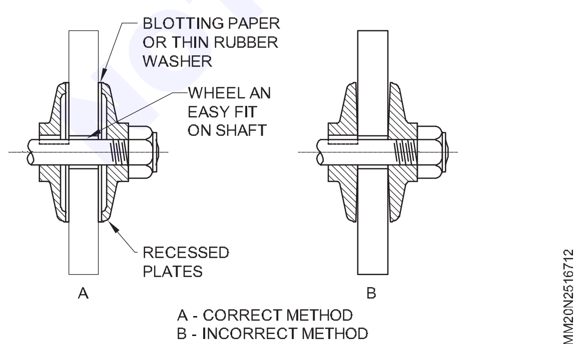
- Before mounting, the wheels are checked for cracks by light tapping. (Fig 1)

Fig 1



- Wheel flanges are also checked to see that they are free from foreign particles.
- Two thin washers of blotting paper or rubber is placed on either side of the hole. The wheel and washers are then gripped between two steel washers or flanges on the spindle. (Fig 2) The function of the paper washers is to distribute the pressure evenly when the flanges are tightened. The size of the steel flanges should be atleast one third the wheel diameter in order to provide sufficient support and grip.

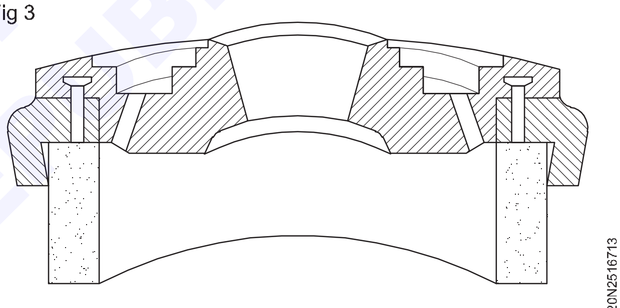
Fig 2



- The flanges are recessed so as to provide an annular bearing at their circumference. The hole in the bushing should be large enough so that the spindle may slide without cramping.
- Fitting of the grinding wheel on the wheel spindle is made a free fit, but without any slackness.
- Nuts should be tightened only sufficiently to hold firmly.
- Excessive tightening will damage the wheel.
- The ends of the spindles wheels are threaded in such a way (left-handed or right-handed) that nuts on both ends tend to tighten as the spindle revolves.

Fig 3 shows a method of mounting wheels for surface grinding purposes. The wheel is cemented into a metal ring which in turn is secured to the main grinding spindle flanged member by means of screws.

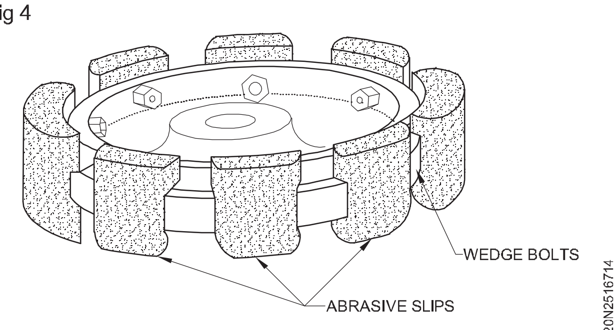
Fig 3



METHOD OF MOUNTING SURFACE GRINDING WHEEL

Fig 4 shows how wheel discs are cemented to specially designed holders and segmental wheels.

Fig 4

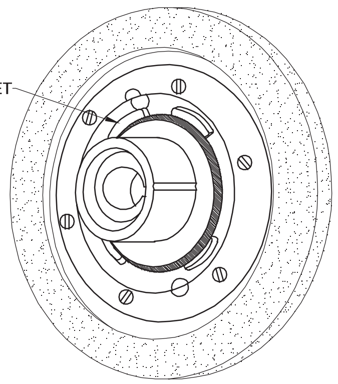


GRINDING WHEEL BALANCING

It is not possible to manufacture grinding wheels having absolutely uniform density throughout. Moreover they change in size and weight while in use. Minor variations in density doesn't in general, affect the grinding action noticeably. But in some cases it affects the balance.

Ordinary commercial wheels provided with snug fit on the wheel cooler run without imbalance and without any difficulty. But in cases like cylindrical grinding and internal grinding where grinding wheel is carried on the end of a long spindle, balancing is generally necessary owing to the over hang of the spindle. Otherwise also wheels should be carefully balanced to maintain a uniform embodying a dovetail shaped groove (Fig 5) are provided in which adjustable and moveable weights are fitted.

Fig 5



WHEEL MOUNT WITH BALANCE COLLET

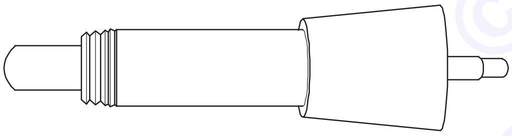
Truing before balancing is necessary because in truing considerable material may be removed from one side only which will again throw the wheel out of balance.

The steps involved in balancing the wheels are as follows:

Assemble the wheel on the collet and mount this unit on the balancing arbor. (Fig 6)

Balancing weights are either removed or set directly against each other so that the correct balancing position of the wheel many be determined.

Fig 6



ARBOR

Arbor with the wheel mounted on it is placed on the balancing ways.

Wheel is turned and allowed to come to rest of its own with the heavy spot down.

A chalk mark is made to indicate the heavy side.

Balancing weights are shifted so that the ends meet under the chalk mark.

Balancing weights are then moved apart until perfect balancing is obtained. (Fig 7)

Set screws are tightened to fit the weights in position.

The whole assembled unit is removed from the balancing ways for mounting on the machine.

Difference between static and dynamic balancing

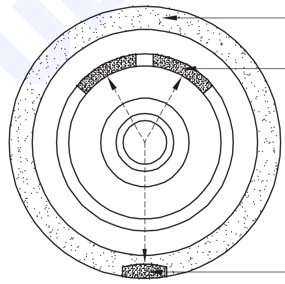
Static balancing means that when the wheel is centred on a horizontal arbor (Frictionless) it remains at rest in any position. It is in dynamic balance if upon rotating there is no vibration nor "whip" action due to unequal distribution of its weight throughout its length.

Adverse effects of wheels which are out of balance

Consumption of more power by the machine.

Excessive wear on bearing.

Fig 7



DIFFERENCE BETWEEN STATIC AND DYNAMIC BALANCING

Grinding wheel dressing

Objectives: At the end of this lesson you shall be able to
- **state three important purposes of dressing a grinding wheel**
- **differentiate between dressing and truing**
- **state the types of wheel dressers and their uses.**

Dressing is an operation to change the cutting action of a wheel or to recondition the grinding surface. Grinding wheels should be dressed and trued regularly to improve the followings:

Work production

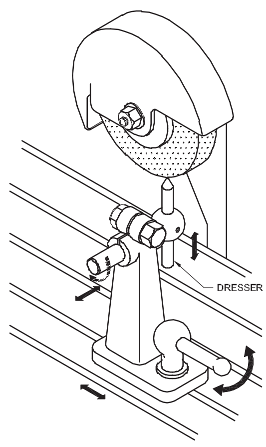
Wheel performance

Grinding economy

Dressing (Fig 1)

Dressing refers to the removing of clogs and blunt abrasive grains from the surface of the grinding wheel. Dressing grains exposes the cutting edges which restore the correct cutting action of the wheel. Dressing is done on a glazed or loaded wheel to recondition it.

Fig 1

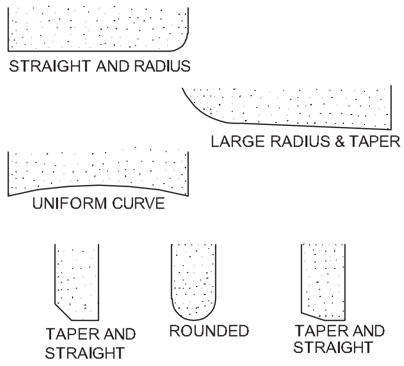


Truing

Truing refers to the shaping of the wheel to make it run concentric with the axis. When a new grinding wheel is mounted, it must be trued before use to remove the run out.

Truing is done on the wheel which is out of shape due to long use. Sometimes a wheel is also trued to change the shape of the grinding wheel face for a specific grinding operation like form grinding. (Fig 2)

Fig 2



In most of the cases both dressing and truing are done at the same time.

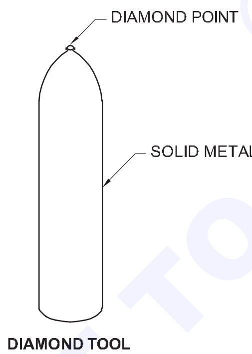
There are three basic types of wheel dressers. They are:

- diamond • steel • abrasive

Diamond dressers (Fig 3)

A diamond dressing tool has a hard diamond mounted in a metal shank. The shank is fitted in a tool holder for location on the grinding machine to perform dressing.

Fig 3



Diamond dressers are most effective for dressing precision grinding wheels.

A low feed of a diamond dresser can glaze the wheel. They are specified by their weight in carats. Usually 0.5 carat to 1 carat diamonds are used for dressing upto 200 mm dia. wheels.

Steel dressing tools (Fig 4)

Steel dressers for dressing grinding wheel have rotary cutting surfaces made from hard steel.

They are held in place against the grinding wheel by hand and moved across the face of the grinding wheel to do the dressing. A tool rest or other rigid support must be used during this operation.

The main types of steel dresser are:

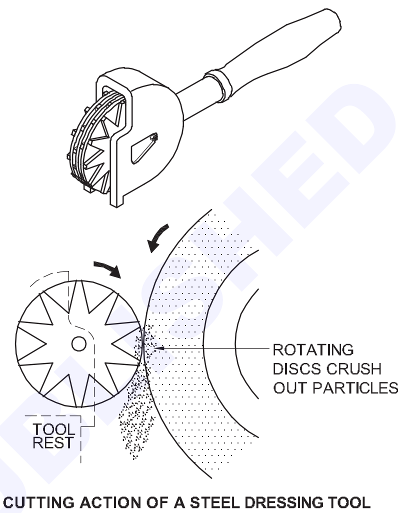
Star and disc dresser (used for coarse grained wheel)

Corrugated disc dresser (used for smooth finish)

Lock disc dresser (used for medium roughing wheel)

Solid cylinder dresser (used for instead of a diamond dress)

Fig 4

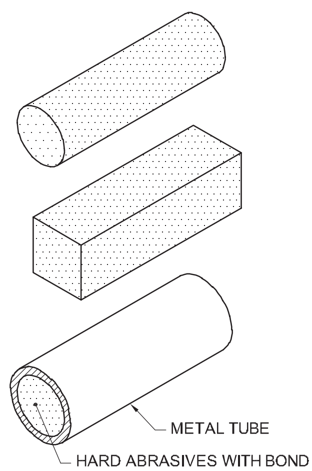


Abrasive dressers (Fig 5)

When only light dressing is required abrasive sticks can be used. There are abrasive materials made in the form of square or round sticks or put in metal tubes for convenient handling.

This type of dressers is more convenient in tool and cutter grinders where frequent dressing and truing is necessary.

Fig 5



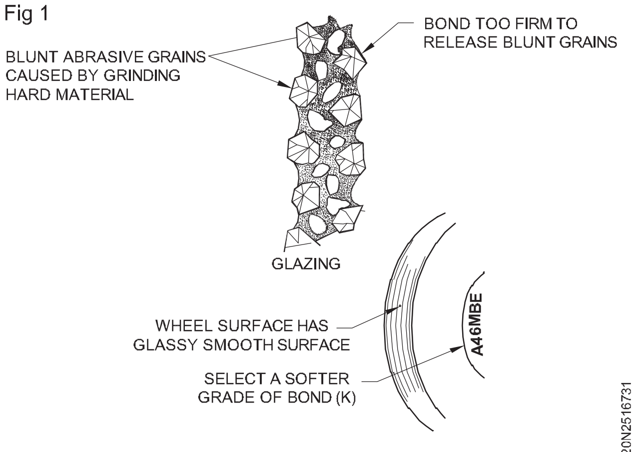
Glazing and Loading, their effects,causes and remedies

Objectives: At the end of this lesson you shall be able to
- **differentiate between glazing and loading of a grinding wheel**
- **state the effects of a glazed and loaded wheel while grinding**
- **state the causes and remedies for glazing**

Glazing

When the surface of a grinding wheel develops a smooth and shining appearance, it is said to be glazed. (Fig 1) This indicates the abrasive particles on the wheel face are not sharp. These are worned down to bond level.

Fig 1



GLAZED WHEEL

Loading

When soft materials like aluminium, copper, lead, etc. are ground the metal particles get clogged between the abrasive particles. This condition is called loading. (Fig 2)

The effects of a glazed or a loaded grinding wheel are almost the same. They are:

- excessive cutting pressure between wheel and work
- more heat generation
- burning of the ground surface
- poor surface finish
- inaccuracies in the size and shape of the workpiece
- wheel breakage (sometimes)

A dull or glazed wheel should be dressed for the following reasons

To reduce heat generated between the work surfaces and the grinding wheel.

To reduce the strain on the grinding wheel and the machine

To improve the surface finish and accuracy of the work

To increase the rate of metal removal

Cause and remedies of glazing

Wrong selection of glazing

> **Wrong selection of grinding wheels means hard grade wheel in place of soft wheel and fine grain size in place of medium grain size.**

Select a grinding wheel of the right grade and size.

High wheel speed

Set the wheel to the recommended speed.

Feed too fine

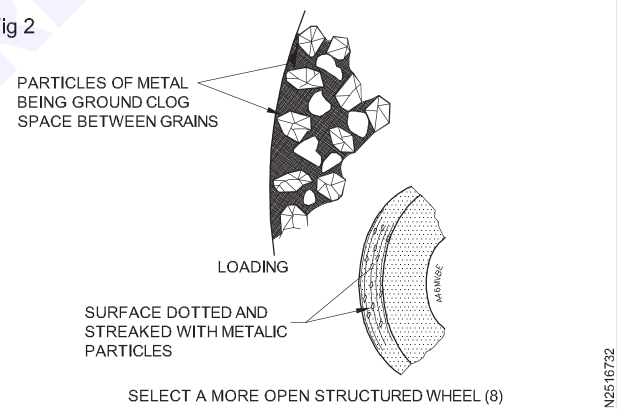
Set the feed rate correctly.

Dirty coolant

Change the coolant

A glazed or a loaded grinding wheel can be reused after removing the glazed or loaded particles from the grinding wheel face. (Fig 2)

Fig 2



LOADED WHEEL

Grinding wheel dressing

Objective : At the end of this lesson you shall be able to
- **state the care and maintenance of grinding machine.**

Machine and maintenance: In the design and manufacture of a grinding machine great care is taken to ensure that the alignment of the machine frame, its bed, work head, and wheel head parts, will be retained over a long period of time.

When lifting with slings, care should be taken to follow the manufacturer's recommendations. Moreover, one should take full advantage of any assistance the makers may render during the period the machine is being brought into service.

Usually the base of the machine is provided with three feet and the machine should rest only upon these, in order that the three-point support may be maintained. When the machine has been correctly designed it is highly advisable, after the final inspectional check, to grout, it using cement. It is however, important that no wedges or packing (apart from the grounting) should be placed between the feet.

The object of grouting is to absorb any vibration that may arise from outside sources, and to carry it to the foundation the grouting is not to ensure alignment.

Foundations: A grinding machine, being a precision tool, requires a sound foundation. For this purpose a concrete bed of adequate size is the best medium. A small machine

Requires a minimum depth of say 2 ft. more if the soil is loose and of the made-up type.

The area dimensions should be equal to the machine base plus about 2 ft. each way. With the larger machines the depth of the concrete base should be a 3 ft. minimum more when the safe bearing load of the soil is very low.

In order to carry the load effectively it may be essential to use a grillage and spread the loading over a wide area. When choosing a site for a grinding machine a careful study should be made of the possibility of vibration from machines in the neighbourhood, or from heavy traffic passing along roads in the vicinity of the factory.

If vibrations are found to exist, and arise from the use of heavy forging presses, or drop stamps in the vicinity, or from the passage of heavy motor traffic in the adjacent roads, the wisdom of using that particular site for a precision grinding machine is open to doubt.

Tests: With the machine in position an alignment test should be made using a precision level or optical instruments to ensure that the bed is truly level in both the longitudinal and traverse directions. Adjustments should be made as and when necessary.

When using the level or the optical instrument, the checking positions should be well place and numerous; it is insufficient to take only one or two readings, particularly when the machine has a long bed.

Belts: All the belts used on a grinding machine should be of the endless type, and be such that it does not favour the creation of vibration on any portion of the machine, otherwise there is a risk that chatter marks may be found on the workpiece. A belt drive must be smooth and free from any impact loading upon the pulleys over which it must pass.

As the belt is required to be endless, then a leather, rubber, or canvas belt with a cemented lap joint may be chosen; alternatively, and according to circumstances, one may use the endless cotton woven or rubber vee-belts. The use of metal belt fasteners on grinding machines is to be avoided.

Lubrication: No grinding machine can operated successfully if due attention is not given to its cleanliness and lubrication. Each operator should acquaint himself or herself with the lubricating points on the machine he or she operates, and ensure that all sliding and rotating parts are thoroughly lubricated several times each shift. In this manner, a few minutes a day are well spent and amply repay the trouble taken.

Daily attention should also be given to the pumps, so that the oil levels are maintained. Inattention in this direction soon leads to machine troubles, poor work, and the inability to achieve the output in a reasonable time.3.3*

Cleanliness: When received from the makers, each machine should be thoroughly cleaned and the slushing grease removed; oil ways should be checked to ensure that they are free from obstruction.

With the machine working, the greatest care should be taken to keep the working surfaces clean and well lubricated. Moreover, it is necessary to keep the grinding grit out of the lubricating system, and all the oil cans used in the grinding section should be of the dust-proof variety.

The nature of the metal cutting performed on a grinding machine carries with it special hazards as regards the maintenance of accuracy.

The extremely small metal chips, tiny particles of abrasive, and the dust from the bonding material, all have a destructive influence when in contact with any machine slide or bearing, whilst the dressing of the wheel and the grinding operation itself tend to spread the particles over a wide area.

Then again the grinding fluid forms a film over the machine table and other parts and thus carries the small metal and other particles in all directions. The need for wiping down the machine at frequent intervals during the day, and at the end of the shift is imperative. Once a week at least, the machine should be given a thorough cleaning.

In order to avoid undue wear at one position on the machine table it is desirable to move the headstock, as operating conditions permit, from one position to another. It is unwise to clamp the headstock at, say, the end of the table, and never move it into a new position such practice only leads to excessive localised table wear.

Coolant bosh: Every two or three days the coolant bosh should be cleaned out and the mud removed. Good work cannot be done when the liquid is carrying, in suspension, a large amount of the grinding grit.

What is required is an adequate stream of the coolant or lubricant free from any suspended matter; hence the need for a clarifier. When conditions permit, it is wise to consider one large coolant tank and clarifier for all machines in the grinding section. Then the clean liquid is supplied to each machine at a standard temperature.

Machine centres: The machine centres should always be maintained in first class order, by regrinding as circumstances require.

Wheel slide: The wheel slide must be maintained in a clean well-oiled condition so that it will work smoothly. If allowed to become dry, stiff, and dirty, it loses that responsiveness which is essential to accurate sizing, for the slide on finishing cuts may be called to move only 0.0001 in. per pass of the wheel. 'Slide-stick' cannot be tolerated.

Wheel head: The wheel head is usually fitted with a forced lubrication system and card should be taken to ensure that this is always working satisfactorily. The following remarks apply to the successful operating of the machine.

No running adjustment should be made to the bearings until the machine has reached the normal operating temperature, which is around 120°F.

With the passing of time all lubricating oils lose some of their properties, and the bearing oil sump on a grinding machine should be drained at frequent intervals, well swilled with paraffin or petrol, and then refilled with new oil.

When the machine has been standing idle for a long period, the lubricators should be well primed with oil

Before setting the machine in motion, and oiling should continue until the pump commences to operate.

Machine overhaul: At times it becomes essential to have each grinding machine thoroughly overhauled. Perhaps the best conditions are when the machine is given a periodic examination once a year. If, as is very unlikely, the machine is sent back to the makers, little can be said, as normally they will do the job effectively.

When, however, the work has to be done by the machine tool fitters attached to the establishment, it is vital to see that the work is done and inspected to the same high standards as those of the makers.

In this direction it may be that the final alignment charts for the machine, taken during its erection, are available. Then they should form the basis of the work performed in the repair section, and be used by the inspection department.

When this important information is not available, then one should use the alignment charts produced by, and obtainable from, the institution of mechanical engineers or the institution of production engineers.

Grinding wheel dressing

Objectives: At the end of this lesson you shall be able to
- **Explain the servicing procedures to be adopted for different parts of grinding machines**
- **Prepare the daily, weekly, monthly and annually maintenance checklist for surface grinding m/c.**

Because of the array of precision functions grinding machines perform, it's vital to properly maintain them to keep them operating at their peak in terms of accuracy and reliability. You can start by devising a maintenance program and sticking with it. This article provides tips on how to set up key parts of that program. The tips apply to virtually all types of grinders, including surface. OD. ID and rotary ones.

A mechanic removes the magnet from a surface grinder for cleaning. Keeping scale and corrosion from accumulating between the bottom of the magnet and the grinder's suitable is a must to help ensure accurate grinding. All images courtesy of Pyramid Rebuild & Machine

While metal cutting professionals understand that grinders must be properly maintained. That doesn't mean it gets done. Frequently, production demands elbow out maintenance chores and before long, the results of neglecting machine care become painfully evident. Inaccurate parts, breakdowns and even safety hazards can result. To avoid potential injuries, costly remedial action and lost production time, shop managers must first identify the maintenance requirements for each grinding machine and use that information to craft a comprehensive maintenance program.

A maintenance program should include a method of determining when each maintenance task was performed and by whom to help ensure accountability

Clean the Machine

Keeping a grinder clean is a no-trainer, right? Yet it's not uncommon to walk into a shop with hundreds of thousands of dollars of precision grinding equipment and see a grimy mess on every machine A chief reason for this is the grinding process itself Grinding produces swarf, a mixture of minute metal particles and abrasive material that quickly works its way into a grinder's clearance areas and crevices. The problem is particularly common on rotary and centerless grinders because of the large volume of material they are able to remove, and it can cause serious damage if left unchecked. Therefore, it's vital that a procedure for cleaning grinders is developed and followed.

It's not enough just to wipe off exposed surfaces on a machine. A cleaning plan must identify the hidden areas where swarf tends to collect and describe how to clean those sections. Water guards, way covers and clearance areas between slides are areas where swarf tends to collect and cause problems. In some cases, the only option is to remove the component for cleaning. Use a scraper or wire brush to remove heavy debris and hot water for lighter debris, such as coolant residue

Keep an eye on coolant. Over time, coolant becomes contaminated and can develop corrosive characteristics that eat machine components. Contaminated coolant can damage everything from machine guards to way surfaces to lubrication lines Periodic cleaning of the coolant storage tank and filtration systems is a must

The coolant mixture itself should be adjusted according to the manufacturer's recommendations to ensure the coolant is still doing its job. If OEM specifications are unavailable, consult a coolant manufacturer.

Monitor Lubrication

Grinders can require costly repairs if their lubrication systems fail or do not operate at 100 percent efficiency. Way lube systems on grinders are typically a terminal design, which means they consume oil. If operators don't have to add oil to the way lube system on a regular basis, then it is probably not working properly. To keep terminal lube systems operating properly, lubricant levels must be rigorously maintained.

It's also critical to use the correct lubricant. Don't assume the right lubricant is what you've always used. Review the OEM specifications or ask a lubricant supplier.

In addition, clean the lube reservoirs and change the filters at least every 6 months. Visually inspect the way surfaces at 6-month intervals to make sure lubricant is being delivered properly. The ways should be clean except for a thin film of lubricant. Dry ways indicate a lube system malfunction that must be addressed immediately

During the visual inspection, note the way wipers. These wipers are not present on all grinders, but when they are they must be kept in first-rate condition because wipers

Remove dirt and contamination from the way surface. Adjust any wipers that are not fully engaged on the way surface and replace those that show signs of deterioration. It's best to err on the side of caution in this regard. When in doubt about the condition of a wiper. replace it

Another key task is examining the lubrication system's lines. It is common for swart buildup and the corrosive action of rancid coolant to damage grinder lube lines. Replacing damaged or broken lines is critical because most grinders have a "parallel type of lube system. On these systems, the lubricant follows the path of least resistance, so a single broken line can defeat the entire system. That results in some surfaces receiving too much oil and others not receiving any. If left unchecked, premature wear of the way surfaces will result

Beware Gummy Gibs

At least once every 6 months, remove and clean the gibs on a grinder's vertical slide Usually, common hand tools are all that's required to remove the gibs Once removed. Clean them by scraping off heavy contamination and then remove any remaining contaminants with hot water followed by thorough drying and applying a light coating of way oil Though somewhat time-consuming, this task is necessary because coolant mist dries on the gibs, making them prone to sticking. Gummy gibs strain the vertical slide lead screw and accelerate wear on this costly precision component. Worn lead screws can reduce accuracy and must either be replaced or rebuilt. In addition to being costly, the process is likely to sideline a grinder for weeks

Carefully and accurately mark each gib before removal so it can be reinstalled to precisely the same depth-a critical adjustment. If maintenance personnel are not familiar with the gib-setting procedure, call a reputable professional. As a gib is removed, make sure the working side of the gib is covered with a thin film of lubricant. If it isn't, track the source of the lube system problem, such as a faulty lube pump or broken lube line and replace the component.

Once the gib and way surfaces are clean, reinstall the gib, setting it to the gib's precise location prior to removal. A gib that is set too tight causes vertical "stick-slip" on a downward move. Stick-slip on a grinder slide can produce grinding errors and be hazardous. A gib that is too loose reduces accuracy and rigidity. Gib adjustment is tricky. so it's probably prudent to seek the aid of a professional for this task.

Maintain the Magnet

Maintaining the magnet is a must for surface grinders. About every 6 months, depending on usage, remove the magnet and clean it and the table beneath it. After removing all the grime and scale, stone the bottom of the magnet and then lightly oil that surface and the table before reinstalling the magnet. Apply a light film of the machine's way oil, which won't contaminate the grinder's coolant.

Stoning a surface grinder magnet is an effective way to remove the final bits of corrosion and to flatten it before reinstalling it on the grinder.

Lack of magnet maintenance will produce a scafe and corrosion buildup between the bottom of the magnet and the table. If left unchecked, this scale can accumulate to a thickness of about 1 16 and distort the surface grinder table to the extent that it no longer rides true in the ways. If scale buildup is permitted to remain, the way surfaces of the bod and table wear because of point loading caused by the table distortion. If this occurs, then the only remedy is to rescrape the ways to restore the grinder’s accuracy, a process that can sideline the grinder for 2 or 3 weeks. The amount of time depends on the complexity of the grinder and degree of wear. One week may be sufficient for a small surface grinder with minimal wear, whereas it may take a week to dismantle a large rotary grinder prior to beginning the realignment work

Magnet maintenance on cylindrical grinders involves removing the swivel table, or suitable, and performing the same table maintenance as recommended for the surface grinder. A 6-month maintenance interval is also appropriate for this task.

Inspect Clamping Gear

On rotary grinders, the stone segment clamps and clamp screws can become bent, worn or damaged. Examine these components daily for these problems and replace them as necessary. Also, inspect the tapped holes in the wheel. If any threads are stripped. Repair them or replace the wheel. Failure to maintain the wheel can result in stones being dropped, which will cause serious damage that’s expensive to repair.

Wheel components should also be cleaned every 6 months. Remove the grinding wheel on surface grinders and thoroughly clean the wheel adapter, the spindle and the threaded pieces. Scrub inside the wheel guard as well. Use scrapers to remove heavy contamination, followed by rinsing with hot water to penetrate residual coolant film Thoroughly dry the components before reassembly. This procedure keeps corrosion in check on these components. Use an antiseize compound during reassembly. Also, replace the wheel blotters and balance the wheel before putting the grinding machine back in service.

Inspect Covers and Guards

Continually scrutinize way covers and water guards on grinders They perform a vital function protecting the operator and preventing grinding swarf from straying onto the slide ways and other critical components

Guards take a beating As previously noted, they can be continuously exposed to the corrosive action of poorly maintained coolants and physically damaged by swarf accumulation. Preserving them demands frequent, thorough cleaning using the tools and techniques previously described to remove swarf and to clear corrosive coolants. When cleaning the guards, inspect them for any damage. If any is spotted, repair or replace them as soon as possible.

Rigorously adhering to these maintenance procedures and performing the care requirements recommended by a grinder’s manufacturer should dramatically reduce production interruptions caused by breakdowns. These actions should also boost parts accuracy and reduce the cost of repair work. Keeping grinding machines properly maintained isn’t difficult, but the hard part is making sure maintenance and routine repairs are undertaken in a timely, thorough fashion. The choice is yours: either do it or pay the consequences. CTE

Preventive and breakdown maintenance of grinding machine

Maintenance of a grinding machine is essential to ensure its performance, longevity, and safety Preventive maintenance aims to keep the machine in good working condition and prevent potential issues, while breakdown maintenance is about addressing unexpected problems. Here’s an overview of preventive and breakdown maintenance for a grinding machine

Preventive Maintenance:

Regular Inspections:

Conduct routine visual inspections of the grinding machine to check for signs of wear, damage, loose bolts, and other uses

Inspect the machine’s electrical wiring for any frayed wires, loose connections, or damaged components.

Lubrication:

Ensure that all lubrication points are properly lubricated according to the manufacturer’s recommendations

Maintain a log of lubrication schedules to avoid over lubrication or under-lubrication

Coolant System:

Check and maintain the coolant system to prevent overheating and maintain consistent cooling during operation

Verify that the coolant flow rate and concentration are within recommended levels.

Spindle and Bearings:

Inspect the spindle and bearings for any signs of wear, misalignment, or damage

Replace worn-out bearings or parts as necessary

Belts and Drive Systems:

Regularly inspect drive belts, chains, and gears for signs of wear or damage

Tension belts as needed and replace worn components

Grinding Wheel:

Ensure that the grinding wheel is in good condition, free of cracks or damage.

Check the wheel for proper balance and dressing.

Electrical Systems:

Regularly inspect electrical components such as switches, buttons, and control panels for proper functioning

Verify that safety interlocks and emergency stops are working correctly

Filters and Fluids:

Clean or replace fluid fitters in hydraulic systems as recommended

Monitor the condition of hydraulic fluid and replace it at regular intervals

Safety Devices:

Ensure all safety devices and guards are in place and functioning correctly to prevent accidents

Documentation:

Maintain comprehensive records of maintenance tasks, including dates, inspections, repairs, and component replacements

Breakdown Maintenance:

Immediate Response

In the event of a breakdown, immediately stop the machine and isolate it from the power source.

Assess the nature and extent of the problem to determine if it can be resolved on-site or requires external repair.

Safety First:

Ensure that safety procedures are followed, and all personnel are aware of the emergency shutdown process.

Do not attempt to repair the machine until it is safe to do so Expert Assistance

Contact a qualified technician or service provider to diagnose and repair the specific issue.

Share information about the breakdown, any unusual sounds, or error messages encountered.

Spare Parts

Ensure that you have a stock of critical spare parts and components to facilitate faster repairs.

Replace any damaged or worn parts with the appropriate replacements

Preventive Measures:

After the machine is repaired, conduct a thorough review of the breakdown's root cause and Implement preventive measures to avoid a recurrence.

Regular and systematic preventive maintenance can significantly reduce the likelihood of breakdowns in a grinding machine. However, it is essential to be prepared for unexpected issues and address them promptly to minimize downtime and maintain the machine's efficiency and safety.

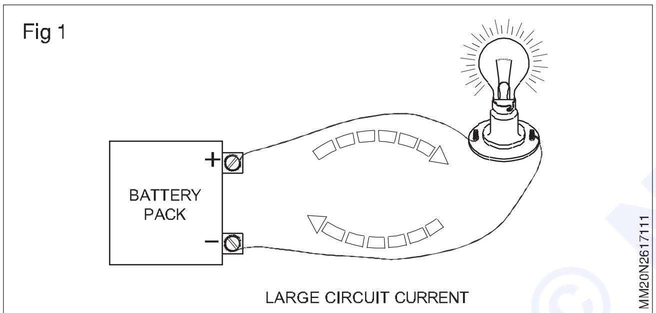
Passive components - Resistors

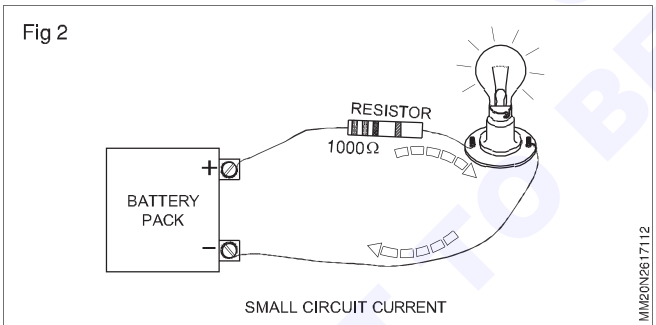
Objectives: At the end of this lesson you shall be able to
- **state maintenance and its types**
- **state the function of each maintenance**
- **distinguish between breakdown maintenance and preventive maintenance**
- **state the importance of breakdown and preventive maintenance in productivity.**

Resistors

Resistors are electronic components, used to reduce, or limit, or resist the flow of current in any electrical or electronic circuit. Chart 1 at the end of this lesson shows different types of resistors.

Fig 1 shows a circuit in which the bulb glows brightly. Fig 2 shows the same circuit with a resistor, and the bulb glows dim. This is because, the current in the circuit is reduced by the 1000 ohms resistor. If the value of this resistor is increased, current in the circuit will be further reduced and the light will glow even dimmer.





Resistors are made of materials whose conductivity fall in- between that of conductors and insulators. This means, the materials used for making resistors have free electrons, but not as many as in conductors. Carbon is one such material used most commonly for making resistors.

When a large number of electrons are made to flow through a resistor, there is opposition to the free flow of electrons. This opposition results in generation of heat.

Unit of resistance

The property of the resistor to limit the flow of current is known as *resistance*. The value, or quantity of *resistance* is measured in units called **ohms** denoted by the symbol Ω.

Resistors are called *passive devices* because, their resistance value does not change even when the level of applied voltage or current to it is changed. Also, the resistance value remains same when the applied voltage is AC or DC.

Resistors can be made to have very small or very large resistance. Very large values of resistances can be represented as given below;

1000 Ω	= 1 x 1000 Ω	= 1 x kilo Ω	= 1 K Ω
10,000 Ω	= 10 x 1000 Ω	= 10 x kilo Ω	= 10 K Ω
100,000 Ω	= 100 x 1000 Ω	= 100 x kilo Ω	= 100 K Ω
1000,000 Ω	= 1000 x 1000Ω	= 1000 x kiloΩ	= 1000KΩ
		= +1Mega Ω	= 1M Ω

Classification of Resistors

Resistors are classified into two main categories.

1 Fixed 2 Variable

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.

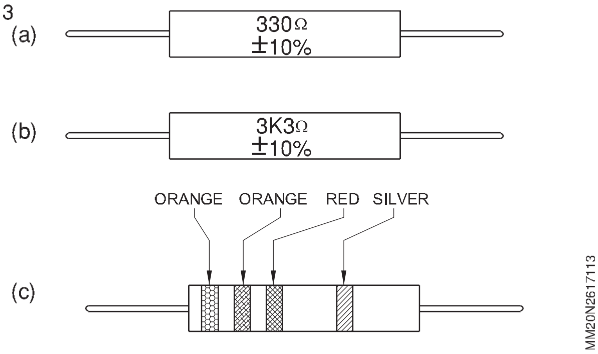
FIXED VALUE RESISTORS
- Carbon composition resistors
- Wire-wound resistors
- Film resistors
  - Carbon - film resistors
  - Metal film resistors
  - Metal oxide film resistors
  - Cermet film resistors
  - Integrated resistors
- Printed resistors

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. Table 1 at the end of this lesson illustrates the physical appearance of most commonly used fixed value resistors. The resistance value of a resistor will generally be printed on the body of the resistor either directly in ohms as shown in Fig 4a or using a typographic code as shown in Fig 3a, 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.

Tolerance

In bulk production/ manufacturing of resistors, it is difficult and expensive to manufacture resistors of particular exact values. Hence the manufacturer indicates a possible variation from the standard value for which it is manufactured. This variation will be specified in percentage tolerance. Tolerance is the range(max -to- min) within which the resistance value of the resistor will exist.

Applications

Carbon composition, fixed value resistors are the most widely used resistors in general purpose electronic circuits such as radio, tape recorder, television etc. More than 50% of the resistors used in electronic industry are carbon resistors.

Measuring ohmic value of resistors

It is not possible to read the exact ohmic value of a resistor from colour/other coding schemes due to manufacturing tolerance built into the resistors. To find the exact ohmic value of resistors *ohmmeters* are used. When a resistor is placed between the test probes of an ohmmeter as shown in Fig 4a, the meter shows nearest to the exact resistance of the resistor directly on the graduated meter scale. Multimeters are also used to measure the value of resistors as shown in Fig 4b.

When a multimeter is used for resistance measurement, the resistance range switch on the meter should be put to the most suitable resistance range, depending upon the value of resistance being measured.

Fig 4

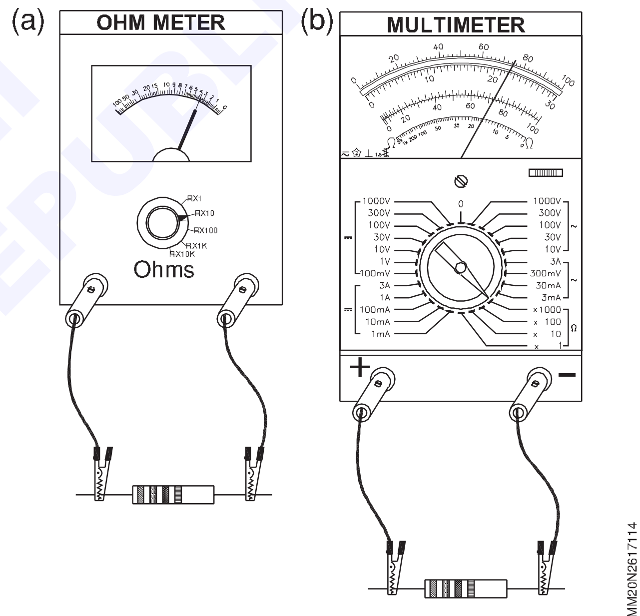
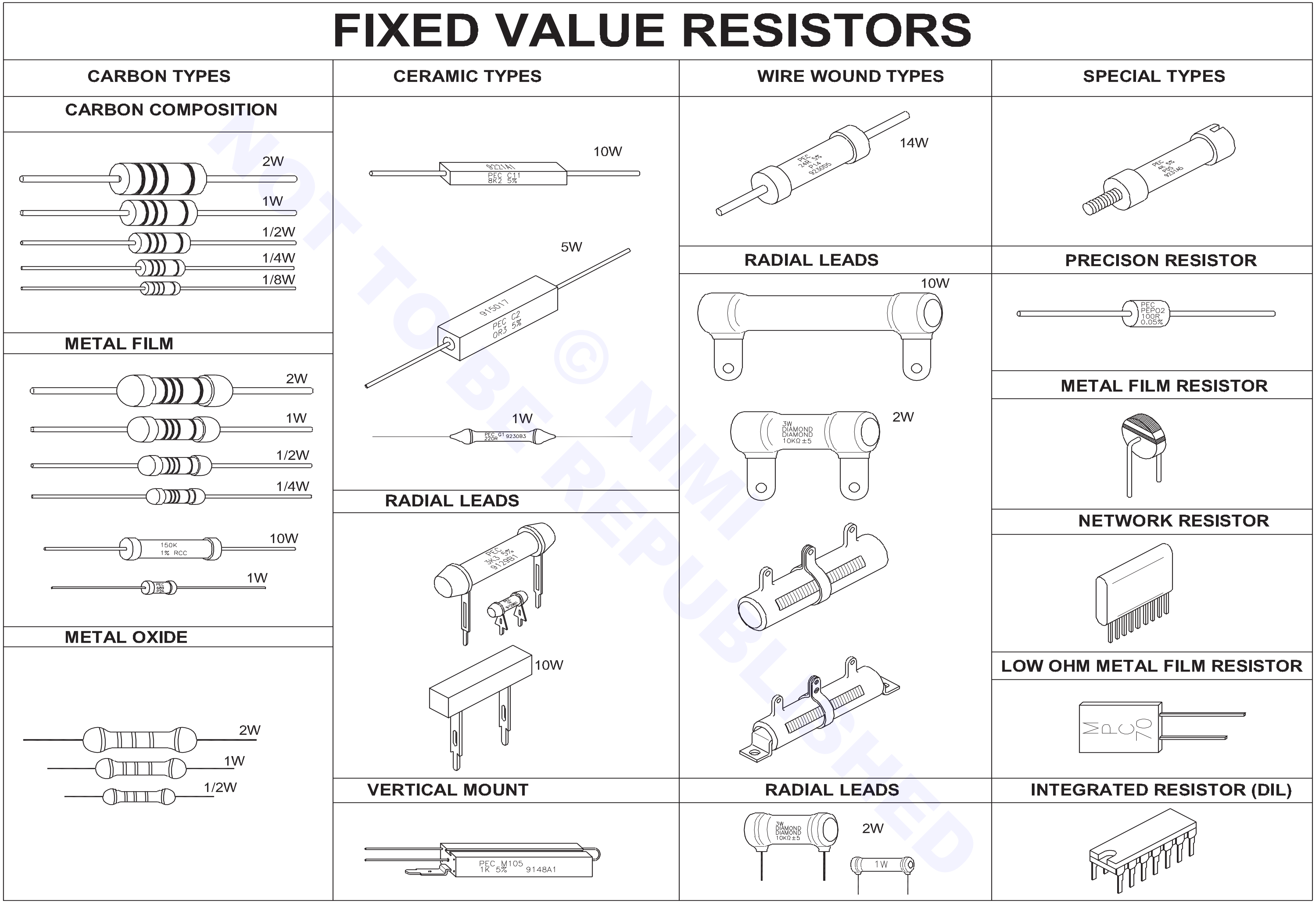


Table 1


FIXED VALUE RESISTORS
CARBON TYPES
CARBON COMPOSITION
2W
1W
1/2W
1/4W
1/8W
METAL FILM
2W
1W
1/2W
1/4W
10W
150K 1% RCC
1W
METAL OXIDE
2W
1W
1/2W
CERAMIC TYPES
10W
PEC C11 8K2 5%
5W
PEC C2 0R3 5%
1W
RADIAL LEADS
10W
VERTICAL MOUNT
PEC M105 1K 5% 9148A1
WIRE WOUND TYPES
14W
RADIAL LEADS
10W
2W
3W DIAMOND DIAMOND 10KΩ±5
RADIAL LEADS
2W
1W
SPECIAL TYPES
PRECISON RESISTOR
PEC PEPO2 100R 0.05%
METAL FILM RESISTOR
NETWORK RESISTOR
LOW OHM METAL FILM RESISTOR
MPC 70
INTEGRATED RESISTOR (DIL)

Passive components - Inductors

Objectives : At the end of this lesson you shall be able to
- **state inductor and inductance**
- **state self induction**
- **state the factors determining the value of an inductor.**

Inductive reactance/DC resistance of Inductance

Inductors are components consisting of coil of wire. The basic function of an inductor is to store electric energy in the form of magnetic field, when current flows through the inductor.

Inductance is the electrical property of inductors. Letter 'L' is used as a symbol to represent Inductance. Inductance, is the ability of a device to oppose any change in the current flowing through it. This opposition to change in current, is achieved by the energy stored by it, in the form of magnetic field.

Inductance, and thus an inductor, chokes off or restricts sudden changes in current through it. The change may be either increasing or decreasing. Hence inductors are also sometimes called as Chokes.

Principle of operation

Recall that, when current begins to flow through a conductor, magnetic flux rings start to expand around the conductor. This expanding flux induces a small voltage in the conductor called back-emf or counter emf. This induced voltage has a polarity that opposes the source voltage which creates the induced voltage.

Thus, the inductance in a coil of wire, carrying current, opposes any rise or fall of current through it and tries to keep the current through it constant.

It should be noted that, the inductance cannot completely stop the increase in current because, the induced voltage is caused by the increasing flux, and the increasing flux depends on the increasing current. Therefore, an inductor can restrict only, the rate at which the current can increase or decrease through it.

Unit of inductance - Henry

The basic unit of measure of Inductance is Henry abbreviated as H. The unit henry is defined in terms of, the amount of cemf produced when the amplitude of current through the inductor is changing. Based on this , One Henry is that amount of Inductance which develops 1 V of cemf in the coil when the current changes at the rate of 1 Amp/sec.

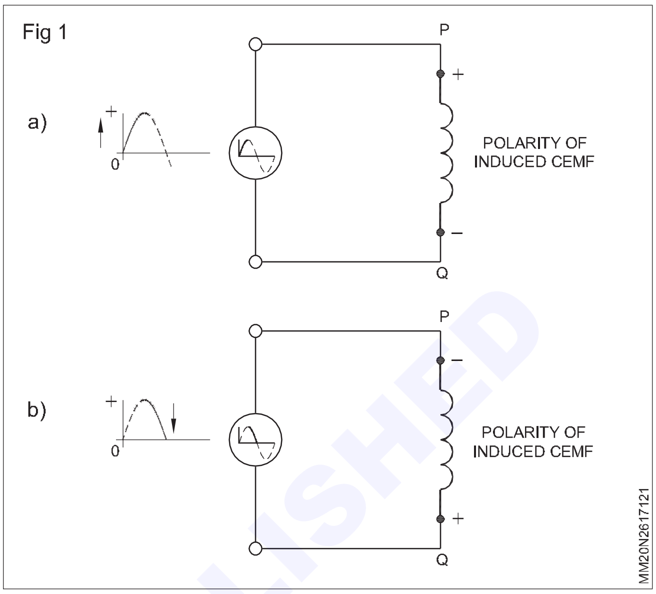
From the above definition, referring Fig 1,

Inductance, $L = \frac{v_1}{di/dt}$

Where, V_L = Induced voltage

and $\frac{di}{dt}$ = rate of change of current. Refer Fig 1.

Fig 1



Factors determining value of Inductance

The inductance of an inductor is primarily determined by the following four factors:

1. The number of turns of wire
2. The material on which the coil is wound or the core material
3. The spacing between turns of wire and
4. The diameter of the coil

Fig 2 illustrates the effect of these factors on the inductance value.

Given the parameters listed above, the inductance of a coil can be calculated using the formula,

$$L = \mu \frac{N^2 A}{l} \text{ Henries}$$

where,

μ = Permeability of the magnetic core around which the coil is wound, in Wb/At-m ($\mu = \mu_o \mu_r$)

N = Number of turns of the coil

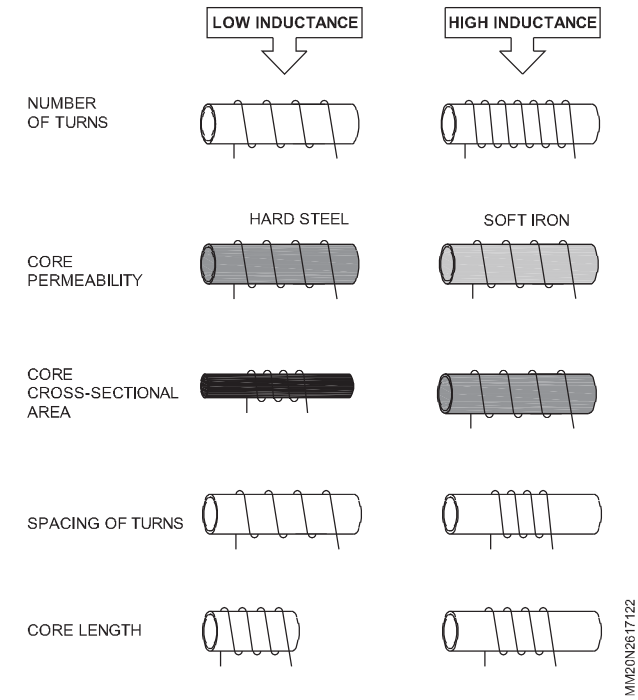
A = Area of cross-section of the core in square metres, m^2

l = length of the coil in meters.

Practical inductors and types

For practical applications, inductors are manufactured to give a specified amount of inductance. Value of practical inductors range from a few micro henries for application in high frequency communication circuits upto several henries for power supply ripple filter circuits.

Fig 2 FACTORS AFFECTING INDUCTANCE



Air core coils have practically no losses from eddy currents or hysteresis. However inductor with air core have their values limited to low values in the range of micro to milli Henries. Air core inductors are used in high frequency applications.

Laminated Iron Core is formed using a group of individual laminations. Each lamination is insulated by a thin coating of iron oxide, silicon steel or varnish. This insulation increases the resistance reducing eddy current losses. These type of inductors are generally used for mains frequency of 50/60 Hz and lower audio frequency range, upto 10 kHz.

Powdered Iron Core is used to reduce the eddy currents in the core when used at radio frequencies. It consists of individual insulated granules pressed into one solid form called *slug*.

Ferrite Core is made from synthetic ceramic material which are ferromagnetic. They provide high value of flux density like iron, but have the advantage of being insulators, thus reducing the eddy current losses to bare minimum. Because of this advantage, inductors with ferrite core are used for high to very high frequency application.

Variable Inductors unlike fixed Inductors, variable inductors have the facility to vary its inductance value either in steps or continuously (Fig 3)

Shielded/Screened inductors will have a metal cover over the inductor. The shield is usually made of copper or aluminium. The reason for shielding is to isolate the coil from external varying magnetic field and to minimize the effect of the coils RF current on external circuits.

While making a shield/screen for an inductor the following points are to be noted;

i metal used as cover should be a good conductor

ii clearance between the sides of the coil and the metal should be equal to or greater than the coil radius. If the clearance is less, the shield reduces the inductance value drastically.

Moulded inductors, looks like resistors with their values colour coded. The coding scheme is same as in resistor, except that the value of L are given in microhenry (μH)

Laboratory type variable inductor are available in the form of a **decade box**. In this decade-inductance box precision inductors are switched in-to or out-of circuit by means of rotary switches. Decade variable inductor is used to carryout experiments and in Inductance (L) meters.

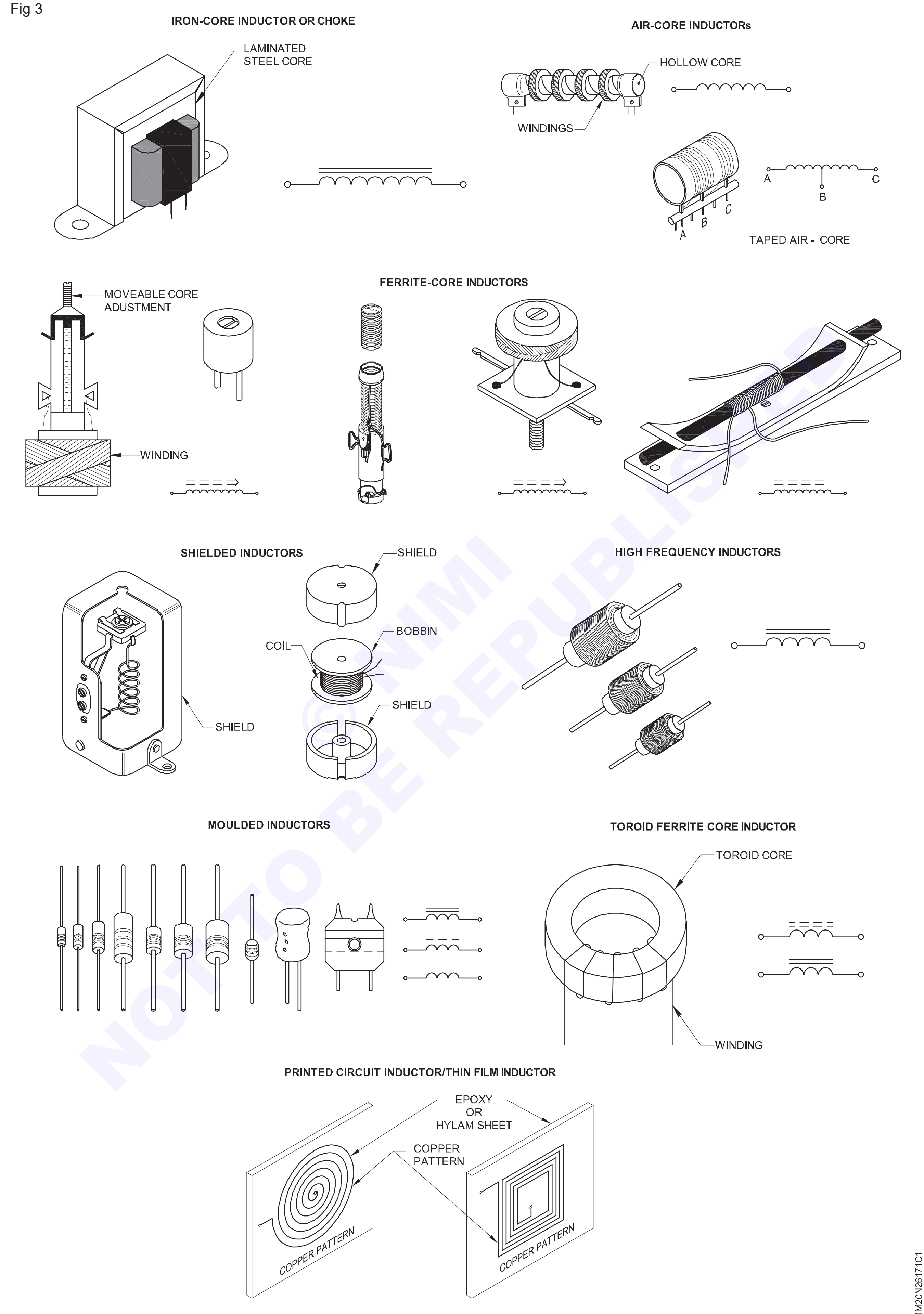
Special types of Inductors

Certain electronic circuits use a special type of Inductor called **Thin-film inductors**. These inductors are thin metal films deposited in the form of a spiral on a ceramic or epoxy base. These are tiny sized and have very low value of inductance.

Copper tube Inductors: At high frequencies, current has a tendency to flow in the skin of the conductor, this is known as **skin effect**. Therefore at high frequency & high power applications hollow copper tube coil is used as inductor instead of solid copper wire.

Variometer: If different radio frequencies are to be received using a single antenna, the electrical length of the antenna will have to be varied, to respond to different wave lengths. Variable inductors used to achieve this are called variometer.

Fig 3


IRON-CORE INDUCTOR OR CHOKE
LAMINATED STEEL CORE
AIR-CORE INDUCTORs
HOLLOW CORE
WINDINGS
A
B
C
TAPED AIR - CORE
MOVEABLE CORE ADUSTMENT
WINDING
FERRITE-CORE INDUCTORS
SHIELDED INDUCTORS
SHIELD
BOBBIN
COIL
SHIELD
SHIELD
HIGH FREQUENCY INDUCTORS
MOULDED INDUCTORS
TOROID FERRITE CORE INDUCTOR
TOROID CORE
WINDING
PRINTED CIRCUIT INDUCTOR/THIN FILM INDUCTOR
EPOXY OR HYLAM SHEET
COPPER PATTERN
COPPER PATTERN
COPPER PATTERN
MM20N26171C1

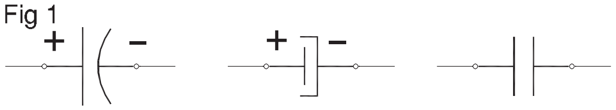
Passive components - Capacitors

Objectives : At the end of this lesson you shall be able to
- **state the function of capacitor.**
- **describe energy storing in capacitor**
- **state the factors that determine capacitance value**
- **state the functions of dielectric in a capacitor.**

Capacitors and Capacitance

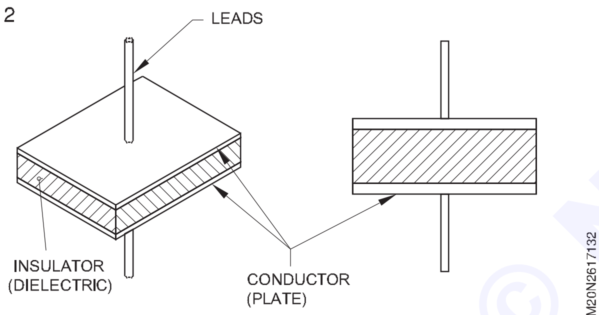
Capacitors are electronic components which can store electric energy in the form of electric charge. The charge storage ability of a capacitor is called the Capacitance of a capacitor. Symbols used to represent capacitors are shown in Fig 1. Alphabet 'C' is used to represent the capacitance of a capacitor.

Fig 1



A simple capacitor consists of two pieces of conductors separated by an insulator as shown in Fig 2.

Fig 2



In capacitors the conductors shown in Fig 2 are called **plates** and the insulator is called **dielectric**.

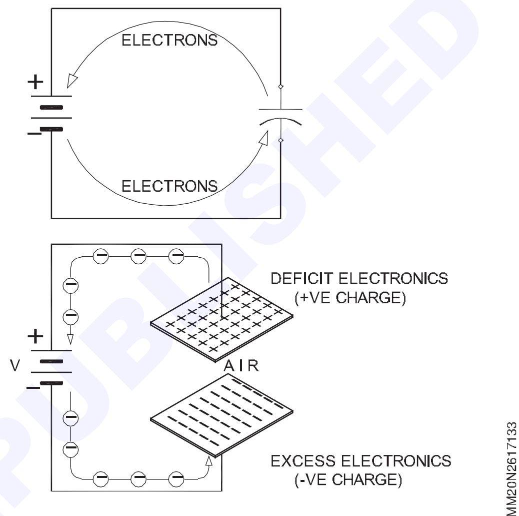
The plates of a capacitor can be of any size and shape and the dielectric may be any one of several insulator materials. Depending on the type of insulator/dielectric used capacitors are called as paper, mica, ceramic, glass, polyester, air electrolyte capacitors etc.,

Capacitor action of storing charge

When electric charge is forced on to the plates of a capacitor by some energy source, such as a battery, the capacitor stores these charges.

When a capacitor is connected to a battery as shown in Fig 3, electrons from the negative terminal of battery move through the connecting leads and pile up on one of the plates of the capacitor. At the same time free electrons from the other plate of the capacitor (remember that plates of a capacitor are conductors having free electrons) move through the connecting lead to the positive terminal of the battery. This process is known as 'charging of capacitor'. As the process of charging continues, the net result is that, one plate of the capacitor ends up with excess of electrons (Negative charge) and the other plate with deficiency of electrons (Positive charge). These charges on the plates of the capacitor represent a voltage source similar to that of the charges on the terminals of a battery/cell. The process of charging stops once the energy stored on the capacitor develops a voltage equal to that of the battery.

Fig 3



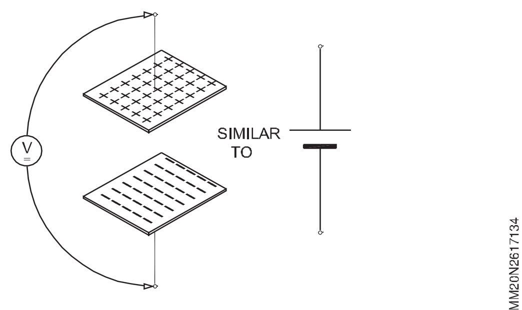
It is important to note that during the process of charging, although electrons were moving from and to the capacitor plates causing current flow in the circuit (you can connect an ammeter to measure it), no electrons moved nor did current flow from one plate through the dielectric to the other plate of the capacitor. The charging current through the circuit stops when the voltage across the capacitor becomes equal to, and in opposition to, the battery voltage. This charged capacitor can be disconnected from the circuit and used as a new energy source as shown in Fig 4.

If a voltmeter is connected across this disconnected charged capacitor, the voltmeter reads the voltage equal to that of the battery which charged it.

If a lamp is connected across this charged capacitor, the bulb glows for a moment indicating current flow through it.

The charge stored in the capacitor is sufficient to supply current through the bulb only for a short duration after which the charge filed up on the capacitor plates gets exhausted. A capacitor has limited use as a primary storage device of energy for two reasons:

Fig 4



1 For its weight and size, the amount of energy it can store is very small when compared with that of a battery.

2 The voltage available from the capacitor diminishes rapidly as energy is removed from the capacitor.

Unit of capacitance

The ability of capacitor to store electrical energy in the form of electrostatic field is known *capacitance*. The unit used to measure capacitance is **Farad** abbreviated as **F**.

A capacitor is said to have a capacitance(C) of 1 Farad, if it stores a charge(Q) of 1 coulomb when a voltage(V) of 1V is applied across its plates.

Therefore, capacitance can be mathematically expressed as,

$$\text{Capacitance} = \frac{\text{Charge}}{\text{Voltage}}$$

$$C = \frac{Q}{V} \text{ Farads}$$

Farad(F) is a very large quantity of capacitance. As most circuits use capacitance values much lower than one farad (F), smaller quantities of capacitance given below are generally used:

1 Microfarad or 1 μF = 1/1000000 F or 10^{-6} farads

1 Nanofarad or 1 nF = $1/10^{9}$ F or 10^{-9} farads

1 Picofarad or 1 pF = $1/10^{12}$ F or 10^{-12} farads

Function of a dielectric in a capacitor

1 Solves the mechanical problem of keeping two metal plates separated by a very small distance.

2 Increases the maximum voltage that can be applied before causing a breakdown, compared with air as dielectric.

3 Increases the amount of capacitance, compared with air, for a given dimension of plates and the distance between them.

Types of capacitors

Capacitors can be classified under two main categories:

1 Fixed value capacitors (Chart 1)

The capacitance value of these capacitors is fixed at the time of manufacture. This value cannot be varied/ altered by the user.

2 Variable capacitors

The capacitance of such capacitors can be varied between the specified minimum to the specified maximum values by the user.

Amongst fixed value capacitors, many different types of capacitors are manufactured to satisfy the needs of the electronic industry. These different types of capacitors are named according to the

1 Type of dielectric material used in capacitor

Example:

a If paper is used as dielectric, the capacitors are called *paper capacitors.*

b If ceramic is used as dielectric, the capacitors are called *Ceramic capacitors.*

2 Type of construction of the capacitor

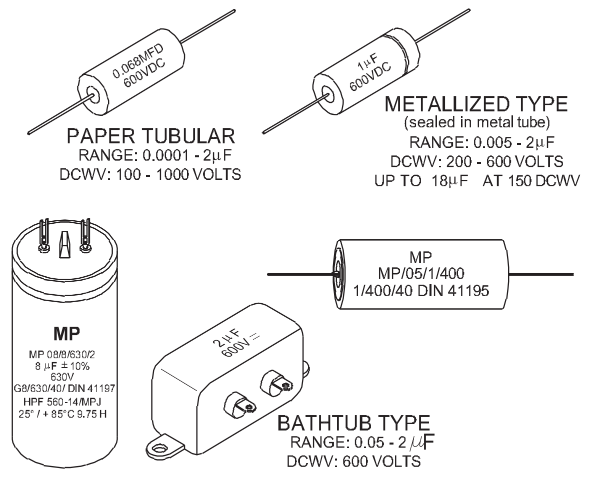
Example:

a If the foils of the conductor and dielectric are rolled to form a capacitor, such capacitors are called as Rolled foil capacitors.

b If the plates and dielectric are in the form of Discs, such capacitors are called as Disc capacitors.

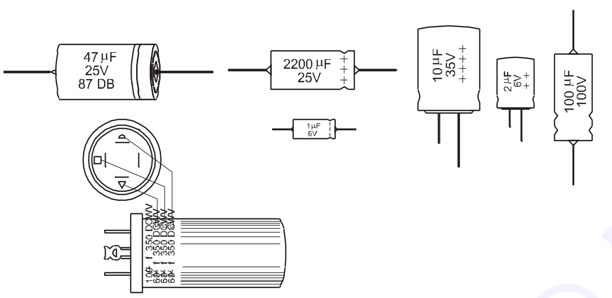
CHART - 1 : Physical appearance of types of fixed value capacitors

PAPER CAPACITORS

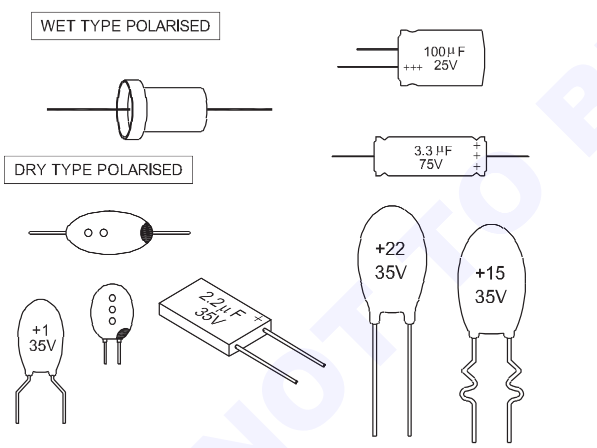


ELECTROLYTIC CAPACITORS

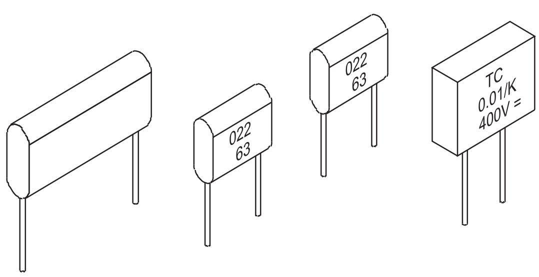
ALUMINIUM TYPE



TANTALUM TYPE

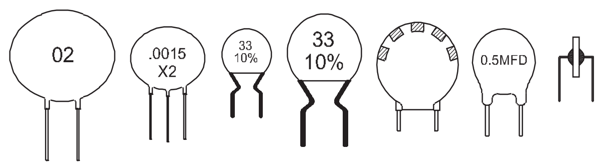


PLASTIC FILM CAPACITORS

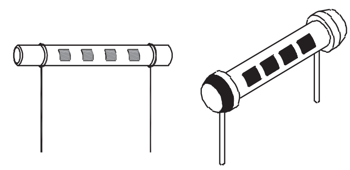


CERAMIC CAPACITORS

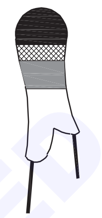
DISC



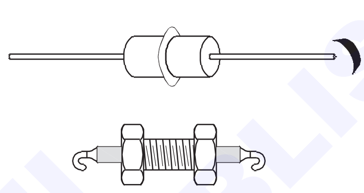
TUBULAR



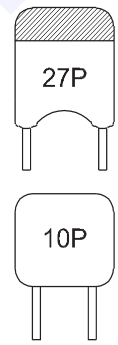
PIN - UP



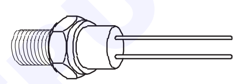
FEED - THROUGH



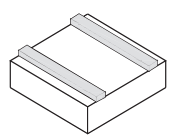
FLAT



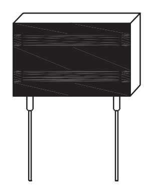
STAND - OFF



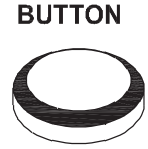
MONOLYTHIC CHIP



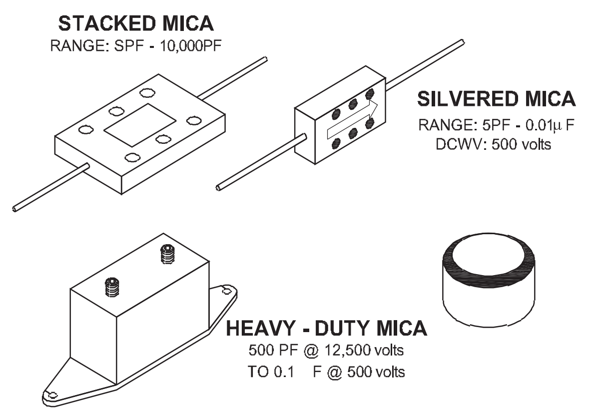
BUNDELED TUBE



BUTTON



MICA CAPACITORS



Fuses-terminology-types-uses

Objectives : At the end of this lesson you shall be able to
- **explain the purpose of the fuse in a circuit**
- **explain the types of fuse bases**
- **classify the different types of fuses and their uses.**

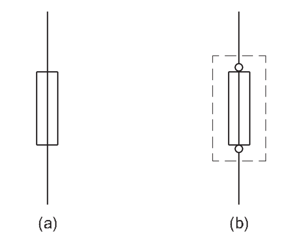
Purpose of fuses : A fuse is a safety device used for the purpose of protecting a circuit against excess current. In the event of excessive current, the fuse element melts and opens up the circuit thereby protecting it from damage.

Symbols : These are the graphical symbols used to illustrate an electrical fuse in electro - technical diagrams.

General symbols of a fuse (Fig 1a)

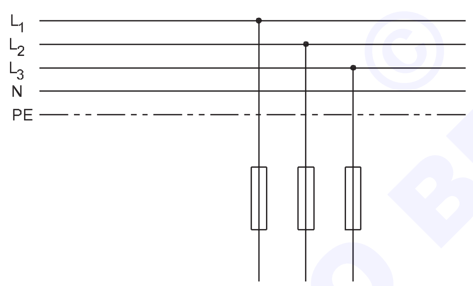
Fuse with terminals and protective housing (Fig 1b)

Fig 1



Placement of fuses : In electrical installations, the fuses are always connected into the live wires (L_1, L_2 and L_3 as shown in Fig 2) and never into the neutral N or the protective earth line (PE).

Fig 2



Terminology

Fuse element : The part of the fuse which is designed to melt and open up a circuit.

Fuse - carrier : The removable portion for carrying the fuse element.

Fuse base : The fixed part of the fuse provided with terminals for connection to the circuit which is suitable for the receptacle of the fuse - carrier.

Current rating : Safe maximum current that can pass continuously without overheating.

Fusing current : The current at which the fuse element melts

Cut - off factor : Time (period) taken for a fuse to interrupt the circuit in the event of a fault.

Fusing factor : Ratio between minimum fusing current and current rating.

$$\text{Fusing factor} = \frac{\text{Minimum fusing current}}{\text{Rated current}}$$

The fusing factor for a re-wireable fuse varies between 1.4 to 1.7 and may go up to 2.0, but for a HRC fuse it is 1.1

However, a fuse selected for over - current protection should not have a fusing factor of more than 1.4.

The fusing factor for a re-wirable fuse varies between 1.4 to 1.7 and may go up to 2.0, but for a HRC fuse it is 1.1

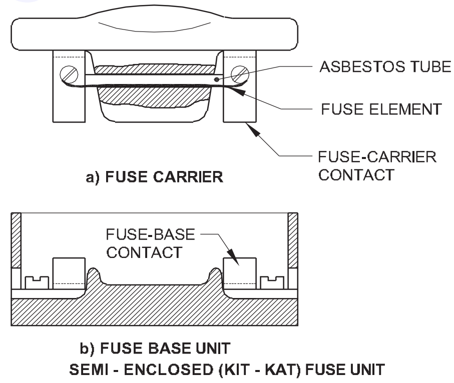
However, a fuse selected for over-current protection should not have a fusing factor of more than 1.4.

Types of fuses used in domestic wiring:

- Re-wirable type (up to 200A)
- Cartridge type (up to 1250A)

Rewirable type fuse (Fig 3): The fuse element in this type of fuse consists of a wire which may be replaced when necessary. These fuses are simple in construction and the initial cost as well as the renewal cost is very low.

Fig 3



The fuse elements used in this type are tinned copper wire, lead and tin alloy.

The fuse element will melt after approximately 2 minutes when carrying a current equal to twice the current rating. However, the cut-off time factor varies in rewirable fuses due to:

- the construction of the carrier (design of fuse-carrier/ base)
- the manner in which the fuse wire has been fitted
- the length of time the fuse was in service
- ambient temperature
- the amount of current etc.

Small fuse wires in parallel in a carrier to carry a large current should be avoided, as far as possible. The actual rating becomes less than the sum of the ratings of the individual strands. A paralleling factor of 0.7 to 0.8 is used to multiply the sum of the rating of individual strands to get the actual current rating.

Disadvantages of rewirable type fuse:

- Deterioration of the fuse element by oxidation due to heating.
- Lack of discrimination.

Cartridge fuses: Cartridge fuses are developed to overcome the disadvantages of the rewirable fuses. Due to high temperature, prolonged use and oxidation, rewirable fuses deteriorate and interrupt the supply even when carrying normal current. As cartridge fuse elements are enclosed in an air tight chamber, deterioration does not take place. Further the rating of a cartridge fuse could be accurately determined from its marking. However, the cost of replacement of cartridge fuses is more than that of rewirable fuses.

Cartridge fuses can be grouped as those with a:

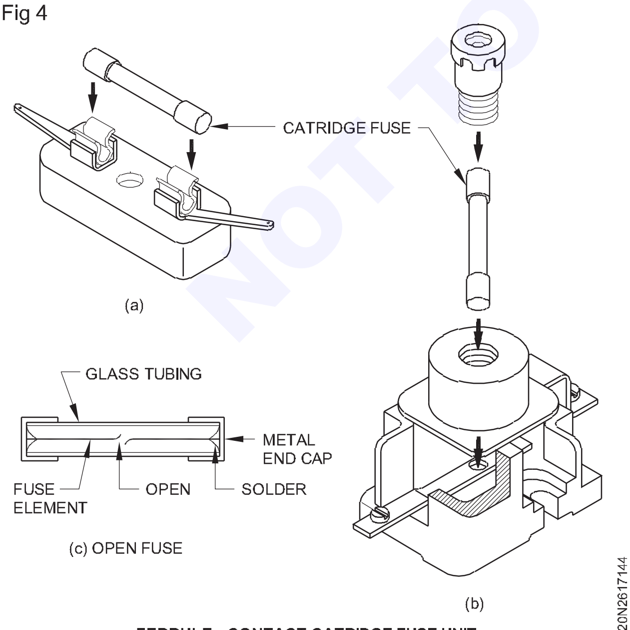
- low rupturing capacity (Say rupturing capacity up to 50 KA.)
- high rupturing capacity. (Say rupturing capacity above 80 KA.)

Rupturing capacity is the ability of a fuse to open the faulty circuit without much arcing or damage to itself. For domestic installations, low rupturing capacity fuses are used whereas for high power factory installations, and for installations connected from high power sources, high rupturing capacity (HRC) fuses are used.

Low rupturing capacity cartridge fuses can be further divided into:

- Ferrule-contact cartridge fuses.(Fig 4)

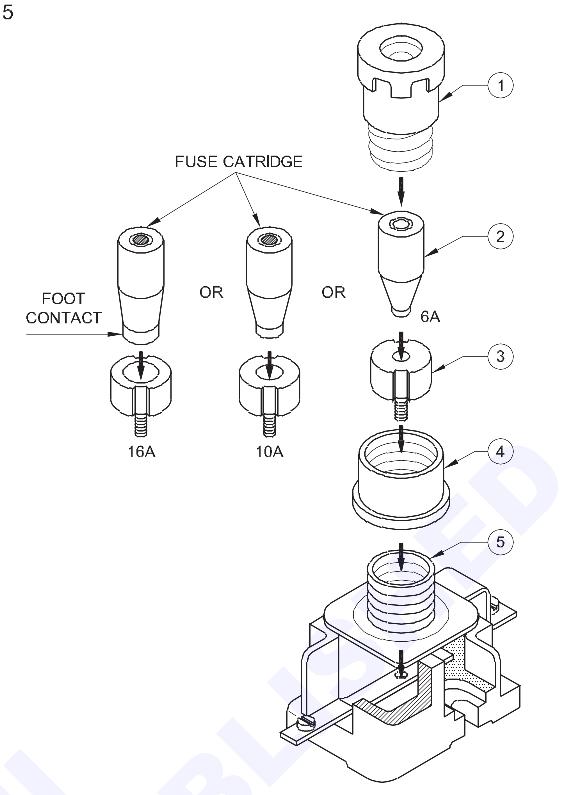
Fig 4



FERRULE - CONTACT CATRIDGE FUSE UNIT

- diazed screw-type cartridge fuses.(Fig 5)

Fig 5



DIAZED SCREW TYPE CATRIDGE FUSE UNIT

Ferrule-contact cartridge fuses: This type, shown in Fig. 4, is used for protecting electrical and electronic circuits. These are available in 25, 50, 100, 200, 250, 500 milliamperes, and also in 1,2,5,6,10,16 & 32 amperes capacity. Normally the current rating is written on one side of the cap, and while replacing, the same capacity fuse should be used. Its body is made of glass and the fuse wire is connected between two metallic caps.

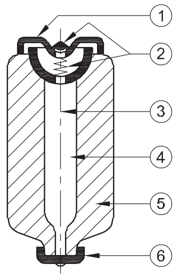
This fuse can be plugged into the fuse socket as shown in Fig 4a or it can be fitted into a fuse base with a screw, in a fuse- holder of the type shown in Fig 4b.

Diazed screw-type cartridge fuses: This is shown in Fig 5. It is also not of a rewirable type. This type of fuse is commonly used in domestic and industrial electrical installations in many countries. It consists of the following parts as shown in Fig 5.

- Screw cap or fuse cartridge-holder (1)
- Fuse cartridge (2)
- Fitting screw or contact screw (3)
- Protective plastic or ceramic ring (4)
- Fuse base or fuse socket (5)

Fuse cartridges are available for rated electric currents of: 2, 4, 6, 10, 16, 20, 25, 35, 50 and 63 amperes. To prevent the insertion of a fuse cartridge having a larger current rating than intended, the foot contacts of the fuse cartridges have different diameters for each rated current(the smaller the current the smaller the diameter of the foot contact). As there is also a separate fitting screw for each type of cartridge, it is not possible to insert, let's say, a 35 amp. fuse cartridge into the fitting screw of a 25 amp fuse cartridge.

Fig 6



FUSE CATRIDGE

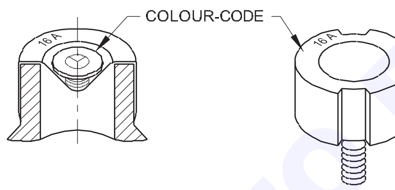
MM20N2617146

Fig. 6 shows the inside of one of the afore-mentioned fuse cartridges. It shows the ceramic body of the cartridge with its foot and head contacts. The two contacts are linked by a fuse wire which is embedded in sand. Each cartridge has a break indicator which will be ejected from the cartridge if the fuse wire is burnt out. The parts of this cartridge, shown in Fig 6, are:

- head contact(1)
- break indicator(2)
- fuse wire(3)
- sand filling(4)
- ceramic fuse body(5)
- foot contact. (6)

For easy identification of the fuse cartridges and the corresponding fitting screws, they are marked with various colours at the places shown in Fig 7. For each current rating, a different colour is used.

Fig 7



MM20N2617147

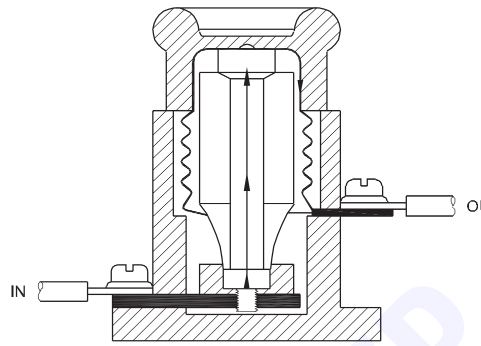
Pink	- 2 amperes	Blue	- 20 amperes
Brown	- 4 amperes	Yellow	- 25 amperes
Green	- 6 amperes	Black	- 35 amperes
Red	- 10 amperes	White	- 50 amperes
Grey	- 16 amperes	Copper	- 63 amperes

Fig 8 shows the flow of the electric current through the fuse base and the fuse. In order to prevent the accidental touching of a live line, the electrical supply must be connected to the terminal which is connected to the fixing screw at the bottom of the base.

Diazed type fuses are available in two categories,

a)quick-response type and b) delayed-action type. The quick-response type is used for heating circuits and normal loads whereas the delayed- action type is used for motor circuits and highly inductive circuits.

Fig 8



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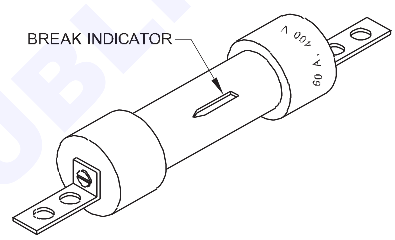
High rupturing capacity fuses (Fig 9): They are cylindrical in shape and are made of a ceramic body filled in with a chemically treated filling powder or silica to quench the arcing quickly without any fire hazard.

Fig 9



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Normally a silver alloy is used as the fusing element and when it melts due to the excessive current, it combines with the surrounded sand/powder, and forms small globules without making an arc, spark or gas. HRC fuses can open a short-circuited circuit within 0.013 second. It has an indicator to show the fuse has blown. The rupturing capacity of the fuse could be calculated from the following formula.

$$\text{Rupturing capacityin MVA} = \frac{\text{Fault current in amperes} \times \text{Circuit voltage}}{10^{6}}$$

As HRC fuses are capable of opening circuits having very high faulty currents, these are preferred in high power circuits even though the replacement cost is high.

Contactors-parts-functions-troubleshooting-symbols

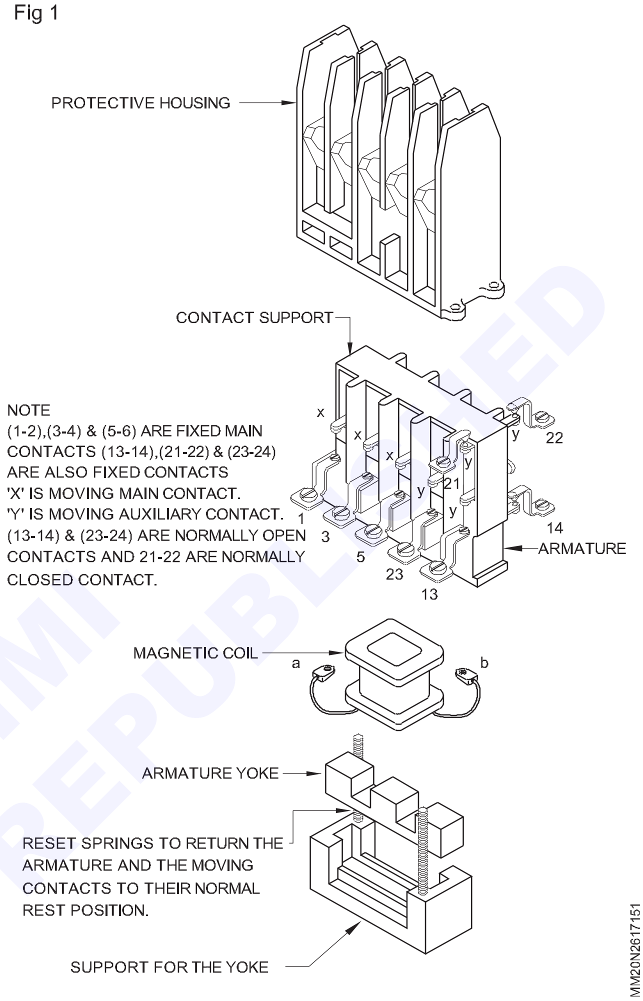
Objectives: At the end of this lesson you shall be able to
- **explain the basic contactor circuit with a single push-button station for start and stop**
- **state the function of a no-volt coil, its rated voltage, position of operation, its common troubles, their causes and remedies.**

i Contactors: The contactor forms the main part in all the starters. A contactor is defined as a switching device capable of making, carrying and breaking a load circuit at a frequency of 60 cycles per hour or more. It may be operated by hand (mechanical), electromagnetic, pneumatic or electro-pneumatic relays.

The contactors shown in Fig 1 consist of main contacts, auxiliary contacts and no-volt coil. As per Fig 1, there are three sets of normally open, main contacts between terminals 1 and 2, 3 and 4, 5 and 6, two sets of normally open auxiliary contacts between terminals 23 and 24, 13 and 14, and one set of normally closed auxiliary contact between terminals 21 and 22. Auxiliary contacts carry less current than main contacts. Normally contactors will not have the push-button stations and O.L. relay as an integrated part, but will have to be used as separate accessories along with the contactor to form the starter function.

The main parts of a magnetic contactor are shown in Fig 1 shows the schematic diagram of the contactor when used along with fused switches (ICTP), push-button stations and OL relay for connecting a squirrel cage motor for starting directly from the main supply. In the same way the direct on-line starter consists of a contactor, OL relay and push-button station in an enclosure.

Fig 1



Circuit breakers

Objective : At the end of this lesson the trainees shall be able to
- **explain the types of protective devices used in a circuit breaker.**

Circuit breakers are used in electrical installations to make or break the circuit with or without load. They also incorporate protective devices.

Definition: A circuit breaker is a device capable of making and breaking a circuit under normal conditions as well as under abnormal conditions such as those of short circuit.

The following are the different types of breakers in common use in electronic industries

1 Miniature circuit breaker(MCB)

2 Earth leakage circuit breakers (ELCB)

Miniature circuit breakers(MCB)

Construction: The Fig 1 shows the internal construction details and parts of a typical MCB. In these MCB's there is no serviceable part as such when they found defective, the whole unit should be replaced.

Over load trips: The overload trips incorporated in the MCBs may be thermal or of the magnetic type or a combination of these two types.

Advantages of using MCB's over switch fuses

1 MCBs are essentially tamper-proof as they have enclosures of a sealed type.

2 MCBs afford closer protection than the rewireable and HRC fuses in common use, because of the narrowly controlled tripping factor i.e. ratio of minimum trip current/rated current.

3 These are available in plug-in design also, in which case they can be pushed into circuit bus-bars even in energized condition. Thus replacement is easy.

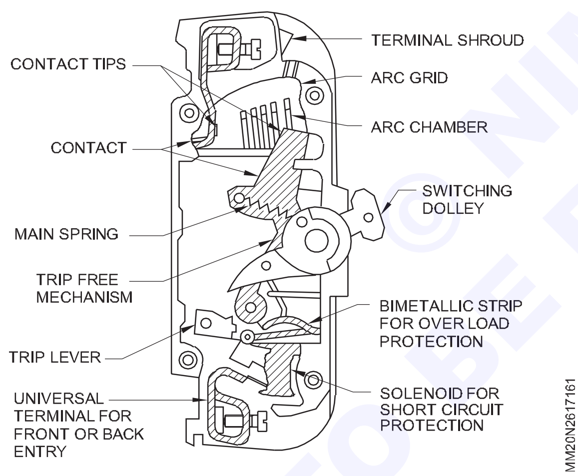
4 These are modular in design which permits their use in various combinations. In the case of triple pole types, since they are gang operated, there is no possibility of single phasing.

5 MCBs can assume the function of a switch as well as a protective device and consequently they may be used to control, as well as protect, the circuits and apparatus.

6 Use in small flats/quarters/rooms. Many large industries and project houses build quarters for their employees/workers wherein fixed light and domestic connections are provided. The electricity bills are not charged as per consumption. A low monthly charge is levied. Sometimes free electricity is provided. In such instances, it is essential that the user does not connect higher load appliances, leading to overheating of wires and burning of supply equipments.

In such cases load rated MCBs can be used as the main incoming circuit breakers. In the event of extra load being connected /drawn, the circuit breaker will trip and cut off supply.

Fig 1



For such applications, the MCBs can be provided in enclosures, with padlocking devices so that only the authorised persons has to be approached for re-switching on the supply. Some manufacturers produce such enclosures with MCBs as well.

For other general small flats/rooms, it is advantageous to install a circuit breaker of 10 amps or 15 amps for over-all protection.

Availability of MCBs: MCBs are available indegeneous in the various combinations of poles and current ratings.

i Single pole MCB. Current rating 5 to 60 amps.

ii Double pole MCB (i.e. two MCBs with common trip bar) 5 to 60 amps.

iii Triple pole MCB (i.e. three MCBs, with common trip bar) current rating 5 to 60 amps.

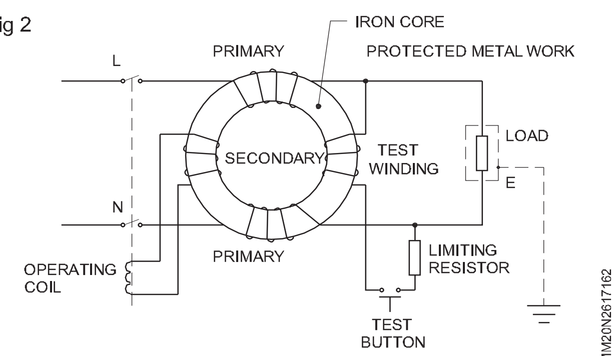
iv Four pole MCB (i.e. four MCBs with common trip bar) current rating 5 to 60 amps.

Earth leakage circuit breaker (ELCB): Earth leakage circuit breakers are the devices designed to provide protection against accidents by rapidly interrupting dangerous contact voltages which may be present in the faulty electrical equipment as a result of ground faults, insufficient insulation, insulation failure or misuse and sabotage. Basically the ELCBs are of two types, voltage operated ELCBs and current operated ELCBs.

Over the years, it has been established that current operated ELCBs are much more reliable in operation, easier to install and maintain. Besides, there is no dangerous ageing of the protective system components involved, as in the voltage operated ELCBs, where the earth electrode resistance changes with time and hence the earth loop impedance does not remain constant over a period. This leads to dangerous touch voltages on the metal enclosures without being sensed by the voltage operated ELCBs, whereas current operated devices are safer as they operate on the principle of the vector sum of the line currents and the neutral current. Any current even in milliamperes which is not returning to the source through the neutral is assumed to be flowing through the earth or through any insulating body. This differential current is immediately sensed by the current operated ELCB which switches off the electricity supply, protecting the people from dangerous electrical shocks and the insulations from failing and inviting dangerous fires.

They also provide a high degree of protection against earth faults and fires. Fig 2 shows the circuit diagram of a residual - current earth leakage circuit breaker. The essential part of the ELCB is a toroid type core transformer with two opposed windings called primary. One is connected in series with the line and the other in series with the neutral. As far as there is no leakage current, the line current is equal to the neutral current and the magnetic flux produced by the two primary windings oppose and cancel each other. Thus the secondary winding which is connected to the trip (operating) coil does not induce any voltage.

Fig 2



However, when there is any leakage in the circuit, the line current differs from neutral current, thus inducing a voltage in the secondary and the trip coil opens the circuit. Working of the ELCB could be checked by the test button at intervals. Specification for ELCB should contain normal rated current, leakage current and the time duration within which the ELCB should trip. Some state electricity authorities in India insist on the use of ELCB in each of the domestic installation as a safety measure.

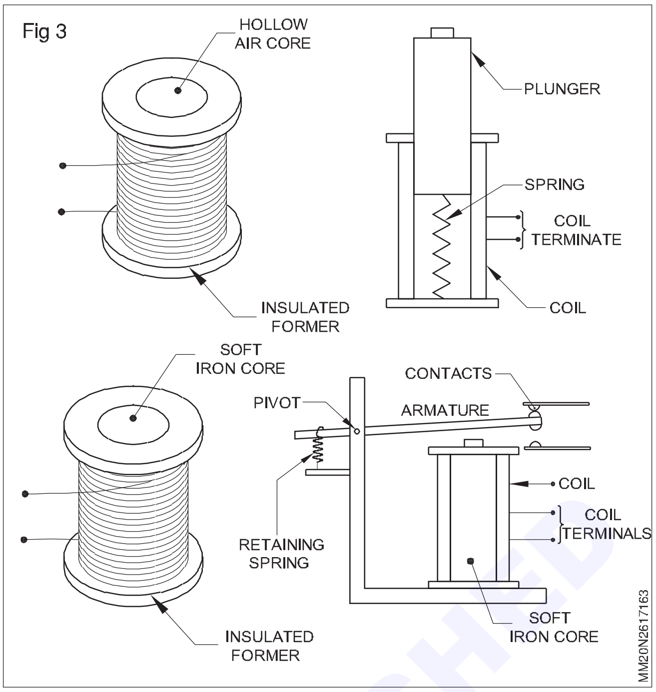
Relays:

Introduction

In addition to solenoids, one other most popular application of electromagnets is in what are called electromagnetic relays.

Important similarities and differences between a solenoid and a relay is illustrated in Fig 3.

Fig 3



Electromagnetic relays

The term relay was used for the first time, to describe an invention made by Samuel Morse in 1836. The device invented by *Morse* was a *Telegraph Amplifying Electromagnetic Device.* 'This device enabled a small current flowing in a coil to switch-ON a large current in another circuit, and thus helped in relaying of telegraph signals.

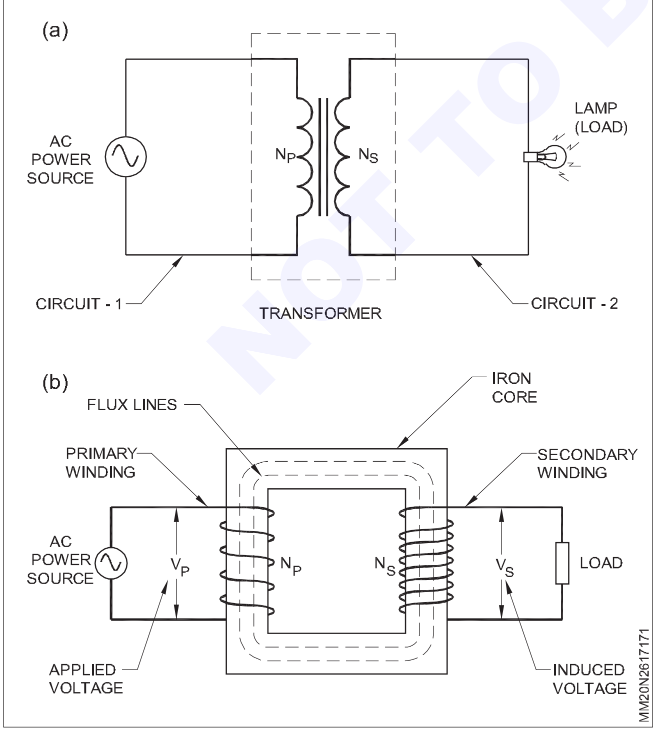
In any application, the object of a relay is generally to act as a remote switch or as a electrical multiplier switch. This means, a relay enables a comparatively weak current to bring into operation a much stronger current or currents.

Transformer

Objectives : At the end of this lesson you shall be able to
- **state the basic function of a transformer**
- **state the classifications of transformers**

Transformer is an electrical device used to transfer electric energy from one AC circuit to another circuit by magnetic coupling as shown in Fig 1a.

Fig 1



A transformer essentially consists of two coils of insulated conducting material, generally copper. These coils are wound on a core made of iron or ferrite as shown in Fig 1b. These coils are so arranged that magnetic flux developed in one coil will link with the other coil. Hence, mutual inductance exists between the two coils with tight-coupling (k=1). A change in current through one coil (say N_p) induces a voltage in the other coil (say N_s). The magnitude of induced voltage in the secondary winding depends on the number of turns of the coils and on how tight the magnetic coupling(k) is, between the two coils.

In a transformer, as shown in Fig 1b, the coil or the winding to which electrical energy is given from an ac power source is called the **primary winding**. In Fig 1 this coil is marked N_p. The second coil to which, energy from the primary winding is coupled magnetically is called the secondary winding (N_s in Fig 1b). If a load, say a lamp or a resistor, is connected across the secondary winding, current flows through the load although there is no direct AC power source connected to it.

Hence, transformers can be defined as devices that make use of the principle of mutual induction, in transferring electrical energy from one ac circuit to another circuit with out direct electrical connection.

> **It is important to note that transformers cannot transfer DC energy from primary winding to secondary winding, because, a DC current cannot produce changing magnetic field and hence cannot develop induced voltage.**

Important terms used with iron-core transformers are explained below;

1 Turns Ratio of a transformer

The ratio of the number of turns of coil in the primary (N_p) to the number of turns of coil in the secondary (N_s) is called the *turns ratio of the transformer*.

$$\text{Turns ratio} = \frac{N_p}{N_S}$$

For example, 1000 turns in the primary and 100 turns in the secondary gives a turns ratio of 1000/100, or 10:1 which is stated as *ten-to-one* turns ratio.

2 Voltage Ratio of a transformer

The ratio of voltage across the primary winding(V_p) to the voltage available across the secondary winding(V_s) is called the *voltage ratio of the transformer*.

$$\text{Voltage ratio} = \frac{V_p}{V_S}$$

When coefficient of mutual coupling(k) between primary and secondary winding is 1, the voltage induced per turn of the secondary winding is the same as the self-induced voltage per turn in the primary winding. The total voltage appearing across the secondary winding depends on the number of turns of secondary winding. Therefore, the voltage ratio is in the same proportion as the turn ratio:

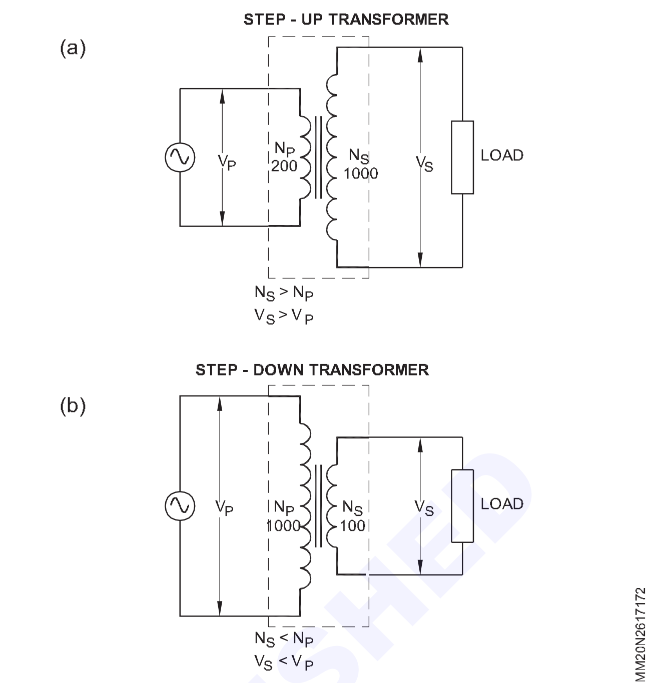
$$\frac{V_p}{V_S} = \frac{N_p}{N_S}$$

This means, if the secondary winding has more turns than the primary winding ($N_s > N_p$) then, the secondary voltage will be higher than the primary voltage. In other words, in such a condition the primary voltage is said to be raised or stepped-up. Such transformers are called STEP-UP transformer as shown in Fig 2a.

Example: As shown in Fig 2a, a tranformer has 200 turns of N_p and 1000 turns of N_s, its turns ratio will be,

$$\text{Turns ratio} = \frac{N_p}{N_S} = \frac{200}{1000} = 1:5$$

Fig 2



For this transformer, if the applied AC primary voltage (V_p) is 110 V_{rms}, the secondary voltage will be stepped up in the same ratio as that of turns ratio. Hence, the secondary voltage will be twice the primary voltage, i.e, 5 x 110 = 550 V_{rms}.

On the other hand, when the secondary winding has less number of turns than the primary winding, the primary voltage is said to be lowered or stepped - down. Such transformers are called Step - down tranformers as shown in Fig 2b.

a **Step-up Transformers**: Transformers in which, the induced secondary voltage is higher than the source voltage given at primary are called *step-up transformers*.

b **Step-down Transformers**: Transformers in which, the induced secondary voltage is lower than the source voltage given at primary are called step-down transformers.

c **Isolation transformers**: Transformers in which, the induced secondary voltage is same as that of the source voltage given at primary are called one-to-one or isolation transformers. In these transformers the number of turns in the secondary will be equal to the number of turns in the primary making the turns ratio equal to 1.

DC generator - principle - parts - types - function - e.m.f. equation

Objectives: At the end of this lesson you shall be able to
- **state the general concepts of rotating Power machine**
- **state the principle of the DC generator**
- **explain the faraday's of laws of electro magnetic induction**
- **explain the production of dynamically induced e.m.f., its magnitude and direction**
- **describe the parts of a DC generator and their function**
- **classify and identify the different type of generators and their terminal markings**
- **explain the armature circuit resistance and its relation**
- **derive the emf equation and calculation of a DC generator**
- **explain about separately excited DC generator with different types of windings.**

General concept of rotating Power machine

In rotating machines, there are two parts, the stator and rotor. Rotating Power machines are also of two types - DC and AC machines. Power machines are widely used. In DC machines the stator is used as a field and the rotor is used as an armature, while reverse is the case for AC machines. That is synchronous generators and synchronous motors. The induction motor is another kind of AC machine, which is singly excited; that is AC supply voltage is only given to the stator and no supply is given to the rotor. In DC machines and synchronous machines, the field is always excited.

Generator:An Power generator is a machine which converts mechanical energy into Power energy.

Principle of the generator:To facilitate this energy conversion, the generator works on the principle of Faraday's Laws of Electromagnetic Induction.

Faraday's Laws of Electromagnetic Induction: There are two laws.

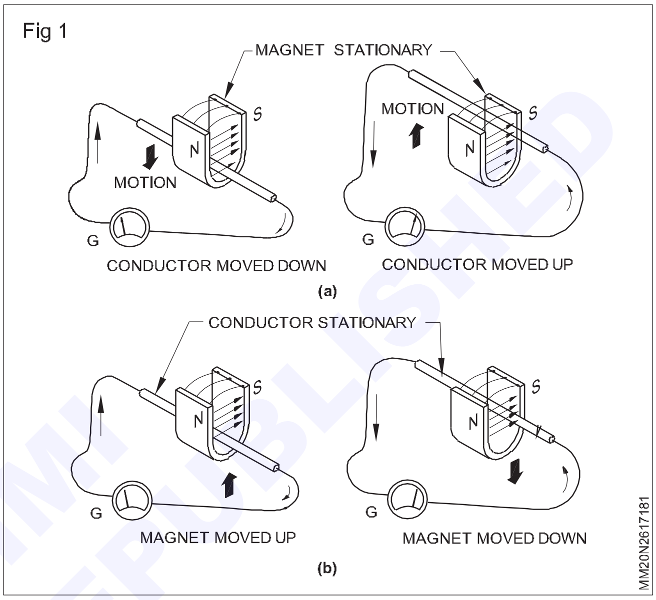
The first law states:

First law: Whenever the flux linking to a conductor or circuit changes, an emf will be induced.

The second law states: The magnitude of such induced emf depends upon the rate of change of the flux linkage.

$$\text{emf} \propto \frac{\text{Change of flux}}{\text{Time taken for change}}$$

Types of emf: According to Faraday's Laws, an emf can be induced, either by the relative movement of the conductor and the magnetic field or by the change of flux linking on a stationary conductor.



Dynamically induced emf: In case, the induced emf is due to the movement of the conductor in a stationary magnetic field as shown in Fig 1a or by the movement of the magnetic field on a stationary conductor as shown in Fig 1b, the induced emf is called dynamically induced emf.

As shown in Figs 1a & 1b, the conductor cuts the lines of force in both cases to induce an emf, and the presence of the emf could be found by the deflection of the needle of the galvanometer `G'. This principle is used in DC and AC generators to produce electricity.

Statically induced emf: In case, the induced emf is due to change of flux linkage over a stationary conductor as shown in Fig 1b, the emf thus induced is termed as statically induced emf. The coils 1 and 2 shown in Fig 1b are not touching each other, and there is no Power connection between them.

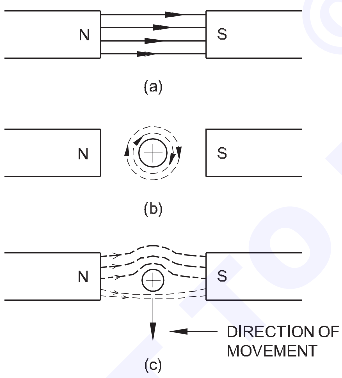
DC motor - principle and types

Objectives: At the end of this lesson you shall be able to
- **explain the working principle of a DC motor**
- **state the different types of DC motors.**

Introduction: A DC motor is a machine which converts DC Power energy into mechanical energy. It is similar to a DC generator in construction. Therefore, a DC machine can be used as a generator or as a motor. Even today, because of the excellent torque, speed and load characteristics of DC motors, 90% of the motors used in precision machines, wire drawing industry and traction are of this type. The DC motor needs frequent care and maintenance by qualified electricians. Hence more job opportunities exist in this area for an electrician.

Principles of a DC motor: It works on the principle that whenever a current-carrying conductor is kept in a uniform magnetic field, a force will be set up on the conductor so as to move it at right angles to the magnetic field. It can be explained as follows. Fig 1a shows the uniform magnetic field produced by a magnet, whereas Fig 1b shows the magnetic field produced around the current-carrying conductor. Combining the effects of Fig 1a and Fig 1b in one figure, Fig 1c shows the resultant field produced by the flux of the magnet and the flux of the current-carrying conductor. Due to the interactions of these two fields, the flux above the conductor will be increased and the flux below the conductor is decreased as represented in Fig 1c. The increased flux above the conductor takes a curved path thus producing a force on the conductor to move it downwards.

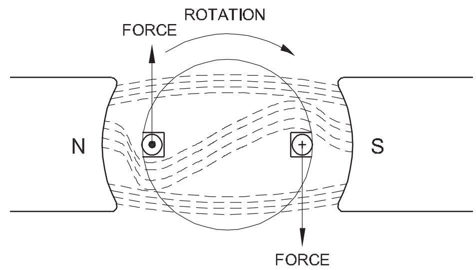
Fig 1



If the conductor in Fig 1 is replaced by a loop of wire as shown in Fig 2, the resultant field makes one side of the conductor move upwards and the other side move downwards. It forms a twisting torque over the conductors, and they tend to rotate, if they are free to rotate. But in a practical motor, there are a number of such conductors/coils. Fig 3 shows the part of a motor. When its armature and field are supplied with current, the armature experiences a force tending to rotate in an anticlockwise direction as shown in Fig 3.

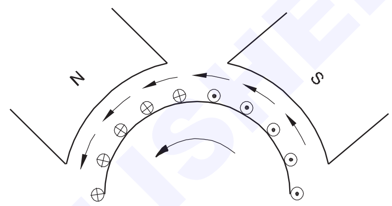
The direction of rotation or movement can be determined by Fleming's left hand rule. Accordingly, the direction of rotation of the armature could be changed either by changing the direction of armature current or the polarity of the field.

Fig 2



REACTION OVER A CURRENT CARRYING LOOP BY THE MAGNETIC FIELD

Fig 3



REACTION OVER THE ARMATURE CURRENT CARRYING CONDUCTORS BY THE MAGNETIC FIELD

Fleming's Left Hand Rule: The direction of force produced on a current-carrying conductor placed in a magnetic field can be determined by this rule. As shown in Fig 4a, hold the thumb, forefinger and middle finger of the left hand mutually at right angles to each other, such that the forefinger is in the direction of flux, and the middle finger is in the direction of current flow in the conductor; then the thumb indicates the direction of motion of the conductor. For example, a loop of coil carrying current, when placed under north and south poles as shown in Fig 4b, rotates in an anticlockwise direction.

Types of DC motors: As the DC motors are identical in construction to that of DC generators, they are also classified as series, shunt and compound motors, depending upon their connection of field winding with the armature and supply.

When the armature and field are connected in series, as shown in Fig 5, it is called a series motor.

When the armature and field are connected in parallel across supply, as shown in Fig 6, it is called a shunt motor

When the motor has two field coils, one in series with the armature and the other in parallel with the armature, as shown in Fig 7, it is called a compound motor.

The relation between applied voltage, back emf, armature voltage drop, speed and flux of DC motor, method of changing direction of rotation.

Fig 4

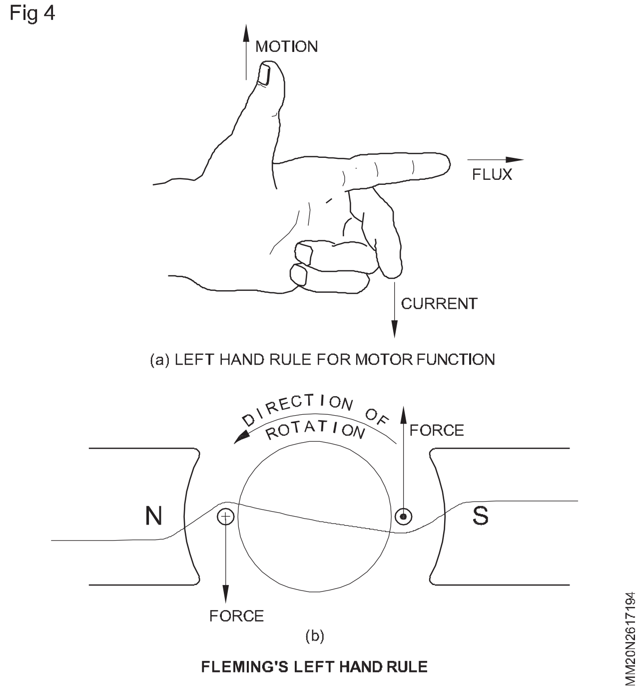


Fig 5

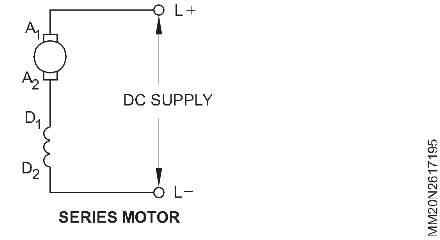


Fig 6

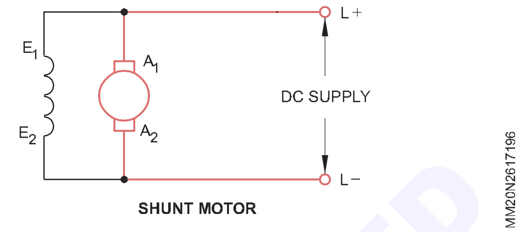
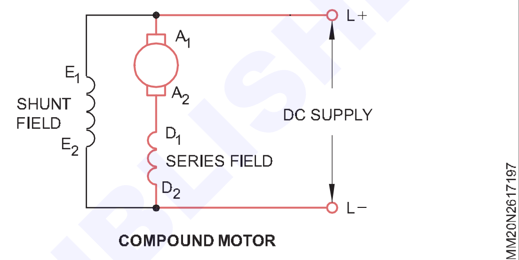


Fig 7



Principle of induction motor

Objectives: At the end of this lesson you shall be able to
- **state the principle of a 3-phase induction motor**
- **explain briefly the method of producing a rotating magnetic field.**

The three-phase induction motor is used more extensively than any other form of Powermotor, due to its simple construction, trouble-free operation, lower cost and a fairly good torque speed characteristic.

Principle of 3-phase induction motor: It works on the same principle as a DC motor, that is, the current-carrying conductors kept in a magnetic field will tend to create a force. However, the induction motor differs from the DC motor in fact that the rotor of the induction motor is not electrically connected to the stator, but induces a voltage/ current in the rotor by the transformer action, as the stator magnetic field sweeps across the rotor. The induction motor derives its name from the fact that the current in the rotor is not drawn directly from the supply, but is induced by the relative motion of the rotor conductors and the magnetic field produced by the stator currents.

The stator of the 3-phase induction motor is similar to that of a 3-phase alternator, of revolving field type. The three-phase winding in the stator produces a rotating magnetic field in the stator core as it will be explained later. The rotor of the induction motor may have either shorted rotor conductors in the form of a squirrel cage or in the form of a 3-phase winding to facilitate the circulation of current through a closed circuit.

Let us assume that the stator field of the induction motor is rotating in a clockwise direction as shown in Fig 1. This makes for the relative motion of the rotor in an anticlockwise direction as shown in Fig 1. Applying Fleming's right hand rule, the direction of emf induced in the rotor will be towards the observer as shown in Fig 2. As the rotor conductors have a closed electric path, due to their shorting, a current will flow through them as in a short-circuited secondary of a transformer.

The magnetic field produced by the rotor currents will be in a counter-clockwise direction as shown in Fig 2 according to Maxwell's Corkscrew rule. The interaction between the stator magnetic field and the rotor magnetic field results in a force to move the rotor in the same direction as that of the rotating magnetic field of the stator, as shown in Fig 3. As such the rotor follows the stator field in the same direction by rotating at a speed lesser than the synchronous speed of the stator rotating magneticfield.

At higher speeds of the rotor nearing to synchronous speeds, the relative speed between the rotor and the rotating magnetic field of the stator reduces and results in a smaller induced emf in the rotor. Theoretically, if we assume that the rotor attains a speed equal to the synchronous speed of the rotating magnetic field of the stator, there will be no relative motion between the stator field and the rotor, and thereby no induced emf or current will be there in the rotor. Consequently there will not be any torque in the rotor. Hence the rotor of the induction motor cannot run at a synchronous speed at all. As the motor is loaded, the rotor speed has to fall to cope up with the mechanical force; thereby the relative speed increases, and the induced emf and current increase in the rotor resulting in an increased torque.

Fig 1

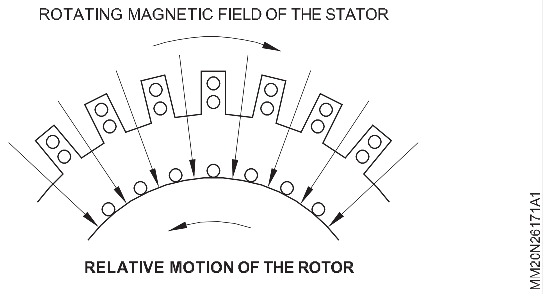


Fig 2

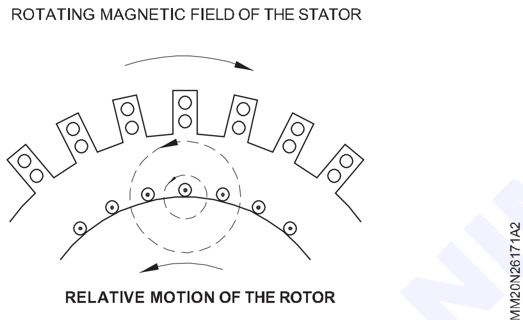
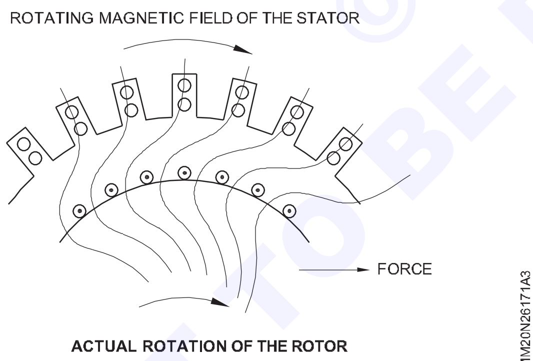


Fig 3



To reverse the direction of rotation of a rotor: The direction of rotation of the stator magnetic field depends upon the phase sequence of the supply. To reverse the direction of rotation of the stator as well as the rotor, the phase sequence of the supply is to be changed by changing any two leads connected to the stator.

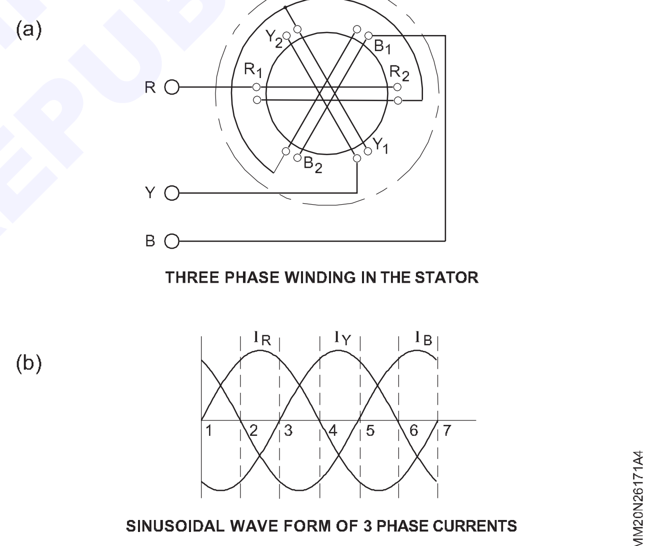
Rotating magnetic field from a three-phase stator: The operation of the induction motor is dependent on the presence of a rotating magnetic field in the stator. The stator of the induction motor contains three-phase windings placed at 120 Power degrees apart from each other. These windings are placed on the stator core to form non-salient stator field poles. When the stator is energized from a three-phase voltage supply, in each phase winding will set up a pulsating field. However, by virtue of the spacing between the windings, and the phase difference, the magnetic fields combine to produce a field rotating at a constant speed around the inside surface of the stator core. This resultant movement of the flux is called the **`rotating magnetic field'**, and its speed is called the **`synchronous speed'**.

The manner, in which the rotating field is set up, may be described by considering the direction of the phase currents at successive instants during a cycle. Fig 4a shows a simplified star-connected, three-phase stator winding. The winding shown is for a two-pole induction motor. Fig 4b shows the phase currents for the three-phase windings. The phase currents will be 120 Power degrees apart as shown in Fig 4b. The resultant magnetic field produced by the combined effect of the three currents is shown at increments of 60° for one cycle of the current.

At position (1) in Fig 4b, the phase current I_R is zero, and hence coil R will be producing zero flux. However, the phase current I_B is positive and I_y is negative.

Considering the instantaneous current directions of these three phase windings, as shown in Fig 4b at position 1, we can indicate the current direction in Fig 5 (1).

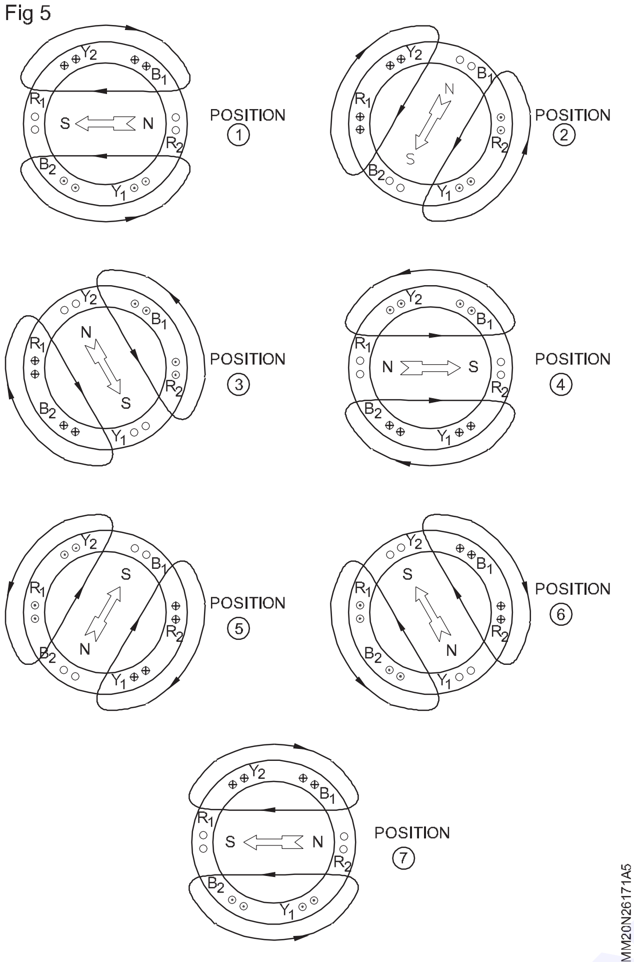
Fig 4



For convenience the +ve current is shown as +ve sign, and the -ve current is shown as dot (•) sign. Accordingly Y_2 and B_1 are shown as positive and Y_1 and B_2 are shown as negative. Using Maxwell's corkscrew rule, the resulting flux by these currents will produce a flux as shown in Fig 5(1). The arrow shows the direction of the magnetic field and the magnetic poles in the stator core.

At position 2, as shown by Fig 5(2), 60 Power degrees later, the phase current I_B is zero, the current I_R is positive and the current I_Y is negative. In Fig 5(2) the current is now observed to be flowing into the conductors at the coil ends R_1 and Y_2, and out of the conductors at coil R_2 and Y_1. Therefore, as shown in Fig 5(2), the resultant magnetic poles are now at a new position in the stator core. In fact the poles in position 2 have also rotated 60° from position (1).

Fig 5



Using the same reasoning as above for the current wave positions 3, 4, 5, 6 and 7, it will be seen that for each successive increment of 60 Power degrees, the resultant stator field will rotate a further 60° as shown in Fig 5. Note that from the resultant flux from position (1) to position (7), it is obvious that for each cycle of applied voltage the field of the two-pole stator will also rotate one revolution around its core.

From what is stated above it will be clear that the rotating magnetic field could be produced by a set of 3-phase stationary windings, placed at 120° Power degrees apart, and supplied with a 3-phase voltage.

The speed at which the field rotates is called synchronous speed, and, it depends upon the frequency of supply and the number of poles for which the stator is wound.

Hence

N_s = Synchronous speed in R.P.M.

$$= \frac{120F}{P} \text{ rpm}$$

where `P' is the number of poles in the stator, and `F' is the frequency of the supply.

Single phase motors - split phase induction motor - induction-start, induction-run motor

Objectives: At the end of this lesson you shall be able to
- **explain briefly the types of AC single phase motors**
- **explain the necessity and methods of split-phasing the single phase to obtain a rotating magnetic field**
- **explain the principle, construction, operation characteristic and application of single phase resistance / induction-start / induction-run motors.**

Single phase motors perform a great variety of useful services at home, office, farm, factory, and in business establishments. These motors are generally referred to as fractional horsepower motors with a rating of less than 1 H.P. Most single phase motors fall into this category. Single phase motors are also manufactured in 1.5,2,3 and up to 10 H.P. as a special requirement.

Single phase motors may be broadly classified as split-phase induction motors and commutator motors according to their construction and method of starting.

Split-phase induction motors can be further classified as:

- resistance-start, induction-run motors
- induction-start, induction-run motors
- permanent capacitor motors
- capacitor-start, induction-run motors
- capacitor-start, capacitor-run motors
- shaded pole motors.
- stepper motor

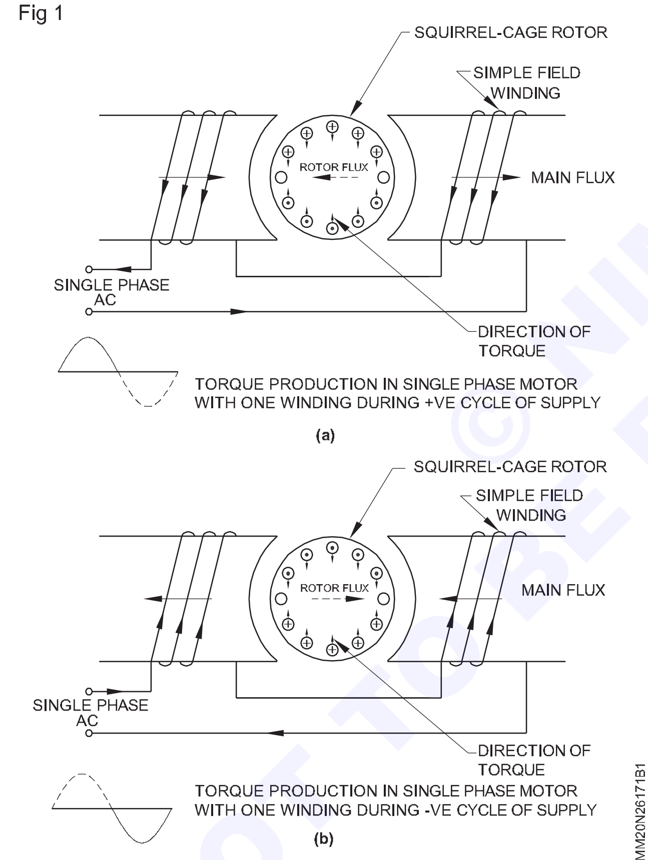
Commutator motors can be classified as:

- repulsion motors
- series motors.

The basic principle of operation of a split-phase induction motor is similar to that of a polyphase induction motor. The main difference is that the single phase motor does not produce a rotating magnetic field but produces only a pulsating field. Hence to produce the rotating magnetic field, phase-splitting is to be done to make the motor to work as a two-phase motor for starting.

First, let us examine the behaviour of the magnetic field as set up by an AC current in a sinlge-phase field winding. With reference to Fig 1, at a particular instant, the current flowing in the field winding produces the magnetic field as shown in Fig 1a. Since the produced magnetic field is varying, it will induce currents in the rotor bars which in turn will create a rotor flux. This stator-induced flux, according to Lenz's law, opposes that of the main field. By applying this principle, the current direction in the rotor bars can be determined as shown in Fig 1a, as well as the torque created between the field and rotor currents. It is apparent that the downward torque produced by the upper rotor conductors is counteracted by the upward torque produced by the lower rotor conductors; hence no rotation results. In the next instant, as shown in Fig 1b, the voltage in the input supply changes its polarity, creating a main field with a change in direction. This main field produces a torque, downward in upper conductors, and upwards in bottom conductors resulting in the cancellation of torque with no movement of the rotor, in this case also. Since the field is pulsating, the torque is pulsating although no net torque is produced over a full cycle.

Fig 1



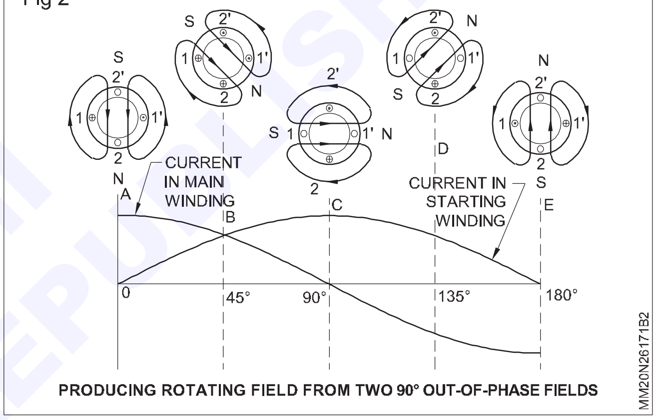
If the rotor is given a small jerk in any direction in the above mentioned cases, it will go on revolving, and will develop a torque in that particular direction due to interaction between the rotor and stator fluxes. Because of this effect, the split-phase motor, once started, needs only one winding to be connected to the supply for running. It is clear that a single phase induction motor, when having only one winding, is not self-starting. If the main field is made revolving instead of pulsating, a rotational torque could be produced in the rotor.

Producing a rotating field from two 90° out-of-phase fields: One of the methods of producing a rotating magnetic field is by split-phasing. This could be done by providing a second set of winding in the stator called the starting winding. This winding should be kept physically at 90 Power degrees from the main winding, and should carry a current out of phase from the main winding. This, out of phase current, could be achieved by making the reactance of the starting winding being different from that of the main winding. In case both the windings have similar reactance and impedance, the resulting field, created by the main and starting windings, will alternate but will not revolve and the motor will not start.

By split-phasing, the two (main and starting) fields would combine to produce a rotating magnetic field as stated below.

Fig 2 shows that the main (1,1') and starting (2,2') windings are kept in the stator at 90° to each other. For consideration, only, one half cycle is shown with the effects at 450 increments.

Fig 2



At position `A', only the main winding is producing flux, and the net flux will be in a vertical direction, as shown in the stator diagram. At instant `B', 45° later, both windings are producing flux, and the net flux direction will also have rotated 45°. At position `C', the maximum flux is now in a horizontal direction because only the starting winding is producing flux. At instant `D', the current from the main winding is building up again, but in a new direction, while that from starting winding is now decreasing. Therefore, the net flux at this instant will be as shown in position D. At position `E', the maximum flux is just the opposite of what it was at instant `A'. It should now be evident that the two out-of-phase fields are combining to produce a net rotating field effect.

Working of split-phase motor: At the time of starting, both the main and starting windings should be connected across the supply to produce the rotating magnetic field. The rotor is of a squirrel cage type, and the revolving magnetic field sweeps past the stationary rotor, inducing an emf in the rotor. As the rotor bars are short-circuited, a current flows through them producing a magnetic field. This magnetic field opposes the revolving magnetic field and will combine with the main field to produce a revolving field. By this action, the rotor starts revolving in the same direction of the rotating magnetic field as in the case of a squirrel cage induction motor, which was explained earlier.

Hence, once the rotor starts rotating, the starting winding can be disconnected from the supply by some mechanical means as the rotor and stator fields form a revolving magnetic field.

Alternator - principle - relation between poles, speed and frequency

Objectives: At the end of this lesson you shall be able to
- **explain the working principle of an alternator**
- **explain the method of production of sine wave voltage by a single loop alternator**
- **describe the relation between frequency, number of poles and synchronous speed.**

Principle of an alternator: An alternator works on the same principle of electromagnetic induction as a DC generator. That is, whenever a conductor moves in a magnetic field so as to cut the lines of force, an emf will be induced in that conductor. Alternatively whenever there is relative motion between the field and the conductor, then, the emf will be induced in the conductor. The amount of induced emf depends upon the rate of change of cutting or linkage of flux.

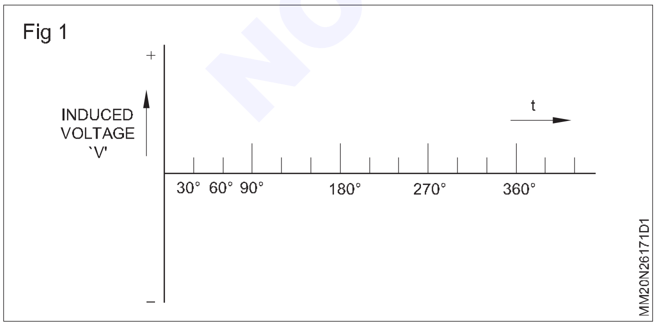
In the case of DC generators, we have seen that the alternating current produced inside the rotating armature coils has to be rectified to DC for the external circuit through the help of a commutator. But in the case of alternators, the alternating current produced in the armature coils can be brought out to the external circuit with the help of slip-rings. Alternatively the stationary conductors in the stator can produce alternating current when subjected to the rotating magnetic field in an alternator.

Production of sine wave voltage by single loop alternator: Fig 2a shows a single loop alternator. As it rotates in the magnetic field, the induced voltage in it varies in its direction and magnitude as follows.

To plot the magnitude and direction of the voltage induced in the wire loop of the AC generator in a graph, the Powerdegrees of displacement of the loop are kept in the `X' axis as shown in Fig 1 through 30 Powerdegrees. As shown in Fig 2c, three divisions on the `X' axis represent a quarter turn of the loop, and six divisions a half turn. The magnitude of the induced voltage is kept in the `Y' axis to a suitable scale.

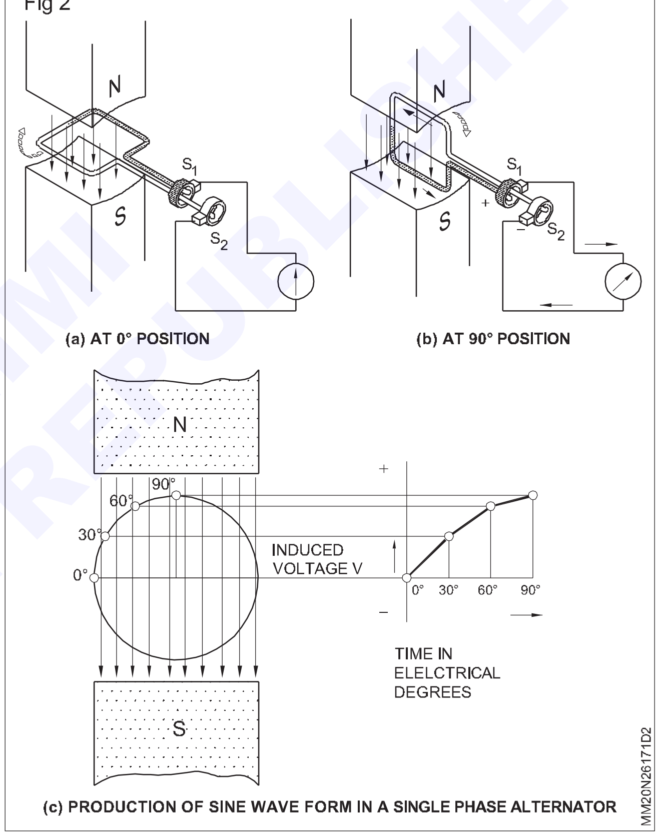
The part above the X-axis represents the positive voltage, and the part below it the negative voltage as shown in Fig 1.

Fig 1



The position of the loop at the time of starting is shown in Fig 2a and indicated in Fig 2c as `O' position. At this position, as the loop moves parallel to the main flux, the loop does not cut any lines of force, and hence, there will be no voltage induced. This zero voltage is represented in the graph as the starting point of the curve as shown in Fig 2c. The magnitude of the induced emf is given by the formula Eo = BLV Sin q

Fig 2



(a) AT 0° POSITION

(b) AT 90° POSITION

(c) PRODUCTION OF SINE WAVE FORM IN A SINGLE PHASE ALTERNATOR

where,

B is the flux density in weber per square metre,

L is the length of the conductors in metres,

V is the velocity of the loop rotation in metres per second and

q is the angle at which the conductor cuts the line of force.

As sin q = 0

E at 0 position is equal to zero. As the loop turns in a clockwise direction at position 30° as shown in Fig 2c, the loop cuts the lines of force and an emf is induced (E30) in the loop whose magnitude will be equal to BLV Sin q where q is equal to 30°.

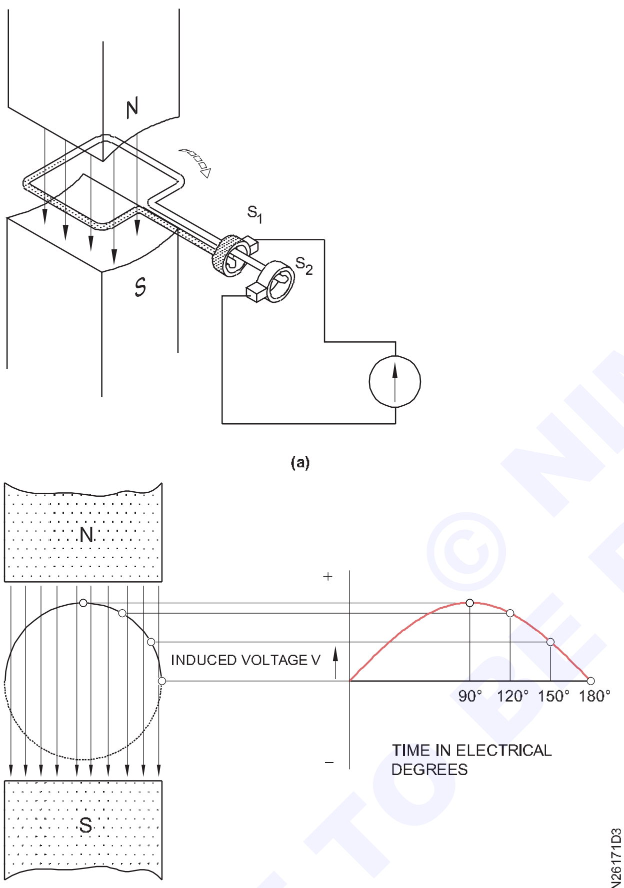
Applying the above formula, we find the emf induced in the loop at 90° position will be maximum as shown in Fig 2c.

As the loop turns further towards 180° it is found the number of lines of force which are cut will be reduced to zero value. If the quantity of emf induced at each position is marked by a point and a curve is drawn along the points, the curve will be having a shape as shown in Fig 3b.

During the turn of the loop, from 0 to 180°, the slip ring S1 will be positive and S2 will be negative.

However, at 180° position, the loop moves parallel to the lines of force, and hence there is no cutting of flux by the loop and there is no emf induced in the loop as shown in Fig 3b.

Fig 3



(b) VALUE OF INDUCED E.M.F. AT POSITION 180° FROM START

Further during the turn of the loop from the position 180° to 270°, the voltage increases again but the polarity is reversed as shown in Fig 4b. During the movement of the loop from 180 to 360°, the slip ring S2 will be positive and S1 will be negative as shown in Fig 4a. However, at 270° the voltage induced will be the maximum and will decrease to zero at 360°. Fig 5b shows the variation of the induced voltage in both magnitude and direction during one complete revolution of the loop. This is called a cycle.

Fig 4

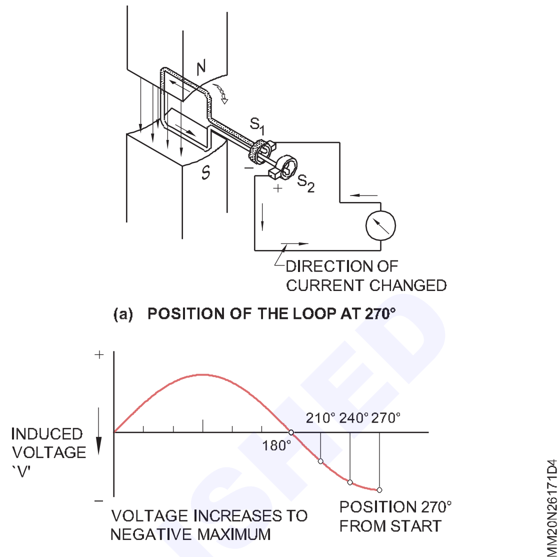
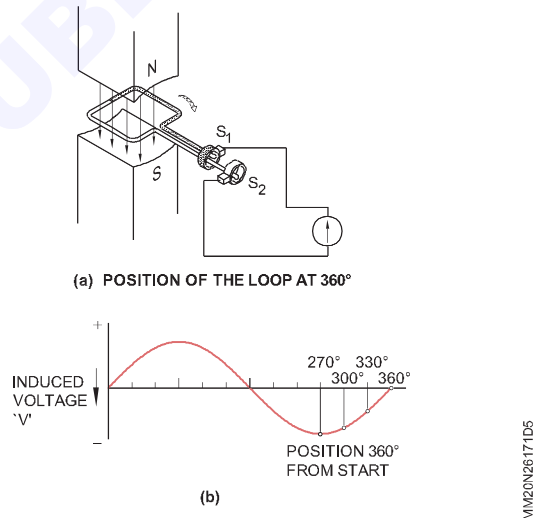


Fig 5



This type of wave-form is called a sine wave as the magnitude and direction of the induced emf, strictly follows the sine law. The number of cycles completed in one second is called a frequency. In our country, we use an AC supply having 50 cycles frequency which is denoted as 50 Hz.

Different types of Level Sensors and their workings

Objectives : At the end of this lesson you shall be able to
- **define the transducers, sensors and basics of passive & active transducers**
- **explain thermistor, its types and construction details**
- **describe the working principle, features, applications, advantage & disadvantages.**

Transducers and sensors

Transducer

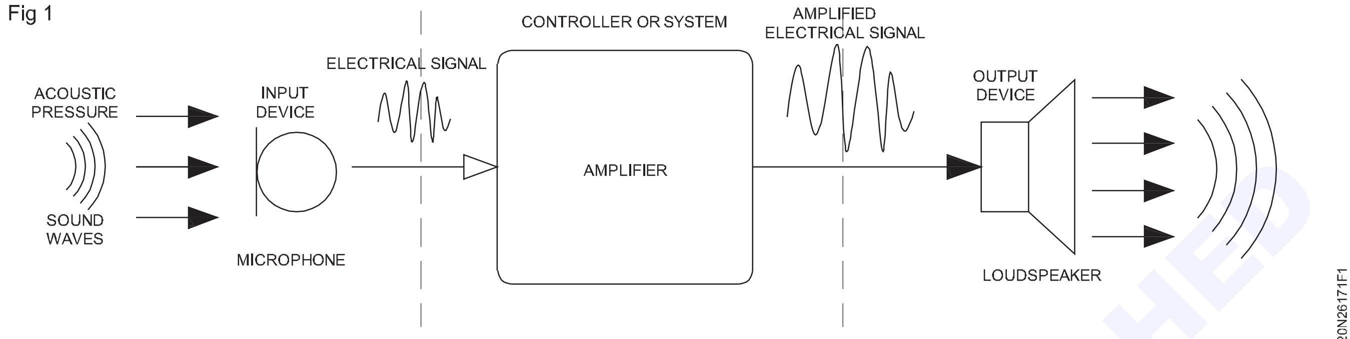
A transducer is a device that is used to convert a physical quantity into its corresponding electrical signal or vice versa. In most of the electrical systems, the input signal will not be an electrical signal, but a non-electrical signal. This will have to be converted into its corresponding electrical signal if its value is to be measured using electrical methods.

Sensor: Devices which perform an "Input" function are commonly called Sensors because they "sense" a physical change in some characteristic that changes in response to some excitation, for example heat or force is converted into an electrical signal.

There are different types of Sensors and Transducers, both analogue & digital and input & output available to choose from. The type of input or output transducer being used, really depends upon the type of signal or process being "Sensed" or "Controlled" but we can define a sensor and transducers as devices that converts one physical quantity into another.

Simple Input/Output System using Sound Transducers as shown in Fig 1

Fig 1



INPUT/OUTPUT SYSTEM USING SOUND TRANSDUCERS

There are different types of sensors and transducers available in the market, and the choice of which one to use really depends upon the quantity being measured or controlled. The more common types given in the Table 1.

Table 1

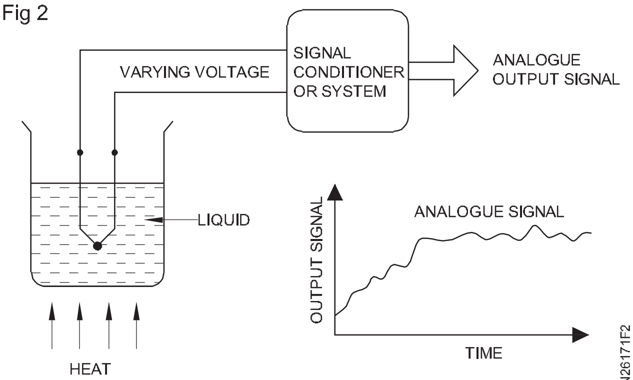
Physical quantity being measured by the sensor	**Input Device (Sensor)**	**Output Device (Actuator)**
Light Level	Light Dependant Resistor (LDR) Photodiode, Photo-transistor Solar Cell	Lights & Lamps LED's & Displays Fibre Optics
Temperature	Thermocouple, Thermistor Thermostat, Resistive Temperature Detectors	Heater, Fan
Force/Pressure	Strain Gauge, Pressure Switch Load Cells	Lifts & Jacks Electromagnet, Vibration
Position	Potentiometer, Encoders Reflective/Slotted Opto-switch LVDT	Motor, Solenoid Panel Meters
Speed	Tacho-generator, Reflective/Slotted Opto-coupler, Doppler Effect Sensors	AC and DC Motors Stepper Motor, Brake
Sound	Carbon Microphone, Piezo-electric Crystal	Bell Buzzer, Loudspeaker

Analogue and Digital Sensors

Analogue Sensors

Analogue Sensors produce a continuous output signal or voltage which is generally proportional to the quantity being measured. Physical quantities such as Temperature, Speed, Pressure, Displacement, Strain etc are all analogue quantities as they tend to be continuous in nature. For example, the temperature of a liquid can be measured using a thermometer or thermocouple which continuously responds to temperature changes as the liquid is heated up or cooled down. as shown in fig. 2

Fig 2



THERMOCOUPLE USED TO PRODUCE AN ANALOGUE SIGNAL

Thermocouple used to produce an Analogue Signal

Analogue sensors tend to produce output signals that are changing smoothly and continuously over time. These signals tend to be very small in value from a few mico-volts (uV) to several milli-volts (mV), so some form of amplification is required. Then circuits which measure analogue signals usually have a slow response and/or low accuracy. Also analogue signals can be easily converted into digital type signals for use in micro-controller systems by the use of analogue-to-digital converters (ADCs).

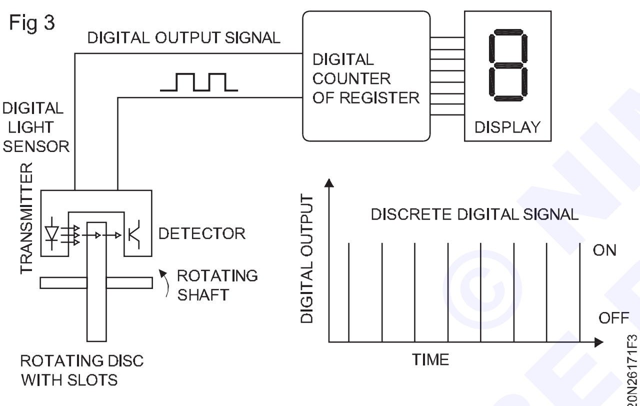
Digital Sensors

As its name implies, **Digital Sensors** produce a discrete digital output signals or voltages that are a digital representation of the quantity being measured. Digital sensors produce a Binary output signal in the form of a logic "1" or a logic "0", ("ON" or "OFF"). This means then that a digital signal only produces discrete (non-continuous) values which may be outputted as a single "bit", (serial transmission) or by combining the bits to produce a single "byte" output (parallel transmission).

Light Sensor used to produce an Digital Signal

In our simple example as shown fig.3 the speed of the rotating shaft is measured by using a digital LED/Opto-detector sensor. The disc which is fixed to a rotating shaft (for example, from a motor or robot wheels), has a number of transparent slots within its design, As the disc rotates with the speed of the shaft, each slot passes by the sensor in turn producing an output pulse representing a logic "1" or logic "0" level.

Fig 3



LIGHT SENSOR USED TO PRODUCE AN DIGITAL SIGNAL

Classification of Level sensors

Capacitance Level Sensors (Fig 4)

These sensors are used to detect the liquid levels like slurries and aqueous liquids They are operated by using a probe for checking level changes. These level changes are transformed into analong signals. The probes are generally made of conducting wire by PTFE insulation But stainless steel probes are extermely responce and hence they are appropriate for measuring non-conductive subsance granular or materials with low dielectric constant. These types of sensors are very simple to use and clean as they do not have any moving components.

They are commonly used in applications like Tank level monitoring in chemical, water treatment, food, battery industries and involving high pressure and temperature

Ultrasonic Level sensors (Fig 5)

Level sensors are classified according to their working principle and their applications.

Ultrasonic level sensors are used to detect the levels of sticky liquid substances and bulkiness materials as well. They are worked by producing audio waves at the range of frequency from 20 to 200 kHz. These waves are then replicated back to a transducer The ultrasonic level sensors are used to control the liquid level, fine-grained solids within mining and powders, food and beverage industries and chemical processing

Optical Level Sensors

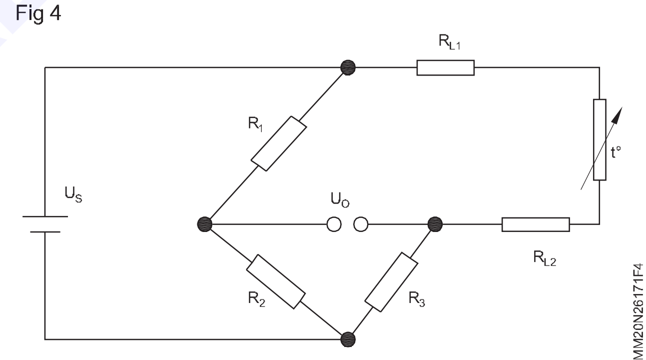
Optical level sensors are used to detect liquid including poised materials, interface between two immiscible liquids and the occurrence of sediments. They are working based on the changes of transmission in infrared light emitted from an IR LED. The interference from the produced light can be reduced by using a high energy IR diode and pulse modulation methods.

Continuous optical level sensors, on the other hand, use the highly釋 internse laser light that can infuse dusty enviroments and notice liquid substances. They are commonly used in applications like leak detection and tank level measurement

RTD Configuration

An RTD can be connected in a two, three or four-wire configuration. The two-wire configuration is the simplest and also the most error prone. In this setup, the RTD is connected by two wires to a Wheatstone bridge circuit and the two output voltage is measured. The disadvntage of this circuit is that the two connecting lead wire resistances add directly two RTD's resistance and error is incurred.

Fig 4

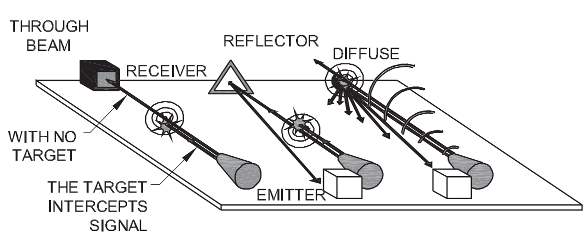


2-Wire Configuration

The four-wire configuration consists of two current leads and two potential leads that measure the voltage drop across the RTD. The two potential leads are high resistance to negate the effect of the voltage drop due to current flowing during the measurement.

This configuration is ideal for canceling the lead wire resistance in the circuit as well as eliminating the effects of different lead resistance, Which was possible problem with the three-wire configuration. The four-wire configuration is commonly used when a highly accurate measurement is requried for the application

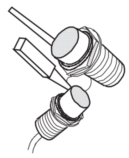
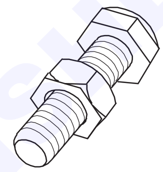
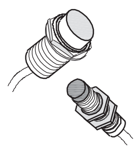
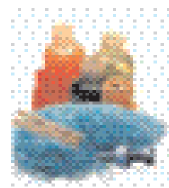
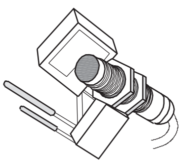
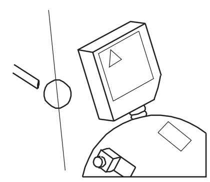
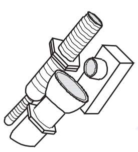
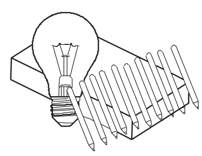
Fig 5



LASERS OF SOUND WAVES SERVE AS THE SIGNAL IN THREE SETUPS. IN THROUGH BEAM AND RETRO-REFLECTIVE, THE SIGNAL SHOOTS FROM THE EMITTER TO RECEIVER UNTIL THE TARGET CUTS IT OFF. IN DIFFUSE SENSING, THE SIGNAL DIVERGES UNTIL A TARGET MOVES IN AND REFLECTS SOME BACK TO THE RECEIVER.

PHOTOELECTRIC / ULTRASONIC SENSING SETUPS

MM20N26171F5

Technology	**Sensing Range**	**Applications**	**Target Materials**
Inductive 	<4-40 mm	Any close - range detection of ferrous material	Iron Steel Aluminum Copper etc. 
Capacitive 	<3-60 mm	Close - range detection of non - ferrous material	Liquids Wood Granulates Plastic Glass etc. 
Photoelectric 	<1mm - 60 mm	Long - range small or large target detection	Silicon Plastic Paper Metal etc. 
Ultrasonic 	<30 mm - 3 mm	Long - range detection of targets with difficult surface properties. Color/ reflectivity insensitive.	Cellophane Foam Glass liquid Powder etc 

Basic electronics and its industrial applications

Objectives : At the end of this lesson you shall be able to
- **define electronics**
- **discuss about types of circuits and elements**
- **explain the industrial applications of electronics**

Introduction:

Electronics is a branch of science and technology of controlling the flow of electrons to produce useful results. It is a fundamental field that plays a crucial role in our modern world to create devices and systems powering everything from smart phones and computers to automatic controllers and guiding systems for rockets to the moon.

Types of circuits and elements

The core of electronics is the understanding of electricity involving voltage, Current, resistance which are fundamental to working with passive and active components like Resistors, Capacitors, Inductors, Diodes, Transistors, Integrated circuits etc are the elements of building blocks of any circuit. There are two types of electronics circuits as analog and Digital circuits. Each one of the components mentioned above serve a purpose within a circuit. Electronics essentially requires a source of power, either from batteries or from external power supply.

Industrial applications of electronics

Electronics plays a pivotal role in a wide range of industrial applications for automation, efficiency and precision. Some of the important industrial applications of electronics have been listed hereunder:

1 Automation in manufacturing sector - CNC machines, PLCs for managing machineries and production lines, Industrial robots for automatic repetitive tasks.

2 Various sensors for monitoring, regulation, Industrial process control with PID controllers.

3 Communication and networking using high speed industrial ethernet, fieldbus, profibus field devices.

4 Energy monitoring and saving systems using SCADA systems track and reduce energy consumption.

5 Health care and medical devices - x ray systems, MRI and ultra scan like diagnostic devices and health care systems.

6 Agriculture and food processing - automation using electronics improve efficiency and quality control in food processing and agriculture.

7 Renewable energy sector - Electricity is generated from solar and wind energy implemented by the use of electronics.

8 Chemical, petrochemical and mining sectors - Electronics automation and control makes the hazardous processes being safety handled with efficiency.

9 Defence and aerospace sectors the crucial areas hacked up by electronics for radar system for aircraft and missile navigation and control, communication systems.

10 Transformation and logistics is controlled by electronics system from inside of automobiles infotainment to external signaling, toll system GPS tracking etc. The advanced electronics technology continue to quality and reliability leading to innovations in various industrial sectors.

Digital IC families and their operational characteristics

Objectives : At the end of this lesson you shall be able to
- **define the basic terms related to digital IC gates**
- **recognize the different types of packages of ICs used in the digital IC**
- **differentiate logic families and their characteristics**
- **explain safety precaution to be adopted while handling CMOS ICs**
- **explain digital IC numbering system.**

Introduction

A digital system is a combination of devices designed to Process information that are represented in digital form. Example of a few most popular digital systems are,

– Digital computers

– Calculators,

– Digital audio and video equipments

– Telephone system etc.,

Digital Telephony is probably the world's largest digital system.

In electronic circuits, signals are represented in voltage or current. In these circuits, the signal representation will have a number of voltage or current levels.

In such analog signals, the transition from one level to another is usually smooth rather than sudden diffence between and the transition between them is also smooth rather than sudden.

Digital signals on the other hand can have only two discrete states. These states can be called as,

- **ON state**: A state at which a predefined voltage is present. For example, the level could be, +5 Volts, +10Volts and it is also represented as high, one, etc.
- **OFF state**: A state at which a predefined voltage is other than the ON state voltage is present. For example, the level could be, 0 Volts, -5 Volts and it is also represented as low, zero etc.,

The discrete levels in digital signals are technically referred to as logic levels. Generally, the ON state described above is referred as the LOGIC 1 state and the OFF state as the LOGIC 0 state. It is very essential to note that, in digital signal representation, no state exists in between the logic-0 and logic-1 state.

For example,if we say Logic-0 corresponds to 0 volts and Logic-1 corresponds to 1 volt. In such a digital system, voltage levels of 2V,3V,4V etc., have no meaning

Because the transition time between ON to OFF state or vice versa is abrupt in digital signals, analysis of digital systems varies from that of pure analog systems such as amplifiers etc.,

Compared to analog circuits, digital circuits contains less number of discrete components such as resistors, capacitors atc., This is mainly for the reason that the Integrated circuit(IC) technology has advanced so much, millions of components can be prefabricated in a single IC. Most digital circuits are made of such VLSI (very large scale Integration) IC as its main circuit component with a few decoupling capacitor for suppling clean DC voltage.

It is important to note that any analog signal can be converted to a digital signal (in the form 1s or 0s). Example given below gives a clue about how analog signals can be represented as digital signals,

ANALOG VOLTAGE	DIGITAL VALUE
0 volt	0 0 0 0
1 volt	0 0 0 1
2 volt	0 0 1 0
3 volt	0 0 1 1
4 volt	0 1 0 0
5 volt	0 1 0 1
6 volt	0 1 1 0
7 volt	0 1 1 1
8 volt	1 0 0 0
9 volt	1 0 0 1
10 volt	1 0 1 0

Details of how this conversion is done is discussed in further lessons.

Digital systems offer the following advantages over analog systems

- Easier to design
- Information storage is easy
- Accuracy and precision are greater
- Programmable
- Circuitry can be fabricated on IC chips more easily
- High speed functions

The operations carried out using digital signals are called Logic operations. Example of Logic operation are given below;

Assuming there are two inputs and if the Inputs are,

- the circuit output should be Logic-1 if atleast any one of the two inputs is Logic-1.

  A circuit that performs such a logical operation is called as a **OR** gate.
- the circuit output should be Logic-1 only when both the inputs are Logic 1's.

  A circuit that performs such a logical operation is called as a **AND** gate.
- the circuit output should be inverse of the input. If the input is Logic-1, then the output should be Logic-0 and vice-versa.

A circuit that performs such a logical operation is called as a **NOT** gate.

Every logic operation, even the most extensive and the most complicated - can be reduced to combinations of the above said three basic logic functions. By combining these three operations, several other functions such NAND, NOR and so on

These basic functional circuits are called Gates, such as OR gate, AND gate and NOT gate. The practical implemantation of logic operations is effected by logic circuits. In the meantime, a large number of circuit families have been produced in integrated circuit technology. The starting point of standard development was the TTL (Transistor-Transistor-Logic) family(earlier to it was the RTL and DTL families), from which several other families with improved properties have been derived. The TTL family of gates have defined voltage levels and permissable tolerences. Some of the important terminologies associated with digital ICs are given below;

Terminology of digital ICs

Saturated logic gate

A form of logic gate in which one output state is the saturation voltage of a transistor.

Example

Resistor Transistor Logic (RTL), Diode Transistor Logic (DTL) and Transistor Transistor Logic (TTL).

Unsaturated logic or current mode logic gate

A form of logic with transistors outside the saturated region.

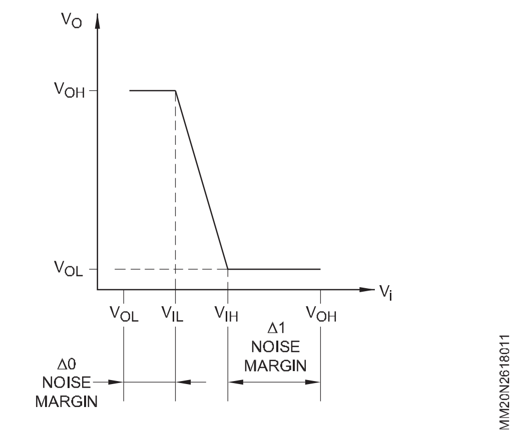
Example

Current Mode Logic (CML) and Emitter Coupled Logic. This has ultra-fast switching speed and low logic swing.

Operating voltages

The various operating voltages of a logic gate can be understood with the help of the transfer characteristic of the gate as shown in Fig 1.

Fig 1



V_{OH} - The minimum voltage which will be available at a gate output when the output is supposed to be at logic '1'.

V_{IL} - The minimum gate input voltage which will unambiguously be accepted by the gate as logic '1'.

V_{OL} - The maximum voltage which will appear at a gate output when the output is supposed to be at logic '0'.

V_{IL} - The maximum gate input voltage which will unambiguously be accepted by the gate as logic '0'.

Logic swing: The difference between the two output voltages (V_{OH} - V_{OL}) is known as the logic swing of the circuit. That is,

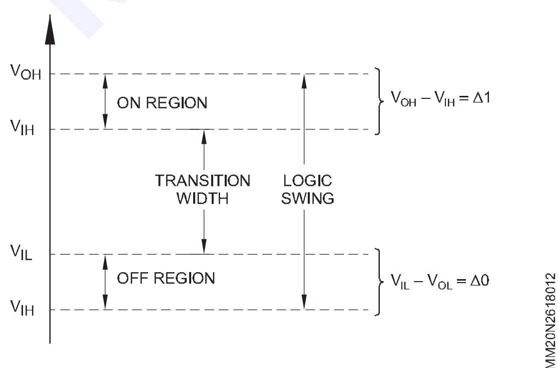
logic swing = $V_{OH} - V_{OL}$

Noise margin

The amount of voltage of extraneous signal which can be tolerated before an output voltage of gate deviates from the allowable logic voltage levels.

The different noise margins of a logic gate can be understood with the help of logic level diagram at Fig 2.

Fig 2



Low-level noise margin

The difference (V_{IL} - V_{OL}) is low level noise margin (D_o) $D_o = V_{IL} - V_{OL}$

High level noise margin

The difference (VOH - VIH) is high level noise margin (D_1) $D_1 = V_{OH} - V_{IL}$

Transistion width:

From Fig 2, transistion width = $V_{IH} - V_{IL}$

It can be seen that an increased noise margin capability is obtained as either VOH and VOL move away from each other or as VIH and VIL move toward each other. With a larger logic swing or a narrower transistion width, the noise margins will improve.

Noise immunity

Stray electric and magnetic fields can induce voltages on the connecting wires between logic circuits. These unwanted signals are known as noise and they may cause the voltage at the input to a logic circuit to drop below VIH (min) or rise above VIL (max), which may lead to unpredictable operation. The noise immunity of a logic circuit refers to the ciruit's ability to tolerate noise without causing unwanted changes in the output voltage.

Fan-out

The number of loads connected to a gate is known as fan-out of the gate. The number of load gates need not be a limiting number of load gates need not be a limiting number. It is also known as loading factor. For example, a logic gate that is specified to have a fan-out of 10 can drive 10 standard logic inputs. If this number is exceeded, the output logic-level voltages cannot be guaranteed.

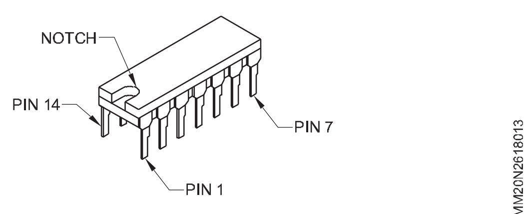
Types of IC package

The ICs come in a wide variety of package types. The factors which determine the type of package are

– amount of circuitry contained in the IC
– number of external connections that need to be made to it.
– humidity of the environment, ambient temperature at which the IC is to operate
– method of mounting on the PCB.

DIP [Dual in line package]

Fig 3

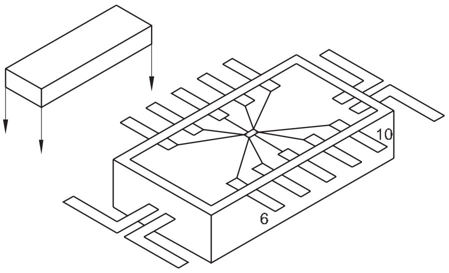


The external connecting pins are in parallel rows along the two long edges of the package as shown in Fig 3. In DIP ICs, number of pins varies from 4 to 64 depending on the internal circuitry. For low temperature and low humidity, epoxy plastic packages are used. For high temperature or for devices that dissipate large amount of power, ceramic packages are used.

Ceramic flat package

This type of IC packages are hermetically sealed as shown in Fig 4, which means that they are totally immune to the effects of humidity. These packages are often used in military equipments that they must be able to withstand harsh environments. Pins are counted around the package from notch or dot. These packages are usually mounted in high quality sockets on the circuit board.

Fig 4



FLAT PACK

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Surface mount package

This popular package is similar to the standard DIP except that it is smaller and, as the name implies, its pins are constructed so that it can be soldered directly to metal pads on the PCB. One type of SMT package called small out line IC is shown in Fig 5. Since surface mount packages are soldered on one surface of the circuit board, holes don't have to be drilled on the PCB. Surface mount devices have further advantages, that they are more easily handled by equipment, which automatically mounts components in the correct position on circuit boards during manufacturing. The PLCC (Plastic Leaded chip carrier) type package is shown in Fig 5. Another variety of SMT package is known as Flat pack is shown in Fig 5.

Ceramic chip carrier package

These chips are intended to be clamped into a socket as shown in Fig 6 so that the pads press against contacts which are connected to P.C.B signal lines pin 100 this package is to the right of the notched corner.

Fig 5

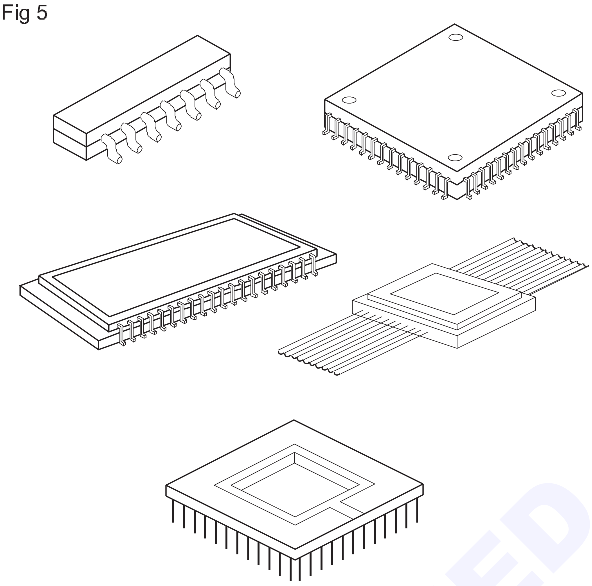

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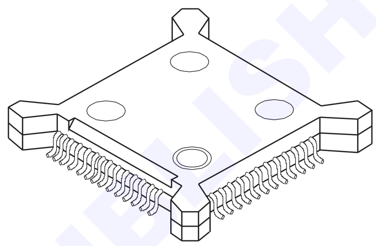
Fig 6



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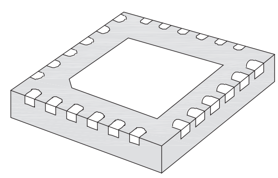
Pin grid array package

These ICs are used for VLSI digital circuits such microprocessor. The number of pins in the array depends on the complexity of the internal circuit. The four corner pin positions are usually left without pins. Common array sizes are 10 x 10, 13 x 13 and 14 x 14, large ICs such as these are put in sockets so they can easily be replaced if the device fails.

Fig 7



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S.No.	Complexity	Number of Gates	Application
1	Small-Scale Integration (SSI)	Fewer than 12	Basic gates
2	Medium-Scale Integration (MSI)	12 to 99	Flip-flops, regiater etc.
3	Large-Scale Integration (LSI)	100 to 9999	Memories, microprocessor
4	Very large-Scale Integration (VLSI)	10,000 to 99,999	-do-
5	Ultra large-Scale Integration (ULSI)	100,000 or more	-do-

Logic family

Digital ICs are classified not only by their complexity, logical operation, speed of operation but also by the specific circuit technology to which they belong. The circuit technology is referred to as a digital logic family.

Each logic family has its own basic electronic circuit upon which more complex digital circuit and components are developed. The basic circuit in each technology is NAND, NOR or an inverter gate. The electronic components, and material used in the construction of the basic circuit are usually used as the name of the technology. The various logic families of ICs used in electronic circuit are briefly discussed below.

TTL Logic family

The word TTL is expanded as Transistor-Transistor Logic. In this family ICs are built with transistors. Most standard TTL ICs require a power supply voltage between +4.75V and +5.25V to operate properly. The ICs of standard TTL family are identified by numbers that start with 74 or for military specification devices 54, two or three digits after the 74 or 54 are used to identify the logic functions performed by the device. Some of the 74 series TTL IC numbers with their functions given at Appendix 'D'.

The TTL logic family consists of several sub families as shown in logic family tree. The difference between the various TTL series are in their electrical characteristics, such as power dissipation, propagation delay and switching speed. They do not differ in the pin assignment or logic operation performed by the internal circuits.

The most popular 7400 series is a line of standard TTL chips. This bipolar family contains variety of compatible SSI and MSI devices. One way to recognise TTL design is the multiple emitter input transistors and the totem pole output transistors. The standard TTL chip has a power dissipation of about 10mw/gate and a propagation delay of around 10ns. The series 74S00 is a schottky version having a schottky diode in parallel with collector-base terminals. In this, transistors are prevented from saturating thereby propagation delay is reduced typically to 3ns. By increasing internal resistances and including schottky diodes, low power schottky diodes numbered from 74LS00 are manufactured limiting the power dissipation to 2mw per gate low power schottky TTL is the most widely used of the TTL types. In this family of devices, a floating input is equivalent to a high input. In electrically noise environment, floating inputs may pick up enough noise voltage to produce unwanted changes in the output stages and hence inputs should not kept be floating in TTL family. A modified TTL design namely three state TTL allows us to connect outputs directly. Earlier computers used open-collector devices with their bases but the passive pull-up limited the operating speed. These newer devices are much faster and have a control input that can turn off the devices. When this happens the output floats and presents a high impedance to whether it is connected to and hence are widely used for connecting to bases.

E.C.L

Emitter-coupled logic circuits provide the highest speed with propagation delay typically of 5ns. The most common ECL ICs are designated as the 10000 series. E.C.L is used in systems such as super computers and signal processors where high speed is essential. The ECL family IC use is restricted to few applications because of the following reasons.

– The gates in ICs dissipate relatively large amounts of power.

– Needs extra circuitry for gates to operate.

– The -ve power supply voltage and logic levels make ECL gates difficult to interface with other logic family members.

MOS

The Metal Oxide Semiconductor is a unipolar transistor that depends upon the flow of only one type of carrier, which may be either electrons or holes. A p-channel MOS is referred to as PMOS and an N-channel as NMOS. NMOS is the one that is commonly used in circuits with only one type of MOS transistor. MOS technology allows a very large number of circuits to be built in a single IC. It is this technology which has made possible the microprocessors, memories and other LSI devices which are used to build microcomputers.

Number systems

Objective : At the end of this lesson you shalll be able to
- **differentiate between different number systems like decimal, octal, binary and hexadecimal and conversion between them and different types of codes**

Introduction

When we hear the word 'number' immediately we recall the decimal digits 0,1,2....9 and their combinations. Modern computers do not process decimal numbers. Instead, they work with binary numbers which use the digits '0' and '1' only. The binary number system and digital codes are fundamental to digital electronics. But people do not like working with binary numbers because they are very long when representing larger decimal quantities. Therefore digital codes like octal, hexadecimal and binary coded decimal are widely used to compress long strings of binary numbers.

Binary number systems consists of 1s and 0s. Hence this number system is well suited for adopting it to the digital electronics.

The decimal number system is the most commonly used number system in the world. It uses 10 different characters to show the values of numbers. Because this number system uses 10 different characters it is called base-10 system. The base of a number system tells you how many different characters are used. The mathematical term for the base of a number system is radix.

The 10 characters used in the decimal number systems are 0,1,2,3,4,5,6,7,8,9.

Positional notation and weightage

A decimal integer value can be expressed in units, tens, hundreds, thousands and so on. For example decimal number 1967 can be written as 1967 = 1000 + 900 + 60 + 7. In powers of 10, this becomes

10^3	10^2	10^1	10^0
1	9	6	7

$1 \times 10^3 = 1000$

$9 \times 10^2 = 900$

$6 \times 10^1 = 60$

$7 \times 10^0 = 7$

1967

i.e. $[1967]_{10} = 1(10^3) + 9(10^2) + 6(10^1) + 7(10^0)$

This decimal number system is an example of positional notation. Each digit position has a weightage. The positional weightage for each digit varies in the sequence 10^0, 10^1, 10^2, 10^3 etc starting from the least significant digit.

The sum of the digits multiplied by their weightage gives the total amount being represented as shown above.

In a similar way, binary number can be written in terms of weightage.

To get the decimal equivalent, then the positional weightage should be written as follows.

$[1010]_2 = 1(2^3) + 0(2^2) + 1(2^1) + 0(2^0)$

$= 8 + 0 + 2 + 0$

$[1010]_2 = [10]_{10}$

Any binary number can be converted into decimal number by the above said positional weightage method.

Decimal to Binary conversion

Divide the given decimal number by 2 as shown below and note down the remainder till you get the quotient - zero.

Example

	0		
2	1	1	→ MSB
2	2	0	
2	4	0	
2	8	0	
2	17	1	
2	34	0	→ LSB

The remainder generated by each division form the binary number. The first remainder becomes the LSB and the last remainder becomes the MSB of binary number.

Therefore, $[34]_{10} = [100010]_2$

Counting binary number

To understand how to count with binary numbers, let us see how an odometer (Km indicator of a car) counts with decimal numbers,

The odometer of a new car starts with the reading 0000.

After traveling 1km, reading becomes 0001.

Successive km produces 0002, 0003 and so on upto 0009

At the end of 10th km, the units wheel turns back from 9

to 0, a tab on this wheel forces the tens wheel to advance by 1. That is why the number changed from 0009 to 0010. That is, the units wheel is reset to 0 and sent a carry to the tens wheel. Let us call this familiar action as reset and carry. The other wheels of odometer also reset and carry. For instance, after covering 999km, the odometer shows 0999.

After the next km, the unit wheel resets and carries, the tens wheel resets and carries, the hundreds wheel resets and carries and the thousands wheel advances by 1 to get the reading 01000.

Binary odometer

Visualize a binary odometer, a device whose wheels have only two digits 0 and 1. When each wheel turns, it displays 0 then 1 and then back to 0 and the cycle repeats. A four digit binary odometer starts with 0000.

After 1km, it indicates - 0001.

The next km forces the units wheel to reset and sends carry. So the number changes to 0010.

The third km results in 0011.

After 4km, the units wheel resets and sends carry, the second wheel resets and sends carry and the third wheel advances by 1. Hence it indicates 0100.

Table below shows all the binary numbers from 0000 to 1111 equivalent to decimal 0 to 15.

Decimal	Binary
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
10	1010
11	1011
12	1100
13	1101
14	1110
15	1111

Hexadecimal number system: In hexadecimal system there are 16 characters. They are 0,1,2,3,4,5,6,7,8,9, A,B,C,D,E,F where A=10, B=11, C=12, D=13, E=14,

F=15 in decimal. In this system, the base is 16. This system is mainly used to develop programmes for computers.

For Example

$[23]_{16} = [35]_{10}$; $16^1 \text{ X } 2 + 16^0 \text{ X } 3 = 32 + 3 = 35$;

$[2C]_{16} = [44]_{10}$; $16^1 \text{ x } 2 + 16^0 \text{ x } 12 = 32 + 12 = 44$;

Decimal to hexadecimal conversions

The conversion of decimal to hexadecimal is similar to binary conversion. Only difference is that divide the decimal number successively by 16, and note down the remainder.

	0	
16	1	1 → MSB
16	27	11 or B
16	432	0 → LSB

$[432]_{10} = [1B0]_{16}$

Hexadecimal to Decimal

This conversion can be done by putting it into the positional notation.

Ex: $223A_{16} = 2 \text{ x } 16^3 + 2 \text{ x } 16^2 + 3 \text{ x } 16^1 + A \text{ x } 16^0$

$= 2 \text{ x } 4096 + 2 \text{ x } 256 + 3 \text{ x } 16 + 10 \text{ x } 1$

$= 8192 + 512 + 48 + 10$

$= 8762_{10}$

Octal number

The octal number system provides a convenient way to express binary numbers. It is used less frequently compared to hexadecimal in conjunction with computers and microprocessors to express binary quantities for input and output purposes.

The octal number system is compared of digit symbols such as right symbols such as 0,1,2,3,4,5,6,7.

Since there are 8-symbols, radix or base is 8. Positional weightage is ....8^3, 8^2, 8^1, 8^0.

To distinguish octal numbers from other number systems subscript 8 is used as follows:

Ex: $(15)_8 \sim (13)_{10}$

Octal Decimal

Octal to Decimal conversion

	0	
8	1	1 → MSB
8	13	5 → LSB

As in other number systems, each digit should be multiplied by its positional weightage and added to get decimal equivalent.

Convert $(2374)_8$ into decimal number

Positional weightage : 8^3, 8^2, 8^1, 8^0

Octal number 2 3 7 4

$(2374)_8 = (2 \text{ x } 8^3)+(3 \text{ x } 8^2)+(7 \text{ x } 8^1)+(4 \text{ x } 8^0)$

$= (2 \text{ x } 512)+(3 \text{ x } 64)+(7 \text{ x } 8)+(4 \text{ x } 1)$

$= 1024 + 192 + 56 + 4$

$(2374)_8 = (1276)_{10}$

Decimal to octal conversion

A method of converting a decimal number to an octal number is the repeated division by 8, each successive division by 8 yields a remainder that becomes a digit in the equivalent octal number. The first remainder generated is the least significant digit (LSD).

$(359)_{10} = (547)_8$

	0	
8	5	5 → MSB
8	44	4 or B
8	359	7 → LSB

Octal to binary

Each octal digit can be represented by a 3-bit binary number, because of this it is very easy to convert from octal to binary. Each octal digit is represented by three bits as shown in the table.

Octal digit	0	1	2	3	4	5	6	7
Binary	000	001	010	011	100	101	110	111

To convert each octal number to a binary, simply replace each octal digits with the corresponding binary bits.

Example

1 $(25)_8 = (\quad)_2$

2 5

010 101

$(25)_8 = (010101)_2$

2 $(7526)_8 = (\quad)_2$

7 5 2 6

111 101 010 110

$(7526)_8 = (111101010110)_2$

Binary to octal

Conversion of a binary number to an octal number is the reverse of the octal-to-binary conversion. The procedure is as follows.

1 Start with the right most group of three bits and moving from right to left, convert each 3-bit group to the equivalent octal digit.

2 If there are not three bits available for the left most group, add either one or two zero's to make complete group. These leading zero's will not affect the value of the binary number.

Example

$(110101)_2 = (\quad)_8$

110 101

6 5 $= (65)_8$

$(11010000100)_2 = (\quad)$

011 010 000 100 $= (3204)_8$

3 2 0 4

BCD (Binary Coded Decimal)

Binary Coded Decimal (BCD) is a way to express each of the decimal digits with a binary code, since there are only ten code groups in the BCD system, it is very easy to convert between decimal and BCD. Because decimal system is used for read and write, BCD code provides an excellent interface to binary systems. Examples of such interfaces are keypad inputs and digital readouts.

8421 code

The 8421 code is a type of binary coded decimal (BCD), binary coded decimal means that each decimal digit, 0 through 9 is represented by a binary code of four bits. The designation 8421 indicates the binary weights of the four bits (2^3, 2^2, 2^1, 2^0). The ease of conversion between 8421 code numbers and the familiar decimal numbers in the main advantage of this code. All you have to remember are the ten binary combinations that represents the ten decimal digits.

Decimal digit	0	1	2	3	4	5	6	7	8	9
BCD	0000	0001	0010	0011	0100	0101	0110	0111	1000	1001

The 8421 code is the pre-dominant BCD code, and when we refer to BCD, we always mean the 8421 code unless otherwise stated.

Invalid code

You should realize that with four bits, sixteen numbers (0000 through 1111) can be represented, but in the 8421 code only ten of these are used. The six code combinations that are not used 1010, 1011, 1100, 1101, 1110 and 1111 are invalid in the 8421 BCD code.

To express any decimal number in BCD, simply replace each decimal digit with the approximate 4-bit binary code.

Example

1 $(35)_{10}$ = (?) 8421 code

3 5

0011 0101 = 00110101

2 $(2458)_{10}$ = (?) 8421 code

2 4 5 8

0010 0100 0101 1000 = 0010010001011000

There are many specialized codes used in digital system other than BCD code. Some codes are strictly numeric, like BCD and others are alphanumeric which are used to represent numbers, letters, symbols and instructions.

The commonly used codes other than BCD codes are

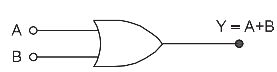
1 Gray code

2 Excess 3 code

3 ASCII code - American, Standard code for Information interchange

4 Alphanumeric code

Fig 1



Logic gates and logic probes

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

- **explain the function of logic gates**
- **explain the AND gate using diode and its truth table**
- **explain the OR gate using diode and its truth table**
- **explain a NOT gate using transistor and its truth table**
- **explain the NAND,NOR gate and their truth table**
- **explain the EX-OR and EX - NOR gates and their truth table.**

Introduction

Lagic gates are electronic circuits used in digital circuits for the purpose of decisions. Logic circuits are basically of two types namely decision making circuits and memory circuits. Their functioning depends on the binary inputs they receive and produce binary output which are a function of the input as well as the characteristics of the logic circuit they implemented.All logic gates have a single output and they may have two or more inputs.

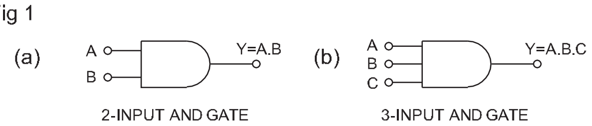
For specific decision making function there are several types of logic gates are used. Basic Logic gates are a group of the logic gates spcifically called as AND,OR and NOT gates.All these gates have their own identical,logical function. By the combination of these gates we can obtain any Boolean or logical functions or any logical function.

AND gates

The AND gate has two or more inputs but only one output. All input signals must be held high to get a high output. Even if one of the inputs is low, the output becomes low.

The schematic symbols for 2 input and 3 input AND gates are shown in Fig 1a and 1b.

Fig 1



Truth table

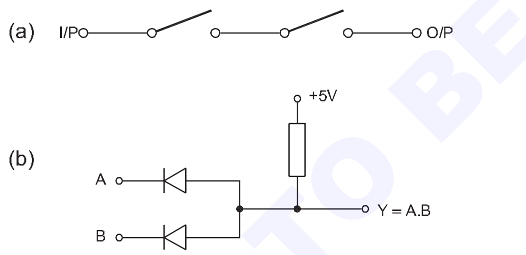
Two input AND gate

A	B	Y=A.B
0	0	0
0	1	0
1	0	0
1	1	1

Electrical equivalent circuit of an AND gate

The electrical equivalent of AND gate and AND gate using diodes are shown in Fig 2a and 2b.

Fig 2



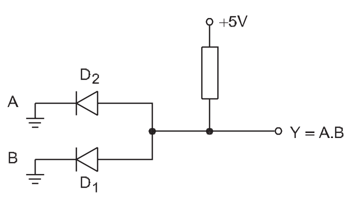
Two input AND gate using diode

Condition-1

A=0, B=0, Y=0 as shown in Fig 3.

During the above condition inputs A and B are connected to ground to make logic low inputs. During this condition, both the diodes conduct, and pulls the output Y to logic0.

Fig 3

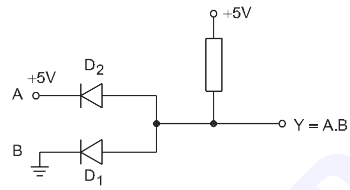


Condition-2

A=0, B=1, Y=0 as shown in Fig 4.

In the condition shown in Fig 4, diode D_1 is connected to logic-0 input and diode D_2 is connected to +5V [Logic high]. Diode D_1 is in forward bias and conducts. Diode D_2 is having equal potential (+5V) at anode and cathode. So potential difference between anode and cathode is 0. Hence diode D2 does not conduct. The output Y is pulled down to logic zero, since D_1 is conducting.

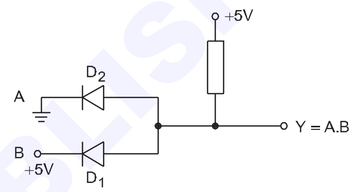
Fig 4



Condition- 3

A=1, B=0, Y=0 as shown in Fig 5.

Fig 5



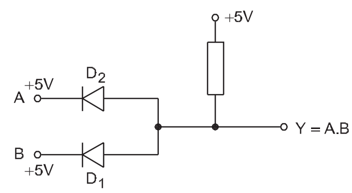
The condition-3 is similar to the condition-2. D_2 is forward biased. D_1 is reverse biased. Hence, output Y is pulled to logic-0.

Condition- 4

A=1, B=1, Y=1 as shown in Fig 6.

In this condition both the diodes are reverse biased. So both the diodes act as open circuit. Therefore, output Y is

Fig 6



+5V i.e y is in logic1 condition.

For pin diagram of AND gate IC refer to the data sheet of the IC.

A. For example, if 1000 pulses pass through the gate in the 1 second interval of the enabled pulse, there are 1000 pulses/sec. That is, frequency is 1000Hz.

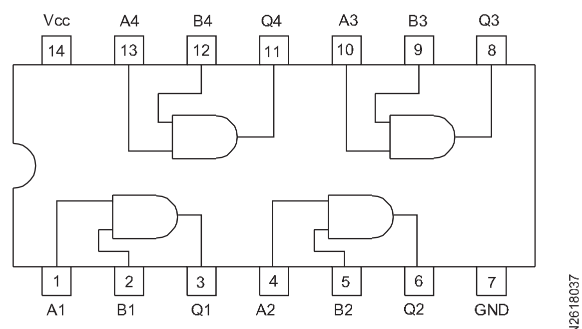
AND gates are available in the form of IC.IC7408 is a TTL type AND gate IC having 4 numbers of AND gates in side it as shown in Fig 7

OR gate

The OR gate has two or more inputs,but only one output.

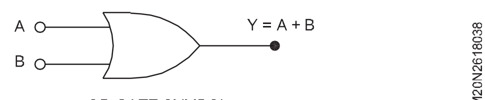
The output of an OR gate will be in 1 state if one or more of the inputs is in 1 state. Only when all the inputs are in 0-state, the output will go to 0-state. Fig 8 shows the schematic Symbol of an OR Gate

Fig 7



AND GATE IC 7408

Fig 8



OR GATE SYMBOL

The boolean expression for OR gate is Y=A+B.

The equation is to be read as Y equals A ORed B. Two-input truth table given below is equivalent to the definition of the OR operation.

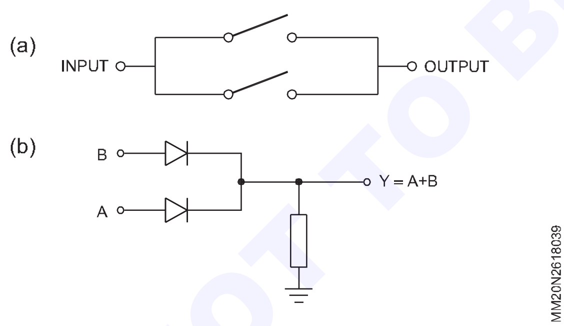
Truth table for OR gate

A	B	Y=A + B
0	0	0
0	1	1
1	0	1
1	1	1

Electrical equivalent circuit

The Fig 9a shows the electrical equivalent circuit of an OR gate. It is evident that if any one of the switch is closed, there will be output.

Fig 9



2 in-put OR gate using diode

The Fig 9b shows one way to build a 2-input OR gate, using diodes. The inputs are labeled as A and B, while the output is Y.

Assume logic 0 = 0V (low)

logic 1 = +5V (high)

Since this is a 2 input OR gate, there are only four possible cases,

Condition:1 A is low and B is low. With both the input voltage low, both the diodes are not conducting. Therefore the output Y is in low level.

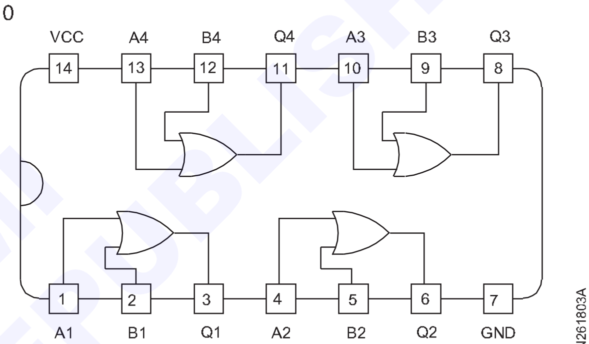
Condition:2 A is low and B is high, The high B input voltage (+5V) forward biases the lower diode, producing an output voltage that is ideally +5V (actually +4.3V taking the diode voltage drop 0.7V into consideration). That is, the output is in high level. During this condition, the diode connected to input A is under reverse bias or OFF condition.

Condition:3 A is high and B is low, the condition is similar to case 2. Input A diode is ON and Input B diode is OFF and Y is in high level.

Condition:4 A is high, B is high. With both the inputs at +5V, both diodes are forward biased, since the input voltages are in parallel, the output voltage is +5V ideally [+4.3V to a second approximation]. That is, the output Y-is in high level.

OR gates are available in the IC form. **IC7432 is a TTL OR** gate IC having 4 OR gates inside it. For pin diagram refer to the data sheet of the ICas shown in fig 10.

Fig 10



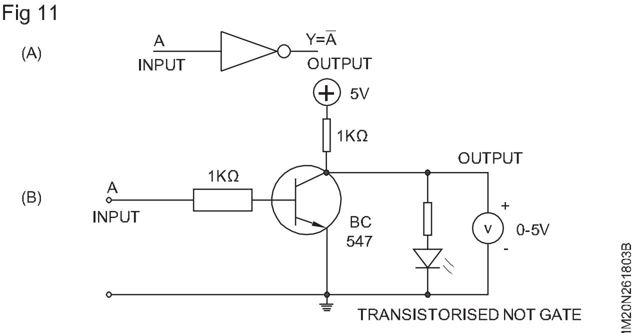
OR GATE IC 7432

Simple application of OR gate

Intrusion detection

Simplified portion of an intrusion detection and alarm system is two windows and a door. The sensors are magnetic switches that produce a high(1) output when windows and doors are opened and a low(0) output when closed. As long as the windows and the door are secured, the switches are closed and all three of the OR gate inputs are in low(0). When one of the windows or the door is opened, a high(1) output is produced on that input of the OR gate and the gate output goes high. It then activities an alarm circuit to warn of the intrusion Fig 11.

Fig 11



NOT gate

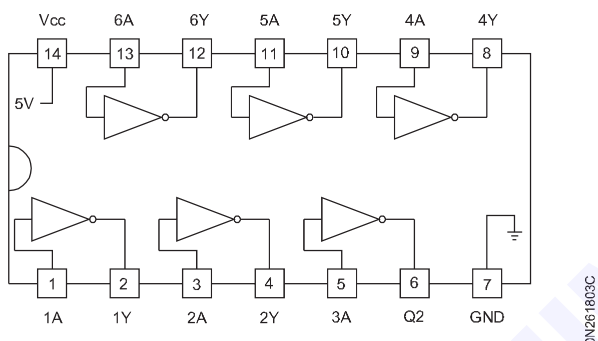
The NOT gate has only one input and one output as per the schematic symbol shown in Fig 11a and the circuit to construct the NOT gate using descrete comporents in Fig 11b and the truth table is given below.

Truth Table for NOT gate

	Input A	Output = Y
1	0	1
2	1	0

The NOT gate inverts the logic stage of a binary signal input. The small circle (bubble) at the output of the symbol is formally called a negation indicator and designates the logical complement for pin diagram refer to the data sheet of these 7404 as shown in Fig 12.

Fig 12



NOT GATE IC 7404

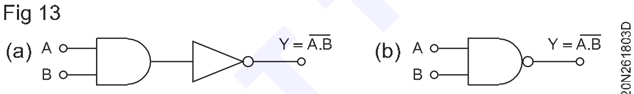
NAND gate

The **NAND** gate is the complement of the **AND** operation. Its name is an abbreviation of NOT **AND**.

The schematic symbol for the NAND gate consists of an AND symbol with a bubble on the output, denoting that that a complement operation is performed on the output of the AND gate.

The schematic symbol and truth table of NAND gate is shown in Fig 13a &b. The pin diagram is shown in fig 14

Fig 13



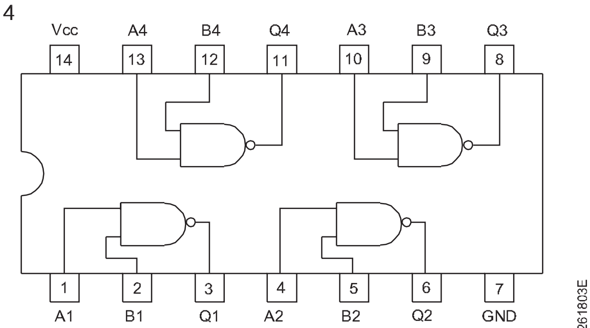
NAND GATE SYMBOL

Truth table

A	B	$Y=\overline{A.B}$
0	0	1
0	1	0
1	0	0
1	1	0

The truth table cleary shows that the NAND gate operation is the complement of the AND gate.

Fig 14



NAND GATE IC 7400

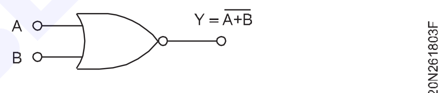
NOR gate:

The NOR gate is the complement of the OR operation. ITS name is an abbreviation of NOT OR.

The schematic symbol for the NOR gate consists of an OR symbol with a bubble on the output, denoting that a complement opertaion is performed on th eoutput of the OR gate.

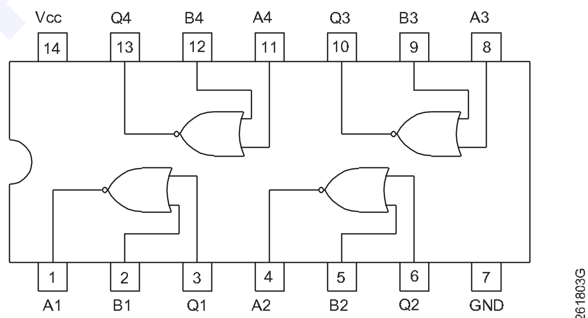
The schematic symbol and the truth table of NOR gate is shown in the figure 15 and pin diagram is shown in Fig 16.

Fig 15



NOR GATE SYMBOL

Fig 16



NOR GATE IC 7402

Truth table

Input		Output
A	B	$Y=\overline{A+B}$
0	0	1
0	1	0
1	0	0
1	1	0

The output of NOR gate is ‘0’ even if one of the input is in logic1. Only when both the inputs are in logic ‘0’,the output is in logic ‘1’.

The IC 7402 is a TTL type NOR gate IC.It contains 4 NOR gates. For pin details of the IC refer to the data sheet of the IC.

EX-OR gate

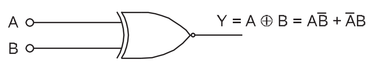
Exclusive-OR gate

Exclusive OR gate is actually formed by a combination of other gates already discussed. However, because of their fundamental importance in many applications, these gates are treated as basic logic elements with their own unique symbols.

The EX-OR gate has only two inputs unlike the other gates, it never has more than two inputs.

The schematic symbols of Exclusive-OR (XOR for short) is gate shown in Fig 17 and the pin diagram shown in fig 18.

Fig 17



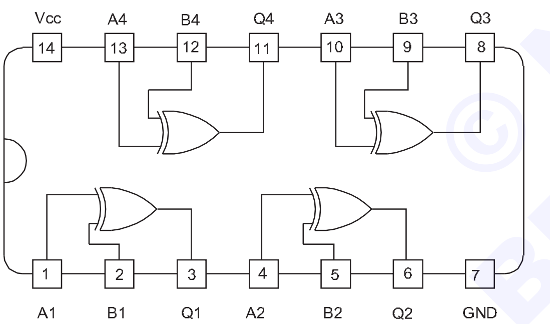
EX-OR GATE SYMBOL

The truth table of EX-OR gate is given below.

Truth Table

A	B	Q=A⊕B
0	0	0
0	1	1
1	0	1
1	1	0

Fig 18



EX-OR GATE IC 7486

UNIVERSAL GATE

An universal gate is a that can be used to implement any Boolean function without the need to use any other type of gate.

The NAND and NOR gates are universal gates.

In actual practice, teh NAND and NOR gates are used to fabricate all the basic gates required in IC digital logic families.

In practice, an AND gate is typically implemented as a NAND gate followed by an inverter not the other way around.

In the some way an OR gate is typically implemented as a NOR gate followed by a NOT gate.

Now let us discuss how to implement the NOT,AND,and OR gates using universal gate.

NAND gate as a universal gate:

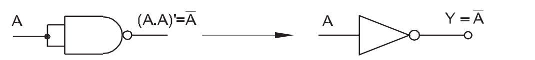
To prove that any Boolean function can be implemented using only NAND gates,we will show that the AND,OR, and NOT operations can be performed using only these gates.

NAND gate implemented as NOT gate.

In the following circuit NAND gate is used as **an inverter (NOT gate).**

All input pins of NAND gates are connected to the input signal A gives an output A as shown in Fig 19.

Fig 19

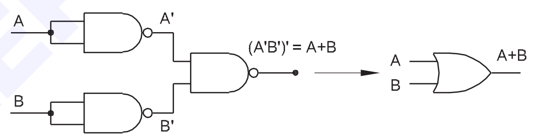


NAND gate implemented as AND gate. An AND gate can be implemented by NAND gate as shown in figure 20. (The AND is replaced by a NAND gate with its output complemented by a NAND gate inverter).

Fig 20

NAND gates implemented as OR gate. An OR gate can be implemented by NAND gates as shown in figure 21. (The OR gate is replaced by a NAND gate with all its inputs complemented by NAND gate inverters).

Fig 21



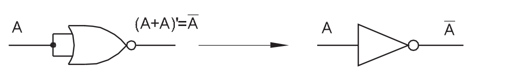
Thus it is proved that the NAND gate is auniversal gate since it can implement the AND, OR and NOT logic functions.

NOR gate as a universal gate. In the following paragraphs the NOR gate is used to prove that any Boolean function can be implemented only with NOR gates.NOR to replace the AND,OR and NOT opertaions .

NOR gate implemented as NOT gate.In the following circuit a NOR gate is used as **an inverter (NOT gate).**

All input pins of NOR gate is connected to the input signal A gives an output $\overline{A}$ as shown in Fig 22.

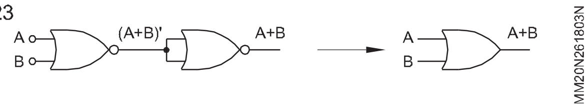
Fig 22



NOR gate implemented as AND gate.

An OR gate can be implemented by NOR gates as shown in figure 23.(The OR is replaced by a NOR gate with its output complemented by a NOR gate inverter)

Fig 23

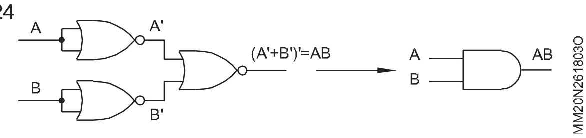


NOR gate implemented as AND gate

An AND gate can be implemented by NOR gates as shown in the figure 24 (The AND gate is replaced by a NOR gate with all its inputs complemented by NOR gate inverters)

Thus it is proved that the NOR gate is a universal gate since it can implement the AND, OR and NOT logic functions.

Fig 24



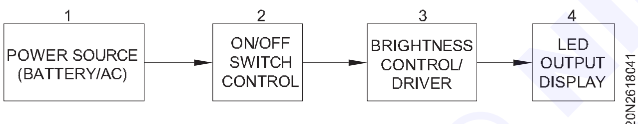
Study of electronic circuit - macro level with block diagram

Objectives : At the end of this lesson you shall be able to
- **draw the block diagram of electronic circuit at macrolevel**
- **explain the functions of each block**
- **describe the function of LED light**

The study of an electronic circuit at macro level using a block diagram makes it easier for understanding the functionality of my complex circuit. It provides the information about the functions performed by various stages linked with arrow heads for visualization of the direction of process flow of signals through the circuit.

Let us study the functioning of one of the consumer electronic devices - LED light shown in Fig 1 using block diagram is explained below:

Fig 1



BLOCK DIAGRAM OF LED LIGHT

1 The first block represents power source either AC supply or Battery supply provides electrical energy to the circuit/device.

2 The second block represents the ON/OFF switching function that connects or disconnects power to the LED lighting circuit

3 The third block represents the brightness controlling circuit comprising of passive or active components such as resistors, capacitors, inductors, diodes, transistors, ICs etc. to control the intensitfy of light emitted by the LED.

4 The fourth block represents the output element that is LED display which emits light, actually controlled by the driver circuit.

Thus, the switch controls the flow of electrical energy from the power source to the LED and the driver circuit controls the light emission. When the switch is open, the total LED light circuit is turned OFF.

PLC - types, Architecture and simulation software

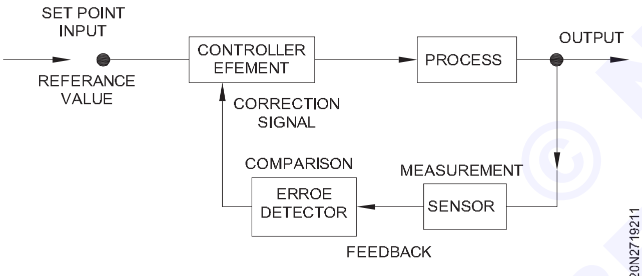
Objectives : At the end of this lesson you shall be able to
- **define control system and its importance**
- **describe the types of control systems**
- **explain the function of control stems used in PLC**
- **describe simulation software for PLC and its uses**
- **explain how to install and launch this software from your computer**
- **explain important steps for using the simulation software**
- **listout the advantages of simulation software.**

Control systems and their importance

Control system is a system designed to manage stable operation, optimise performance, ensures safety to achieve the desired result or output efficiently as per the predefined set point value.

Control systems are essential in modern industrial automation processes, automotive systems, etc for controlling everything from house hold appliances like automatic washing machines to sophisticated space craft. A typical closed loop control system is shown in Fig 1 for easy understanding of the principle of operation.

Fig 1



CLOSED LOOP CONTROL SYSTEM

Types of control systems

There are different control systems commonly used across various fields including engineering and technology are listed here under:

1 ON - OFF control system
2 Sequential control system - traffic signal
3 Fuzzy logic control system used in washing machines
4 Adaptive control system - used in automotive engine control
5 Analog control system - analog voltage regulators
6 Digital control system - Digital thermostats, CNC machines.

Besides the above, some of the important types of control systems used in industrial process automation field is explained below:

a Open - loop control system: is one in which control action is not influenced by feed bevels from the system being controlled. It solely dependent on a predefined input to produce the desired result.

b Closed loop (Feedback) control system: uses feedback from the system to control the operation to produce the desired output result by continuously monitoring the input, output and make corrections as per the pre defined set point values.

c Proportional integral - derivative (PID): control is a method uses the three parameters - proportional, integral and derivative values to calculate the control output based on the system error and behavior.

d **Distributed control system (DCS):** is a centralised control system that uses multiple controllers, distributed throughout a large industrial automation processing plant, in which it monitors and controls the entire system.

e Supervisory control and data acquisition (SCADA): systems are used to provide remote monitoring and controlling functions for managing large scale industrial plants.

Function of control system used in PLC

PLCs are versatile devices that are utilized for controlling different applications. Different control systems used in PLCs and their important functions are explained below:

- PLC uses the ladder logic to create control programs by this graphical programming language, various controlling functions are accomplished.
- Industrial automation processes are executed in a specific sequential order. PLC programs are designed to be executed in a series of step by step sequential control based on input conditions or timers.
- Proportional integral derivative (PID) control algorithms are utilized for processing of certain variable parameters like temperature, pressure, or flow at set point values by adjusting output field devices.
- For some imprecise or uncertain data, fuzzy logic control is utilized to support PLC operation.
- In real time collection of data, PLCs are used as data acquisition and monitoring and alerting operators by alarming capabilities for any abnormal conditions.
- Safety relays and safety certified hardware and

software are utilized to ensure the safety of personnel and equipment by the PLCs in industrial environments.

- Commonly used communication and networking protocols are included to interact with human machine interface, other PLCs and control systems.
- To control and monitor various sub systems and devices across large scale industrial systems distributed control systems (DCS) or PLCs with distributed control capabilities are utilized.

PLC and its role in industrial automation

PLCs are industrial computers designed to control and monitor processes in automated systems. PLC architecture refers to different types of hardware components consisting of input/output field devices to the internal modules used in PLC system such as input/ output modules, communication modules, and power supply etc. Each type of component has its own specific function in the automation process.

The use of PLCs has revolutionised the industrial automation growth by maximizing performance, providing a reliable automation processes with reduced maintenance cost for wide range of industrial processes.

PLC has to function in any kind of industrial atmosphere such as in Acid plant (Fertilizer industry), Dust atmosphere (cement industry), and Noisy atmosphere (Power plant) without any malfunction or failure. The components used in PLCs can with stand any extreme climatic conditions that is from - 40°C to + 150°C, so that the plant run without breakdown.

By choosing the right type of PLC architecture for the required application can ensure the users quickly adapt and easily expand their system hardware as needed. This ultimately leading to improved operational efficiency and higher profits utilizing these type of PLCs for industrial automation solutions.

Familiarization of PLC Simulation Software

Simulation software used for PLC is a computer program prepared to emulate the behavior of a PLC. It allows the user to apply the features of the program for developing, testing and trouble shooting. Since it provides the easiest and cost effective method for developing, testing and troubleshooting of PLC even without the need for physical hard wares, it is invaluable for those people in PLC programming and automation engineering.

Installation and launching the software

Use of PLC simulation software involves several steps to create program, and simulate a PLC system operation specific to the make and model the user has to refer to the manufacturer’s guide /reference manual in the real time situation.

- Downloading and installing the PLC simulation software onto your computer system follow as per the instructions given by the software designer.
- After installation, open the simulation software and run the application by starting a new project or creating a new simulation within the software.

Steps for simulation

In general the step by step procedure for using PLC simulation software is almost similar to the steps given below:

- Defining the inputs and outputs for the PLC program, you have to configure the simulation parameters, labelling, addressing and other relevant settings and editing using ladder logic or other programming languages.
- Checking and validating, downloading the program and start or RUN the simulation by checking it to test operation.
- Debugging or troubleshooting has to be done if the simulation does not produce the expected result by using the tools provided and diagnostic messages.
- Necessary changes also have to be made to the program based on the results, until it performs as expected.
- More importantly the project has to be saved to ensure that the created program should not be lost.
- After successful result, document the program, inputs, outputs, any specific points to help the future attempts.
- If necessary or required to export the PLC program for use on physical PLC hardware setting, use the function for real world implementation.
- Finally shut down the simulation software by closing the stop function provided within the software.

Advantages of using simulation software

1 Simulation software is used in training environments helping learners understand complex concepts and practice skills easily and quickly.

2 These simulation software can function faster than real-time field devices to connect under such complex configuration and wiring for testing or troubleshooting.

3 It helps the programmer to develop the program in the correct sequence without causing any damage to field devices.

4 It helps the user to avoid the actual hazardous environment and reach the fail - safe condition always.

5 Latest simulation software provide simple and realistic like representation of complex systems, that reduces need for physical devices saving huge money on material resources.

6 Simulation software also creates and displays observable graphical images of consequences of fault symptoms. This will alert the programmer to avoid such undesirable effects by incorporating safety devices like limit switches or sensors at lower end or upper end of set points of operation as the case may be.

Block diagram of PLC

Objectives : At the end of this lesson you shall be able to
- **draw the simplified block diagram of PLC**
- **name the important functional blocks of PLC**
- **describe the functions of various modules**
- **list the different types of PLC and explain briefly about each type**
- **tell the names of different PLC architecture**
- **explain briefly about each type of architecture.**

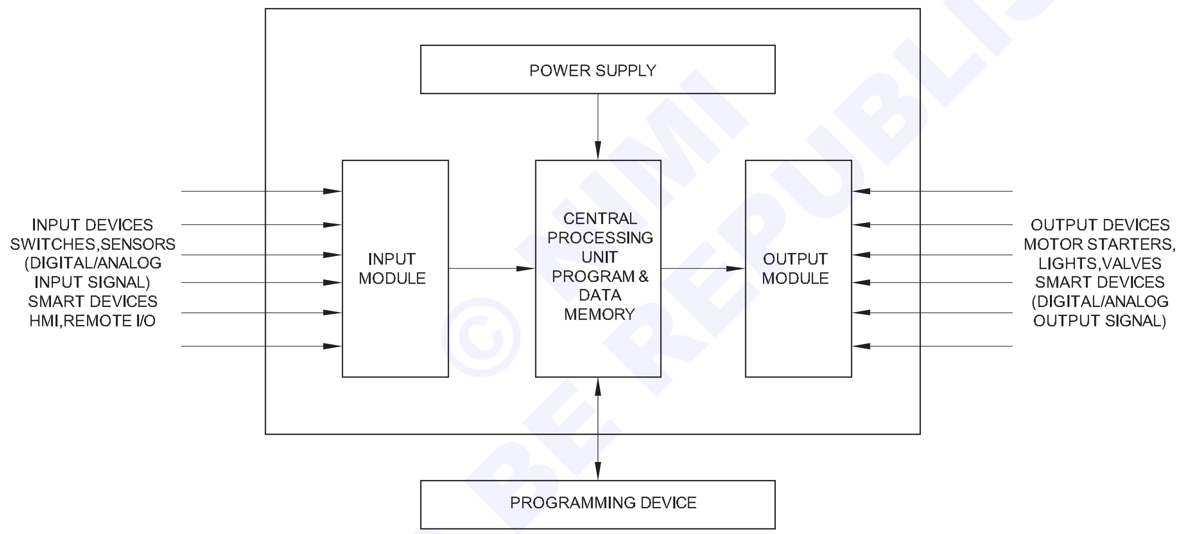
Block diagram of PLC

The simplified block diagram of PLC is shown in Fig 1 It illustrates the major functional hardware items and their interconnections within the PLC system. There may be variations in actual components used for the functions depending on the manufacturer, and model of the PLC. The functions performed by each module block is explained below:

Input module

Input modules consists of sensors, switches, and other external devices to collect input signals (analog or digital) from the environment where they are used. It may have analog input for temperature, level, pressure, speed etc. The analog inputs are of two types such as 1) Voltage input from 0-10V, and 2) the current input is 4-20mA. The analog input signal is converted into digital form and processed. The devices in the input modules condition and convert these signals into a format according to the design of the PLC's internal processing unit.

Fig 1



BLOCK DUAGRAM OF PLC

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Control Processing Unit (CPU)

The CPU is the brain of PLC and is responsible for processing input signals. The CPU contains a microprocessor and memory (RAM and ROM) in it to store and execute the user programmed control logic and communicates to various hardware components, interact with one another for execution. PLC manufacturers may include certain function logics as functional blocks to ease the programming operation e.g. PID control module, drum control, position control algorithm as functional blocks.

Memory: The memory in the PLC receives and stores the user program, system configuration data, and temporary data storage in its RAM and ROM used for the firmware, operating system and built-in functions etc. EPROM or Flash Memory is used to store he user program written to control the behavior of PLC. The ladder logic is programming language used for PLC.

Output modules: The output control signals are interface with actuators, motors, valves, and other input devices to physical field devices.

Output:

Digital outputs are two types as i) Logic output and ii) Relay output

i) Logic output will give output of 24VDC on high signal and zero volt for low signal.

ii) The relay output type of PLC has a COM terminal. The voltage applied on this terminal will be the output for logical thigh and open circuit for low signal.

Analog outputs: also are of two types as i) Voltage output and ii) Current output

i) The voltage output will be of 0-10V which can be used for VFD or any actuators

ii) The current output will be of 4-20 mA, which is the process standard, can be interfaced with any process actuator like control valve/annunciator etc.

The CPU continuously performs the a seam cycle and reads input signal values from the input module. It executes the user program to determine the state of outputs based on the input data values, and the CPU writes output valves to the output modules.

Output module receives commands from the CPU, and convert them into control signals for the external devices.

Communication ports: PLCs include communication ports for connecting to other devices, networks, or human Machine Interfaces (HMIs) like these ports can support communication protocols like RS-232, RS-485, Ethernet or PROFIBUS protocols.

Power supply: The power supply module provides the necessary electrical power to all the hardware items such as input modules, output modules, and other peripheral devices of the PLCs internal components. The power supply voltage designed from 120V - 240VAC or 5V-24VDC with output current 2A to 5A at 5VDC or according to the manufacturer's specifications to the PLC the proper voltage and providing proper grounding.

Since the PLC is a flexible system, that allows addition of some more number of specialised modules such as analog I/O modules, high sped counter modules, or motion control module etc depending upon application or deletion of modules also can be done.

The information about the addition or deletion of modules - name, descriptions etc to the CPU to be updated in the programming. And this helps the CPU to configure the number of I/Os physically available and their sequence of operation, condition and action that the PLC should perform without any unexpected error message or situations.

Different types of PLCs

There are various types of PLCs designed to meet the demands in industries for automation and control applications. Some of the PLCs used in industries with current technologies are given below:

- Compact PLCs are physically small in size with limited input and output provisions and simple control tasks. They are economical and suitable for small machines and applications.
- Modular PLCs are designed with separate modules and can be expanded for larger number of I/O points and for more complex tasks with flexibility and scalable for a wide range of processes.
- Rack mount PLCs are designed to be installed on racks of industrial control panels and enclosures. These are very much suitable for medium to large requirements.
- DIN rail mounted PLCs are another version of compact controllers used in industrial automation and control with the ease of maintenance.
- Safety PLCs are specifically designed to handle safety critical applications in-built to ensure safety standards in manufacturing and process industries.
- High performance PLCs are designed for high speed manufacturing processes and robotics with better real-time control.
- HMI - integrated PLCs are specifically designed with Human - Machine Interface (HMI) capabilities provided with touch screen interfaced for operators to interact the control the system directly.
- IoT enabled PLCs are designed with the advanced IoT (Internet of Things) connectivity features, for remote monitoring by connect to the internet or cloud services.
- Specialised PLCs are designed to meet the specific application for automotive, pharmaceutical, food processing and other fields as well.
- PLCs are also available as Micro PLC and Nano PLCs; Where the total number of I/Os are less than 15 or for smaller applications the Nano PLCs are designed.

PLC architecture (Fixed and Modular)

PLC architecture is the design specification of its hardware an software components, how they are interfaced to interact and communicate with one another as a PLC system to access large amount of peripheral inputs and outputs.

The architecture of PLC is based on the same principle used in that of computer system. The CPU is the heart of PLC system, made up of control unit and processor. The CPU processor exchanges data with the program and data memory. It controls the interaction between various modules, devices and handles the industrial environment reliably with ease of maintenance.

Types of PLC architecture

Today there are three distinct types of PLC architectures available for industrial automation as i) Fixed type, ii) Modular type and iii) Distributed type.

i) **Fixed type PLC:** is shown in Fig 2 It is used for smaller sized less complex applications, in which all the hardware components such as the power supply, CPU, memory, input, output, communication interfaces are all embedded into a single unit. The common name given to this fixed type PLC by different manufacturers are fixed, integrated, Nano, micro, compact, mini, basic, standard and Brick. The present day fixed types of PLCs are designed with expandable modules using ribbon cables.

ii) **Modular type PLC:** is shown in Fig... in which the main modules are processor module, power supply module input module, output module, communication module, where higher powered processor and large number of input and output devices associated with higher level of complexity of operation and control.

Fig 2

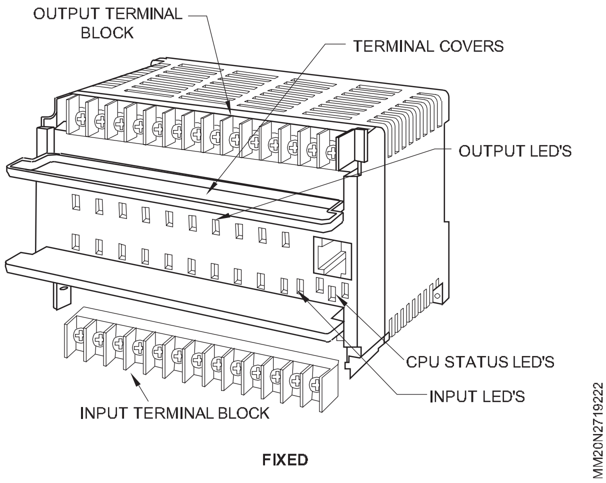
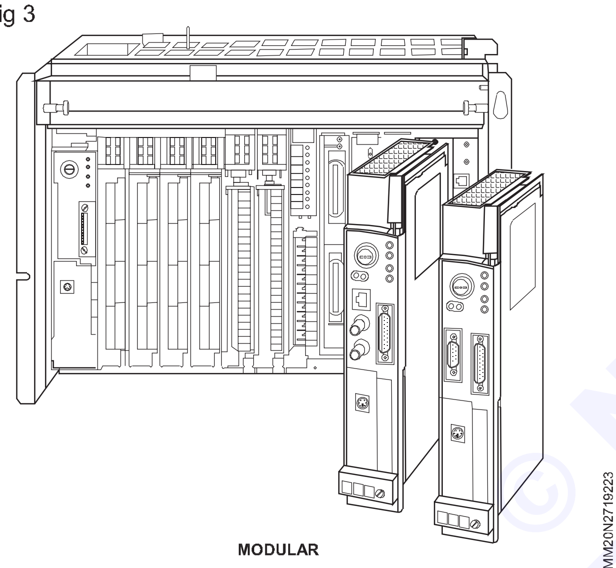
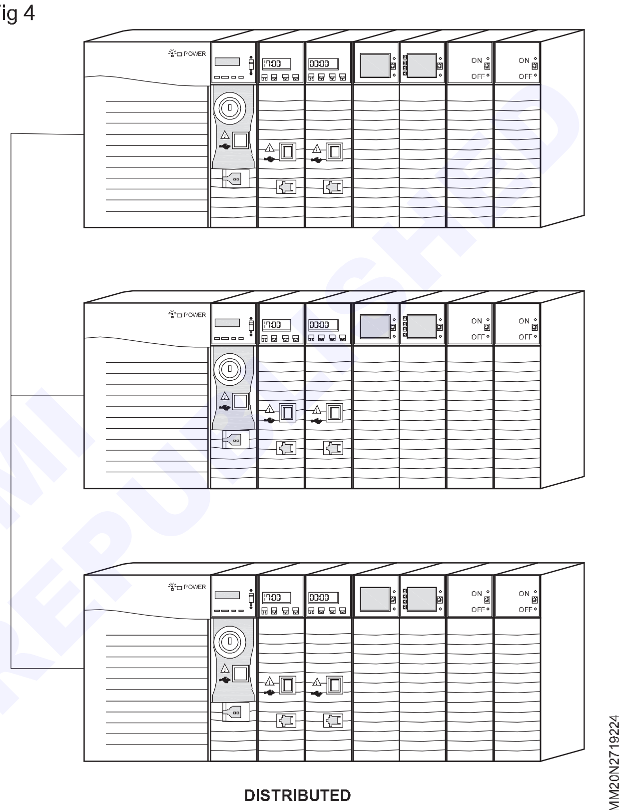


Fig 3



iii) **Distributed type PLC:** is shown in Fig... It is a high end PLC system with modular architecture, and the hardware components are interconnected across different locations using high speed communication link cables. Each location is provided with multiple hardware modules that are housed in a mounting system known as a node, rack or drop. Each node must have a communication module and can have a PLC processor module with I/O module or just I/O modules only. Where there is communication module with no PLC processor module and I/O modules then it is called as distributed I/O or remote I/O.

Fig 4



Various modules in PLC

Objectives : At the end of this lesson you shall be able to
- **list the names of modules used in PLC**
- **describe the functions of various modules in PLC.**

There are several modular devices integrated into the construction and functioning of PLCs for a wide range of industrial automation applications. These modules can be combined to create a customised control system to meet any specific requirements as shown in Fig 5

The names and functions of various modules used in PLCs are explained below:

1 **Power Supply Modules** module provide the necessary voltage and current to operate the PLC and its connected modules.

2 **Input Module** interface with external sensors, switches, and devices to read digital or analog signals. Digital input modules handle signals like limit switches, push buttons, and proximity sensors, whereas analog input modules deal with continuous signals such as temperature or pressure.

3 **CPU Module** is like the brain of the PLC, and it is responsible for executing the control program, handling communication between modules, and processing input and output signals.

4 **Communication Modules** enable the PLC to exchange data with other PLCs, Human-Machine Interfaces, SCADA systems, or even connect to the internet using common protocols including Ethernet, RS-232, RS-485, Profibus, and others.

5 **Output Modules** interface with external field devices like actuators, relays, and devices to send control signals. Digital output modules are used for motors, solenoids, and lights, whereas, analog output modules can control devices like Variable Frequency Drives or control valves.

6 **Safety Modules** are used to implement safety in operations like safety door interlocks, functions, emergency stop, or safety in monitoring of machines and processes.

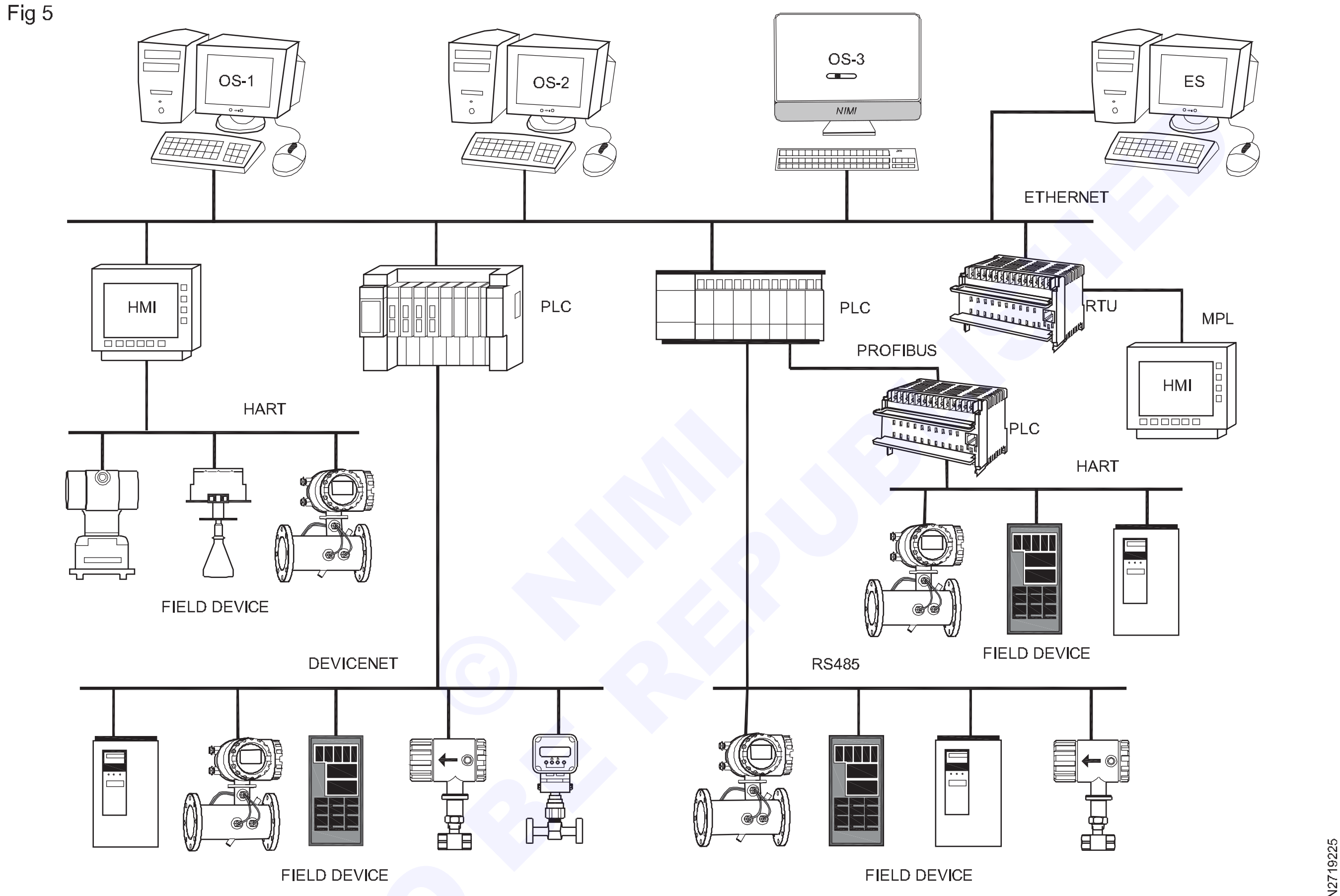
7 **Analog I/O Modules** are essential for tasks requiring precise control and monitoring of temperature control or speed regulation. Analog I/O modules convert voltage or current from sensors and send analog control signals to devices.

8 **Memory Modules** are used in some PLCs to store additional program data or to increase memory capacity for larger control applications.

9 **Special Function Modules** are specially designed to perform specific tasks, such as high-speed counting, motion control, temperature control, or data logging applications.

10 **Positioning Modules** are used for robotics and conveyor system applications involving precise positioning or control of motors and actuators.

Fig 5



VARIOUS MODULES OF PLC'S FOR WIDE RANGE OF INDUSTRIAL AUTOMATION

Selection of PLC, adavantages and application

Objectives : At the end of this lesson you shall be able to
- **explain different parameters for the selection of PLC**
- **discuss about the I/O budgeting for PLC control system**
- **list out the advantages of PLC**
- **describe the applications of PLC**
- **explain the Start - Stop operation of a motor using PLC.**

Selection of PLC

Selecting the right PLC for any application is a crucial decision in industrial automation. A thorough analysis should be made based on the particular requirement and characteristics of the PLCs available for selection.

The following points will guide and help to select the most suitable PLC for the specific application

- First determine the required type of control tasks need to be performed by the PLC, like process control, motion control, temperature control, discrete control etc.
- Decide the number of input and output (I/O) and types required for the specific application
- Consider the conditions of the environments where the PLC has to be operated (like temperature, humidity, hazardous areas, etc).

- Determine the communication protocol and network connectivity, and comply with the industry specific standards and regulations.
- Prepare the budget for the automation project inclusive of cost of hardware, software, installation and maintenance expenses etc.
- Choose the PLC that allows the expansion or addition of hardware scalability in future.
- Select the PLC compatible with the existing hardware items like sensors, actuators and HMI devices.
- Test the PLC in a controlled environment to ensure its performance, supports advanced programming languages, technical support, training programs and reputation of the manufacturer or vendor, their reliability.
- Additionally, consult with industrial automation experts, take assistance in the selection of PLC.

Input / Output budgeting for PLC control system

Input/output budgeting in a PLC control system refers to the activities taken up to manage and allocate the input and output points of the PLC available in the industrial process system effectively and controlling the resources efficiently. It is crucial to prevent resource shortages, avoid unexpected operational issues, and ensure that performance of the control system is optimised.

The key points for judiciously carrying output input/output budgeting of PLC are explained below:

- Plan properly to determine the requirement and identify sensors, switches, devices that are to be connected to the PLC as input devices.
- Determine the output devices like actuators, motors, valves, and other devices controlled by the PLC.
- Calculate appropriate number of digital and analog input and output points required for monitoring and controlling various parameters for the specific tasks like discrete signals (ON/OFF') or continuous signals.
- Ensure compatibility with the communication protocols like RS-485, Ethernet / IP, Profibus for adding remote Input/output modules.
- Plan for expansion modules that can be added to increase capacity of PLC.
- Consider redundancy for critical applications using standby PLC configurations to system reliability.

Advantages of PLCs

In industrial automation and control application processes PLCs play a vital role mainly in a wide range of industries. Some of the advantages of PLCs are given below:

- PLCs are highly reliable and rugged design to operate in extreme temperature, humidity, vibration or any harsh conditions without any performance degradation.
- PLCs can be programmed easily using ladder logic or other graphical programming languages to control a wide variety of automation tasks from a simple ON-OFF to any complex sequential processes.
- PLCs are adaptable and flexible to different applications and can be reprogrammed or re configured for changed processes or production requirements.
- Ability to process real-time control, rapid response to input signals and built-in diagnostics / troubleshooting tools makes it easier. Also, reduces down time and maintenance costs.
- Remote monitoring and control capabilities make operators and engineers to access the PLC system from a remote place and to make modifications in the control system.
- Safety relays, certified hardware and software can be implemented with interlocks and shutdown procedures for protection of all aspects concerned.
- PLCs systems allow adding or removing input and outputting field devices as per the requirement. Also system can be scaled up or down by modular system for expansion and maintenance.
- PLCs can be integrated with other automation systems, HMI panels, SCADA systems, adhering to the industry standards, making them compatible with wide range of input output field devices utilized in industrial environment.
- The flexibility and reliability of PLCs lead to long operational life span lasting for many years leads to cost saving and good return on investment over the long term.

Applications of PLC

PLCs are widely used in various applications from material handling, process control, manufacturing, packaging, labelling, transportation and storage, power generation, distribution, water supply and waste water treatment etc for automated processes.

Some of the applications of PLCs in various industrial and other important fields are given below:

- Material handling and manufacturing starting from movement of goods on conveyor systems, sorting machines, storage in wave houses; manufacturing processes using CNC machine tools, assembly processes etc.
- Process control and pharmaceutical production to control drug formulation, blending, tablet manufacturing consistently and compliance with regulatory requirements, Food and beverages processing cooking control parameters like temperature, pressure, flow, and level etc to ensure product quality and safety standards.
- Power generation and distribution in power plants to control generators, switchgears, distribution systems, load balancing and fault detection.
- Agricultural and environmental control – Automated irrigation systems, grain handling, improve crop yields,

optimise utilization. Environmental system, green houses, climate chambers and maintaining specific conditions, regulate.

START / STOP operation using PLC

PLCs are commonly used to control machinery and processes in industrial automation. Starting and stopping are used as fundamental operations of PLCs. Digital inputs of PLCs are used to sense the logical states of the input and change the states of digital outputs as per the control logic.

The start and stop functionality of a motor through PLC is described below:

To implement the above operation we need two push button switches for ON and OFF functions. The push button switches should be connected to the digital inputs of the PLC wide XÆ/1:1/Æ, X1/I:1/2 and inputs (The addressing formats may vary according to the PLC manufacturer, refer to the reference manual). A relay / contactor or motor or solenoid may be connected to a digital output terminal 'I'Æ/O:2/Æ. The control logic may be as shown in Fig 1.

As per the above logic the push button connected on the input will act as a START button and the switch connected on the input terminal 1 act as a STOP switch. The output O:2/ is the output where we have to connect a relay a contactor through which we have to control the motor.

If the start switch is pressed once the coil O:2/ will be ON. The same is connected across the input, so it maintains the latched condition of the OUTPUT. The circuit behaves like a DOL starter. The same can be achieved using SET/ RESET (LATCH/UNLATCH) command.

The input switch I: I/ is ON for a moment which latches the OUTPUT O:2/ . The switch I:1/1 is ON it will UNLATCH the output O: 2/ as shown in Fig 2.

Fig 1

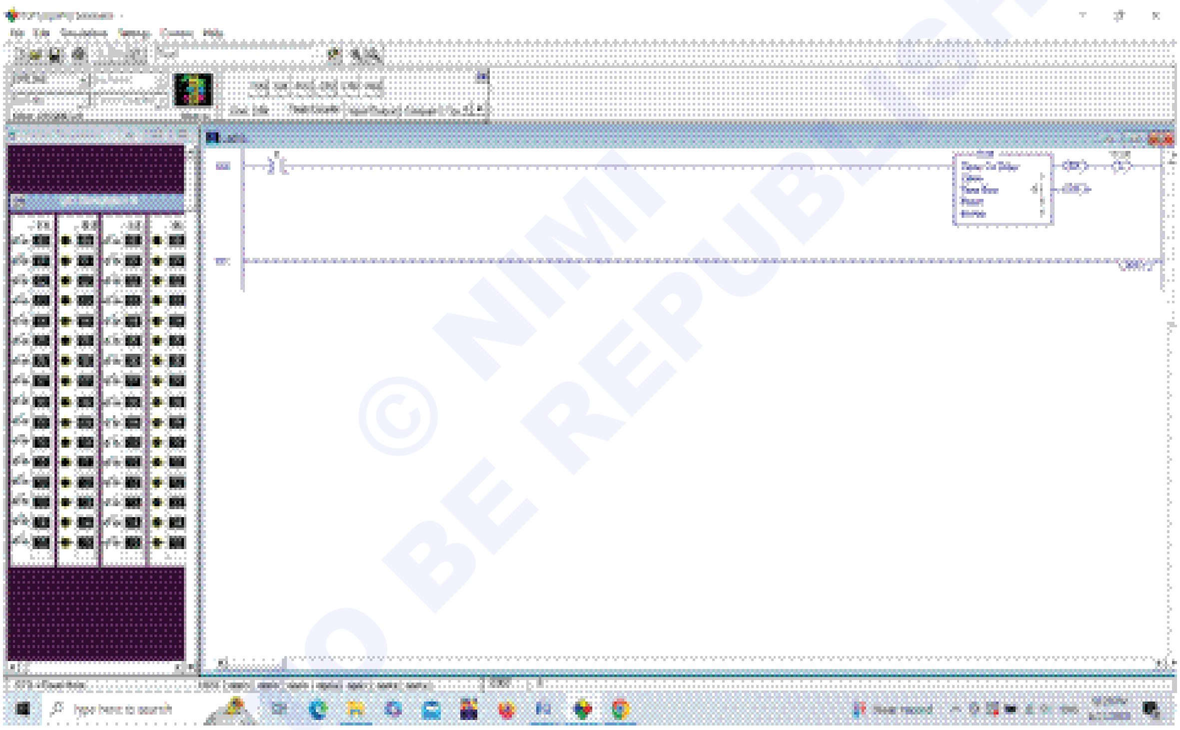
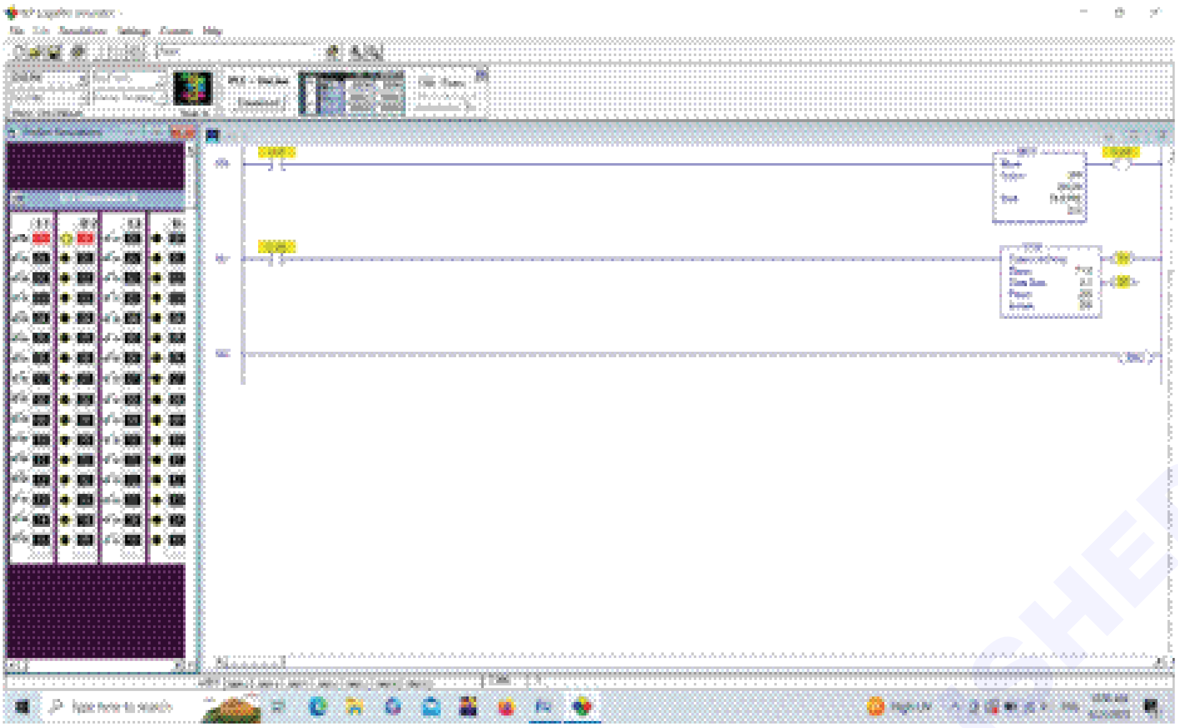


Fig 2



Different logic functions in PLC

Objectives : At the end of this lesson you shall be able to
- **explain different parameters for the selection of PLC**
- **describe different logic functions used in PLC**
- **explain the AND logic functions used in PLC**
- **explain the OR logic functions used in PLC**
- **explain the NOT logic functions used in PLC.**

Logic functions in PLC

In industrial automation processes PLCs are widely used and logic functions are essential for programming the PLC to control and manipulate various input and output operations based on logical conditions.

In a ladder diagram the normally open (NO) and normally closed (NC) contacts merely tell us what state and even is in TRUE or FALSE for PLC programming are i) AND function, ii) OR function and iii) NOT functions. Besides, the NAND, NOR, XOR functions and latch / unlatch operations are also used with combinational logic.

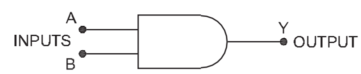
The fundamental logic functions of AND, OR and NOT operations with their truth table are explained below:

AND logic function

The AND logic gate symbol is shown in Fig 1 with its truth table.

It is used to evaluate multiple input conditions from the sensing devices and the resultant output. The output is TRUE only if all the input conditions are TRUE. If any one of the PLC input is FALSE, then the corresponding output is also FALSE.

Fig 1



TRUTH TABLE

INPUTS		OUTPUT
A	B	Y
FLASE	FLASE	FLASE
FLASE	TRUE	FLASE
TRUE	FLASE	FLASE
TRUE	TRUE	TRUE

AND GATE

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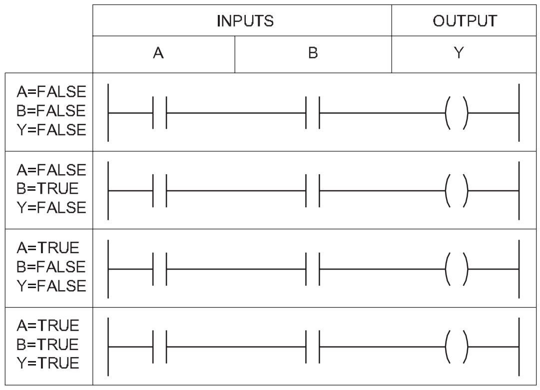
The truth table shows that the output is turned ON only when all the inputs are TRUE. The ladder logic diagram of AND function is shown in Fig 2 in which it looks like two normal contacts connected side by side in series.

In practical AND logic application for some important machine operations are carried out using one supervisory control switch and the another one for operator control switch.

OR logic function

The OR logic gate symbol is shown in Fig 3 with its truth table.

Fig 2



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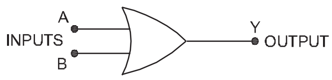
LADDER LOGIC BASICS TRUTH TABLE - AND FUNCTION

Fig 3



TRUTH TABLE

INPUTS		OUTPUT
A	**B**	**Y**
FLASE	FLASE	FALSE
FLASE	TRUE	TRUE
TRUE	FLASE	TRUE
TRUE	TRUE	TRUE

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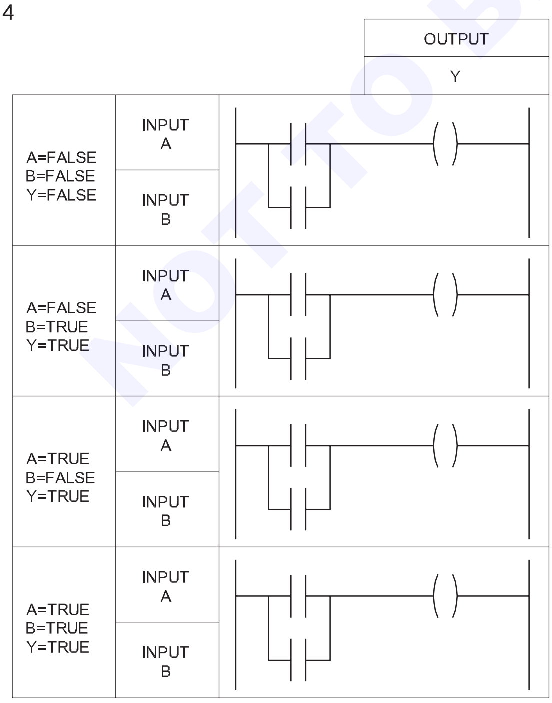
OR GATE

It is also used to evaluate multiple input conditions from the sensing devices and the resultant output. The output is TRUE if atleast any one of the input condition is TRUE. If all the inputs are FALSE under that condition only the output becomes FALSE. This can be verified from the truth table.

The ladder logic diagram of OR function is shown in Fig 4 in which it looks like tow normal controls are connected in parallel across each other on the rung.

Fig 4



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LADDER LOGIC BASICS TRUTH TABLE - OR FUNCTION

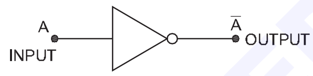
Since the PLC input A and B follows the binary concept of OR function, there are four possible logic iterations as given in the truth table.

In practical application, the OR logic function is realised for the machine operation using two switch contacts A and B. It can be switched ON either by the main panel switch or by the remote switch contact.

NOT logic function

The NOT logic gate symbol is shown in Fig 5 with its truth table. This logic gate is also called as INVERTER. The NOT function is used to negate the state of an input. If the input in TRUE, the NOT function makes if FALSE, and vice versa.

Fig 5



TRUTH TABLE

A	NOT A
FALSE	TRUE
TRUE	FALSE

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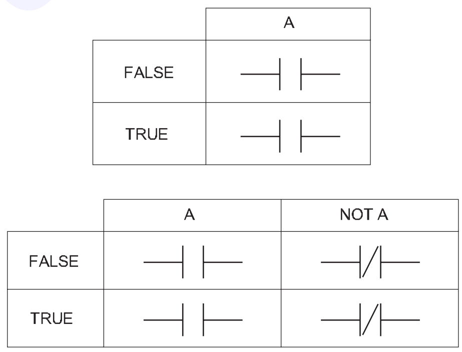
NOT GATE

In ladder logic diagram the NOT function is symbolically expressed as shown in Fig 6 in the form of normally closed contact (NC)

Fig 6



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LADDER LOGIC BASICS TRUTH TABLE - NOT FUNCTION

In ladder logic programming the event associated with a normally closed contact (NC) can be TRUE or FALSE.

The result of normally closed contact (NC) is the opposite state of the event that occurs. So, if PLC input A is FALSE, the result will be true, and vice versa. If is sometimes referred to as reverse logic.

Thus, the binary and logic concepts are what makes ladder logic work with their functions into the structure of the ladder diagram.

Registers, timer and counter in PLC

Objectives : At the end of this lesson you shall be able to
- **describe register in PLC and list important register names**
- **explain the functions of different registers of PLC.**
- **define timer in PLC**
- **explain different timer functions in PLC.**
- **define counter in PLC**
- **explain the counter function in PLCs.**

Registers in PLC

In PLC, the memory structure consists of different types of registers as fundamental components used to store data and control information. These registers serve various purposes in PLC programming. Some of the important register names are given below:

1 Input register

2 Output register

3 Data register (status)

4 Binary register

5 Timer register

6 Counter register

7 Control register

8 Integer register

9 Float register

1 **Input register** is used to store data from sensors or external devices. The digital inputs are directly connected to hold the information such as digital or analog values with this register on every scan cycle. This register is updated according to the inputs.

2 **Output register** is used to store data connected with the digital output devices such as relays or actuators. On the scan cycle the output registers modified as per the status of the input registers and program. It holds the information about the desired state to digital output, whether a relay to be activated or analog values, that is set-point for a motor speed.

3 **Data register/status register** these registers are general purpose registers used for temporary storage of data and for performing calculations within the PLC program like counting, timing or holding intermediate values during logical operations.

4 **Binary registers** are accessible for bit-wise. Each bit can be addressed individually. During the operation, some results can be stored as flags in this registers that can be used further.

5 **Timer register** is used for timer function/operation. The time base value, preset value or accumulator value must be stored in this register.

6 **Counter register** is similar to the timer register. The counter operation preset value and accumulator values are stored in the counter register.

7 **Control register** - When the program calling the sub-routines or program jump to a specific rung, the address must be stored. Also for the RESET function command address is stored in the control register. Also the force and fault are also stored in this register.

8 **Integer register** is used for intermittent result in integer format during arithmetic and logical operations.

9 **Float register** is used for floating point arithmetic operation.

Timers and counters

Objectives : At the end of this lesson you shall be able to
- **define timer in PLC**
- **explain different timer functions in PLC.**
- **define counter in PLC**
- **explain the counter function in PLCs**

Timer in PLC

Timers are essential for managing various time based tasks like turning ON or OFF switches of devices, or delaying operations after a predetermined time interval.

In PLCs, timer is a digital functions block and uses several timer blocks depending upon its memory capacity for so many applications with certain parameters like time base, set value / preset and accumulator to indicate the elapsed time counts. The timer has two outputs by default; they are named as EN and DN, both are bit outputs.

Timer functions in PLC

1 **ON-Delay Timer (TON)** is used to delay the activation of an output. The timer is enabled by the enable contact by a Normally Open/Close contact. When the input condition becomes true, the timer starts counting and turns ON the motor at the output when the preset time has elapsed. It is used for the task like delayed start of a motor after the pressing of a button.

The ON DELAY Timer is used to switch ON the next sequence after the specified time duration. Like in

STAR /DELTA starter, the start function is operated first in STAR position and after the motor achieved 75% of its rated speed, it switch-over to DELTA connection; for this application TON timer is used.

2 **OFF-Delay Timer (TOF)** is similar on TON explained above, but it delays the deactivation of the output. When the input condition goes false, the timer starts counting and keeps the output ON for the preset time before turning it OFF.

OFF Delay Timer is enabled immediately the DN bit goes high and becomes ZERO after the time duration specified by the Timer. E.g., When the Electric generator made OFF immediately, the Engine stops. But the cooling fan should RUN to a certain period of time and thereafter goes OFF. For this application TOF timer is used.

3 **Retentive Timer (RTO)** is used for processes that need to resume timing even after a power interruption without resetting the timer. The RTO maintains its accumulated time value even if the PLC looses power or is restarted.

4 **Pulse Timer (TP)** generates a single pulse output when the input condition is done for a specified time to trigger one time action for a continuous signal.

Depending upon the specific model/type of the PLC, the programming has to be done with reference to the manufacturer's documentation. E.g., In Allen Bradley PLC, the Timers are addressed as T4:O … T4:1, T4:2 and so on. When the accumulated value is EQUAL to the PRESET value, the DN bit goes HIGH and the timer stop counting.

COUNTERS IN PLC

Counters are commonly used in industrial automation and control systems to keep track of various processes or events like counting the units produced on a conveyor belt, tracking machine cycles or monitoring the number of times a particular event occurs.

In PLCs counter is a digital function block used to count events or pulses. There are different types of counters used to implement various applications including up counting, down counting and also as Up/Down counters.

Types of counters in PLC

1 **Up Counter (CTU)** is used to increment its count valve each time on input condition of sensor signal transitions from false to true. After reached the preset count value is reached, the counter triggers an output when it reaches the set value. Up counters are used for tasks like counting product units like bottles or tablets passed on to get the total number of goods produced.

EN bit will set when counter input pulse is ON

DN bit will set when accumulator value reaches the preset value and above. Counters are addressed as C5:O, C5:1.. C5:2 and so on. The counter counts the ON and OFF transition pulses. Like the timer the counter accumulator value cannot be resettled. It should be done through the (RST) reset command.

2 **Down Counter (CTD)** is used to decrement its count value each time on input condition transitions from false to TRUE. It is also necessary to count the objects in downwards. For example sealing should be done on 15 tablets (preset value). For each pulse the accumulator value decremented. When it reaches the ZERO, the DN bit enable, which is used for other sequence of operations. Down counters are used for tasks like counting down inventory levels or tracking the number of parts needed for a production run.

3 **Up/Down counter (CTUD)** can increment or decrement its count value based on two separate input conditions. One input condition increment the value while the other decrements it. Up/Down counters are versatile and can be used for tasks where both forward and backward tracking such as the net movement of a machine operations.

4 **Pre-settable Counter** is a type of counter designed to be used for certain tasks that require counting to a predetermined target. When this reaches this preset value, it can trigger an output or perform an action. The RESET button can be used to reset the counter.

Sequential control system and protocols used in PLC

Objectives : At the end of this lesson you shall be able to
- **define the sequential control system in PLC**
- **explain the importance of sequential control system**
- **list the standard protocols used in PLC programming**
- **explain briefly about RS-232, RS-485,Ethernet, PROFIBUS protocols used for PLC programming.**

Sequential control system

Definition: Sequential control system is an industrial automation process carryout by controlling the sequence of operations, designed to carry out the task consistently with quality, precision of the product in a pre-determined manner. This system can be integrated with PLC, DCS or SCADA systems and suitable for small scale or large industrial plants for efficient energy management, material handling, and to minimise waste and human errors.

Importance of sequential control systems

In any process operation, the sequence must be followed. In this context, sequential control systems become the backbone like in various industries and application due to their ability to manage and coordinate complex processes. The important features and several key points are given below:

- The sequential control system is utilized for industrial processes automatically in a predetermined sequence of operations and it does not need the manual intervention which minimises the risk of human error.
- This control system ensures safety of both equipments and personnel incorporating safety interlocks and emergency shutdown procedure to prevent accident promptly.
- In manufacturing industries where product quality and reliability and paramount, the control system ensures it with process efficiency and productivity with precision.
- It helps to identify issues if any early to trouble shoot and maintenance to optimise the resource, energy management, or material handling and reduce cost.
- It can provide a record of all process operations, ensuring compliance with industry standards and regulations, which is crucial for audits and reporting.

Thus, the sequential control systems plays a vital role in modern industrial automation in improving productivity, safety, consistency to changing needs efficiently.

(i) RS-232

RS-232 is a serial communication standard used for transmitting data between a computer terminal and various peripheral devices, such as modern printers, scanners and other hardware devices like micro controllers etc.

- Using this data is transmitted one bit at a time through a pair of wires. Voltage levels between +5 Volt to-5 Volt to represent data while a positive voltage represent a binary 'O' and a negative voltage represents a binary '1'.
- RS-232 connectors are commonly known as DB-9 that has 9 pins, designed for short distance communication typically up to 50 feet (15 meters).
- In RS-232, the baud rate used to transfer data is 1200, 2400, 9600, 19200 and 115200 bits per sec.
- Even though RS-232 has been widely replaced by the latest communication standards like USB and Ethernet it is still used in certain specialized applications in industrial settings with the use of RS-232-to-USB adapters.

(ii) RS-485

RS-485 is also a serial communication standard similar to RS-232, but designed for use in longer distance data communication. It is used in industrial, automation, and computer networking applications where reliable data transmission is required.

RS-485 has used differential signalling technique; by this it transmits data as the voltage difference between two wires. One wire carries the positive signal and the other wire carries the inverted signal. It is less susceptible to noise and interference to operate over long distances and even in electrically noisy environments.

RS-485 supports multiple devices by connected to the same bus, in which each device has a unique address, and only the specific addressed device will respond to the transmitted data. Using RS-485 communication can be configured as half-duplex or full-duplex modes. In half-duplex mode, transmitting and receiving data the same pair of wires used while for full-duplex separate pair of wires are used with longer cable lengths up to 1200 m (4000 feet) for various data rates to several mega bits (Mbps).

Termination resistors and bias resistors are used to ensure signal integrity and prevent signal reflections on the transmission lines.

Since RS-485 is designed to be robust in industrial environments, it is used in industrial automation systems, building automation, HVAC systems, security systems and building automation, HVAC system, security systems and many other applications where reliable and long distance communication is required.

The above serial communication is also used for wireless communication as well.

(iii) Ethernet

Ethernet is a widely used networking standard that enable computers and other devices to communicate with each other over a Local Area Network (LAN) or, Wide Area Network (WAN) or the internet. The important aspects of Ethernet are given below:

- Ethernet can be implemented over twisted pair copper cables, fiber optic cables and also through wireless communication.

  The most common Ethernet standard today is based on twisted -pair cables, with variations like Cat 5e, Cat 6, and Cat 7, which offers different levels of performance and speed.
- Ethernet operates at the data line layer of the OSI model. Each data packet is encapsulated in frame based protocol, which includes sources and destination Media Access Control addresses, as well as other control and error checking information.
- Different data transfer speeds are commonly used for Ethernet
  - **10 Base - T** Ethernet standard with a data transfer rate of 10 Mega bits per second (Mbps) through twisted pair copper cables.
  - **100 Base - T** standard offers data rate of 100 Mbps.
  - **Gigabit Ethernet (1000 Base - T)** provides data rate of 1 Giga bits per second (Gbps) is commonly used in modern networks.
  - **10 Gigabit Ethernet** standards offers data rates of 10 Gbps.
  - **40 Gigabit** Ethernet and 100 Gigabit Ethernets are designed for high performance data centres and back bone networks.

- Ethernet switches are essential network devices in modern networks.
- Ethernet can also be extended wirelessly using Wi-Fi technology allowing devices to connect to a network without physical cables.
- Ethernet is used to provide internet connectivity through devices like routers and modems connected to the internet service provider's network.

(iv) PROFIBUS

PROFIBUS is a field bus communication standard protocol used in industrial automation and process control applications.

- It is a digital communication protocol that allows devices such as PLCs, sensors, actuators, and other industrial automation components to exchange data and control information.
- It operates at the data link layer (Layer -2) and the physical layer (Layer -1) of the OSI model.
- There are two variants of PROFIBUS 1) PROFIBUS -DP (De centralised peripheral) and 2) PROFIBUS - PA (Process Automation)
- PROFIBUS -DP is used for fast, deterministic communication between PLCs and field devices in process automation systems for real-time control.
- PROFIBUS - PA is specially designed for hazardous environments like chemical and petrochemical industries.
- PROFIBUS network can be configured in various topologies like point-to-point, multi-point and ring configurations to share a single communication line for multiple devices.
- This network is implemented using different physical media like RS-485 for PROFIBUS-DP or Manchester -encoded current loops for PROFIBUS - PA.
- PROFIBUS supports data rates ranging from 9.6 kbps to 12 Mbps, depending on the cable type and network configuration.
- It provides deterministic communication, by which devices can exchange data with precise timing, making real-time control and synchronisation.

  It includes features for easier troubleshooting and maintenance of industrial automation systems.
- It reduces the wiring harness by the field devices need not be connected directly with the PLC; rather they all connected on the communication bus itself.
- PROFIBUS networks can be integrated into larger industrial control systems and SCADA systems for reliable and robust communication standards for various applications.

Programming languages used in PLC, configuration and wiring

Objectives : At the end of this lesson you shall be able to
- **list the popular programming languages used in PLC**
- **explain briefly about PLC programming languages LDR, STL, FBD, SFC**
- **define the ladder logic diagram used in PLC**
- **explain the parts of ladder diagram used for programming the PLC**
- **explain the need for configuration of PLC and its modules**
- **draw the wiring layout of PLC with field devices**
- **explain the wiring procedure, method and precautions followed in PLC.**

Different programming languages of PLC

PLCs are programmed using number of specialized languages designed for real-time control and automation tasks. The choice of programming language depends on the specific requirements of the control system, the preferences of the programmer, and the capabilities of the PLC hardware and software.

Many PLC programming environments support multiple languages, allowing programmers to choose the most suitable language for a given task within a single project. Here is a list of some of the programming languages for PLC:

Ladder Logic Diagram (LD)

Structured Text Language (STL)

Function Block Diagram (FBD)

Sequential Function Chart (SFC)

Structured Control Language (SCL)

Continuous Function Chart (CFC)

High-Level Languages (HLLs)

Let us describe about few of the commonly used programming languages for PLC:

(i) LAD

(ii) STL

(iii) FBD and

(iv) SFC

(i) LD for programming PLC

Ladder diagram is a graphical programming language used to program a PLC with symbolic notation using ladder diagrams like the rails and rungs of relay logic circuit. It is used to automate repetitive machine tasks and sequences in industrial automation applications.

Ladder logic is a fast and simple way of creating PLC programming that resembles an electrical schematic diagram in which the horizontal lines of the control logic are called Rungs and vertical lines at the start and end of each rung is called Rails. Since it looks like a ladder, it is called "ladder diagram".

The logic functions are executed following the binary concepts expressed symbolically in the form of a normally open (NO) contact and normally closed (NC) contact. Essentially the three basic logic functions in ladder logic are 1) AND, 2) OR, 3) NOT gates, will be utilized to program the majority of automation control requirements and for some applications the combinational logics are also used.

The ladder logic is also helps to troubleshoot the codes by visually seeing the flow of logic from the left to right and from the first rung on the top to the bottom rungs easily.

(ii) STL for programming PLC

Structured Text Language (STL) is a textual programming language used for IEC 61131-3 compliant PLCs. It is similar to high-level programming languages like Pascal or C. STL is well suited for complex control logic and mathematical operations.

STL allows for the creation of modular and well organised codes using structured syntax with key words, operators and control structures similar to other programming languages. It includes arithmetic, comparison, and logical operators for calculations and conditional branching for decision making and looping within the program. Also, it allows to implement time delays and time-based actions using timers and time-related functions.

(iii) FBD for programming PLC

Function Block Diagram (FBD) is a graphical programming language used in PLCs. It is used especially for control systems that are visualised clearly and intuitively in industries.

In FBD programs, the blocks are used as fundamental elements representing a specific function or operation. By using them the basic operations like AND, OR, NOT, timers, counters, mathematical calculations etc are performed. Input terminals and output terminals are used to connect blocks together to receive input signal from the other blocks and send them to other blocks or output devices accordingly.

Wires are used to connect the flow of data or control signal between blocks, while connectors are used to route wires and organise the FBD program data flows from left to right and top to bottom. Conditional logical operations are implemented using comparators, timers and counter blocks; mathematical operations and control done by adders, subtractors, multipliers and divider blocks; Time based operations by timers and counter blocks in industrial process control and automation applications.

(iv) Sequential Function chart for programming PLC

A Sequential Function Chart (SFC) is a graphical language used for PLCs and other automation software's, making it easier for engineers and technicians understand and visualize the control logic of a system.

The chart consisting of boxes interconnected with arrows representing steps and transitions in a control process. Multiple steps can be executed simultaneously in a complex automation system. It also can have hierarchical structure in breaking down complex control system into manageable and modular components.

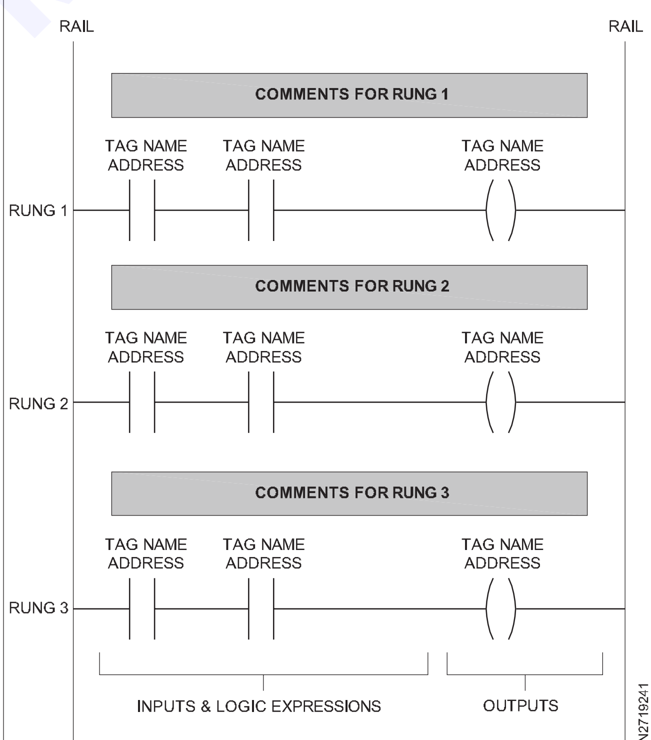
SFCs include actions, conditions, timers and counters as elements in programming. It also offers a clear and initiative way to debug control logic by tracing the flow of the chart and identify potential issues, that helps engineers and technician to design, implement and maintain complex control system reliably and efficiently.

Basic ladder programming of PLC

The earlier control system was achieved by the relays. One contact of the relay is used to energise the other relay coil and so on. Those having little electrical knowledge can understand the relay logic circuit diagram easily. The same method is adopted for PLC programming is called ladder logic. (Fig 1)

Ladder logic is a graphical programming language used to program a PLC with symbolic notation using ladder diagrams like the rails and rungs of relay logic circuit. It is used to automate repetitive machine tasks and sequences in industrial automation applications.

Fig 1



LADDER DIAGRAM AND ITS PARTS

Ladder logic is fast and simple way of creating PLC programming that resembles an electrical schematic diagram.

A typical ladder diagram is shown in Fig 1, in which the horizontal lines of the control logic are called Rungs and vertical lines at the start and end of each rung is called rails.

There are seven parts used in ladder logic programs as rails, rungs, inputs, outputs, logic expressions, address notation tag narrations and comments; of these some are essential and others optional.

The logic functions in ladder logic are automatically built into the structure of a ladder. The ladder logic is read from the left to right and from the first rung on the top to the bottom rungs. Since it looks like a ladder, it is called "ladder diagram".

The logic functions are executed following the binary concepts expressed symbolically in the form of a normally open (NO) contact and normally closed (NC) contact.

Essentially the five basic logic functions in ladder logic are AND, 2) OR, 3) NOT, 4) IF, 5) THEN will be utilized to program the majority of automation control requirements.

It also helps to troubleshoot the codes by visually seeing the flow of logic from the LHS, starting on the rail through the symbols on the rung and to the RHS end rail easily.

Configuration of PLC and its modules

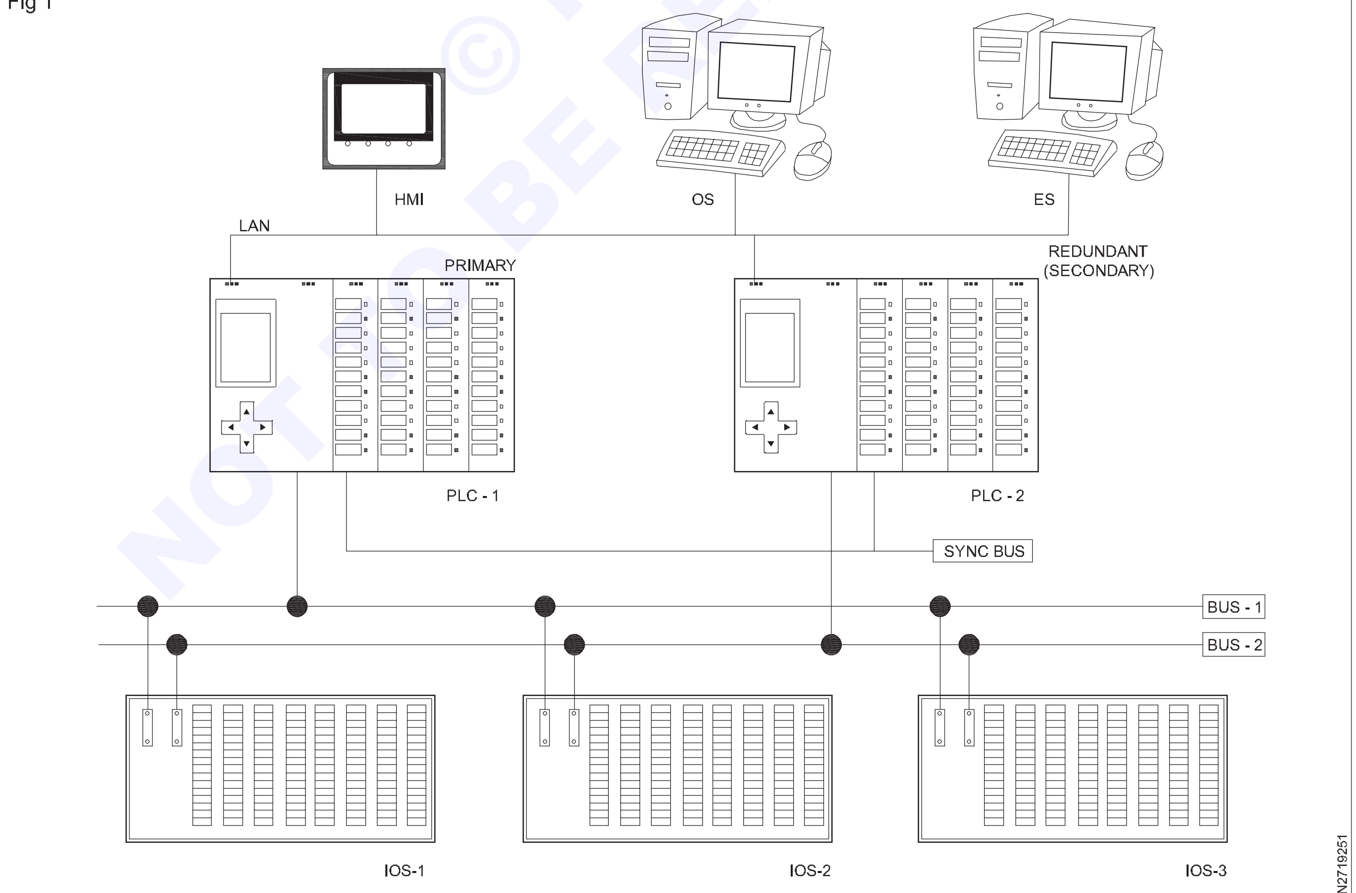
Objectives : At the end of this lesson you shall be able to
- **describe the configuration of PLC**
- **explain the need for configuration of PLC and its modules.**

Configuration of PLC

Configuration of PLC is the process of setting up the hardware and software components to achieve the desired automation control functions. It involves the selection of the necessary input output modules for interfacing with sensors, actuators and other field devices for the application. Choosing the correct power supply, PLC CPU based on the processing power, memory capacities, processing speeds, and communication options.

- Installation of PLC programming software provided by the manufacturer and developing the PLC program logic to control the desired automation tasks. Assigning addresses and define data types for each I/O point.
- Configuring the communication settings with other devices or systems, protocols and network connections.
- Implement safety features, interlocks within the PLC programming to ensure safe operation.

Fig 1



PLCS WITH REDUNDANCY

Need for Configuration of PLC

1 Configuration of PLC is a crucial step for any specific application in industrial automation system that allows for the customisation, adaptation, implementation of the control logic, and optimisation of machineries and processes.

2 Since there are different types / models and make PLCs manufactured and it is essential to adhere to the guidelines provided by the manufacturers for programming and configuration.

3 PLCs are used in critical applications like Power generation, Nuclear Plant etc. In these real time applications no down time or failure should come. For this purpose redundancy plays the vital role by keep running the critical process without intervention. In this context, configuration of PLC, Power supply, I/O modules are selected to have redundant one as shown in Fig 1.

4 When the main CPU fails, immediately Redundant CPU take over the action. To achieve this hand shaking method is adopted and the same is for I/O Modules also.

5 Therefore, most of the real time applications, uses Redundant configuration which in each module will have a duplicate module to carry out the work when the main unit fails

6 Thoroughly test and debug the PLC program, and then after configuration and testing processes deploy the PLC for the industrial processes intended and monitor regularly for reliable operation continuously.

Wiring of PLC

Objectives : At the end of this lesson you shall be able to
- **describe the configuration of PLC**
- **draw the wiring layout of PLC with field devices**
- **explain the wiring procedure and precautions to be followed.**

Wiring of PLC with field devices

Proper wiring of PLC is crucial for the reliable operation of the control system. It involves connecting various input and output devices, sensors, switches, actuators and power supplies and safety devices to the PLC's input and output modules are as shown in Fig 1.

The following are some of the key points to be followed for wiring a PLC:

- Select and ensure the location for the PLC such that it is easily accessible and free from dust, moisture and temperature extremes; also for maintenance and trouble shooting.
- Follow the manufacturer's specification and recommended practices to connect the PLC to Power supply both DC and AC (24VDC, 240VAC) and ensure proper grounding of the PLC chassis and all connected devices to protect from electrical noise and voltage spikes.
- Use wires, connectors and terminal blocks rated for the voltage and current; observe the polarity and connect input devices to the PLC either analog or digital input and signal levels required. Label input connectors for easy identification.
- Similarly connect output devices to the PLC analog or digital output terminals. For inductive loads use the preventive arrangement for back EMF; follow labelling for output connections also.
- Connect the communication cables to appropriate ports according to the system with other devices or networks; use high quality terminal blocks for making connections.
- Organise and route cables neatly to prevent interference; use cable trays conduit or cable ties to secure wiring. Simplify the connections to each input - output module wires are bundled by tie-wrap and the bundled wires connected to the module are routed through the duct with other bundles of wire which have the same characteristics be kept in separated ducts organised to avoid interference as shown in Fig 2
- Ensure safety interlocks and emergency stop buttons are wired and tested correctly to ensure safety for all. Replace worn-out cables, inspect and tighten connections.
- Keep thorough records of the wiring, Labelling and any changes made to the PLC system wiring with field devices.

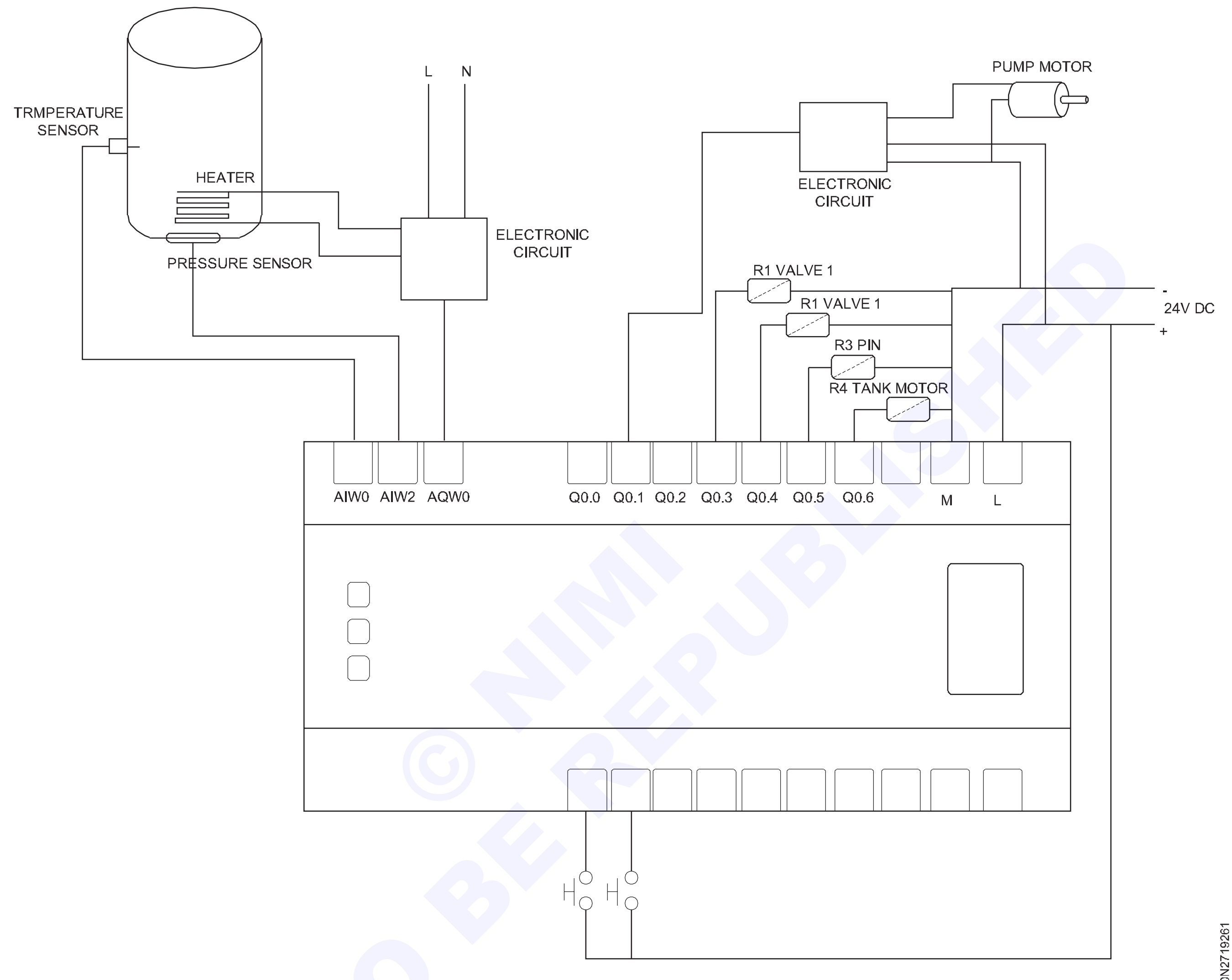
Precautions to follow in PLC Wiring

In order to ensure safety, reliability of PLC control system working correctly, here under

- Before start wiring determine the requirement and plan and design for the control system, select appropriate wires, cables, conduits, switches, outlets and other electrical components; ensure their voltage, current ratings.
- Follow colour coding standards, use colour codes wires, and labelling to distinguish phase, neutral, ground, positive, negative wires.
- Refer to schematics and wiring diagrams electrical codes provided by the manufacturer and follow the connections. Properly ground electrical circuits and equipment to protect against electrical faults.

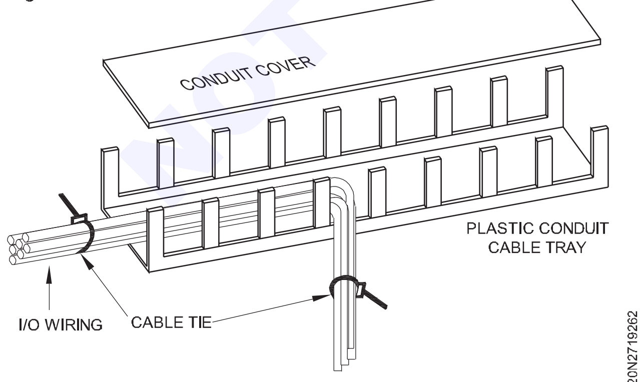
- Use protection devices like circuit breakers, or fuses to protect from over current situations.
- For outdoor wiring use weather proof boxes, covers and conduit seals to protect connections from moisture and environmental elements.
- Use continuity tester or multimeter to verify that wires are correctly connected and ensure there are no short circuits or open circuits; also ensure correct polarity

Fig 1



WIRING OF PLC

Fig 2



PLC WIRING IN A CABLE TRAY

- Always consult and involve qualified electricians or engineers with experience in industrial automation to thoroughly inspect the wiring to ensure that everything is connected correctly and securely.

Coordinate Geometry & Machine Axis

Objectives: At the end of this lesson you shall be able to
- **understand the machine coordinate system**
- **state real number line**
- **understand cartesion coordinates system**
- **understand the cartesion coordinates of three-dimensional space.**

Machine coordinate system

Most of the CNC machinery have a default coordinate assumed during power up of machine coordinate system. The origin of the system is called machine origin are home zero location. Home zero is usually located at the tool change position.

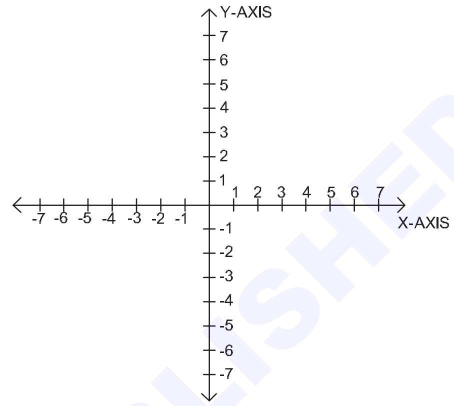
In the manufacturing industry, with regard to numerically controlled machine tools, the phrase machine coordinate system refers to the physical limits of the motion of the machine in each of its axes, and to the numerical coordinate which is assigned (by the machine tool builder) to each of these limits. CNC Machinery refers to machines and devices that are controlled by the using programmed commands which are encoded on to a storage medium, and NC refers to the automation of machine tools that are operated by abstract commands programmed and encoded onto a storage medium.

The cartesian coordinate system

Cartesian coordinates allow one to specify the location of a point in the plane, or in three dimensional space. the cartesian coordinates or rectangular coordinates system of a point are a pair of numbers (in two dimensions) or a triplet of numbers (in three - dimensions) that specified signed distances from the coordinate axis. First we must understand a coordinate system to define our directions and relative positions (axis) and a reference position (origin). A coordinate system can be rectangular or polar,

Just as points on the line can be placed in one to one correspondence with the real number line, so points in plane can be placed in one to one correspondence with pairs of real number line by using two coordinate lines. To do this, we construct two perpendicular coordinate line that intersect at their origins, for convenience. Assign a set of equally space graduations to the x and y axes starting at the origin and going in both directions, left and right (x axis) and up and down (y axis) point along each axis may be established.We make one of the number lines vertical with its positive direction upward and negative direction downward. The other number lines horizontal with its positive direction upward to the right and negative direction to the left. The two number lines are called coordinate axes; the horizontal line is the x axis, the vertical line is the y axis, and the coordinate axes together form the cartesian coordinate system or a rectangular coordinate system. The point of intersection of the coordinate axes is denoted by O and is the origin of the coordinate system. See Fig 1.

Fig 1



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It is basically, Two Real Number lines Put Together, one going left - right, and the other going up- down. The horizontal line is called x-axis and the vertical line is called y-axis.

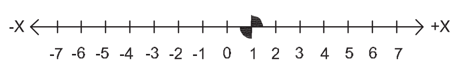
The origin

The point (0,0) is given the special name "The Origin" , and is given the letter "O".

Real number line

The basis of this system is the real number line marked at equal intervals. The axis is labelled (X,Y or Z). One point on the line is designated as the Origin. Numbers on one side of the line are marked as positive and those to the other side marked negative. See Fig 2.

Fig 2



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Cartesian coordinates of the plane

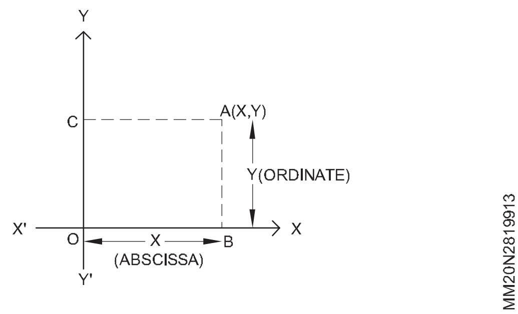
A plane in which a rectangular coordinate system has been introduced is a coordinate plane or an x-y-plane. We will now show how to establish a one to one correspondence between points in a coordinate plane and pairs of real number. If A is a point coordinate plane, then we draw two lines through A, one perpendicular to the x-axis and one perpendicular to the y-axis. If the first line intersects the x-axis at the point with coordinate x and the second line intersects the y-axis at the point with coordinate y, then we associate the pair (x,y) with the A (See Fig 2). The number a is the x-coordinate or abscissa of P and the number b is the y-coordinate or ordinate of p; we say that A is the point with coordinate (x,y) and denote the point by A (x,y). The point (0,0) is given the special name "The Origin" , and is sometimes given the letter "O".

Abscissa and Ordinate (Fig 3)

The words "Abscissa" and "Ordinate" ... they are just the x and y values:

- Abscissa: the horizontal ("x") value in a pair of coordinates: how far along the point is.
- Ordinate: the vertical ("y") value in a pair of coordinates: how far up or down the point is.

Fig 3

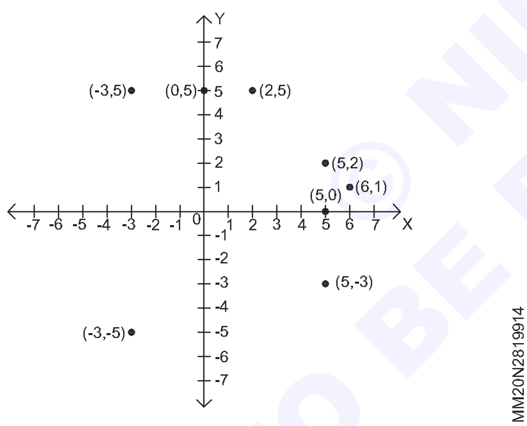


Negative Values of X and Y

The Real Number Line, you can also have negative values.

Negative: start at zero and head in the opposite direction; See Fig 4

Fig 4



So, for a negative number:

- go left for x
- go down for y

For example (-3,-5) means :

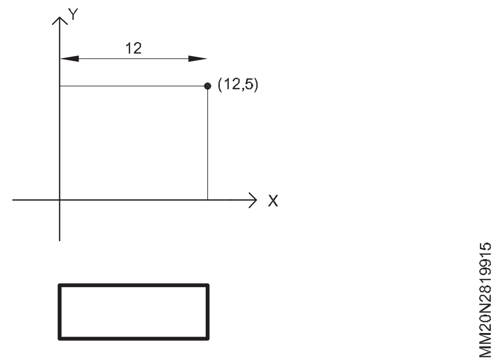
Go left along the x axis 3 then go up 5 in the y-axis. (Quadrant II x is negative , y is positive)

And (-3,-5) means :

go left along the axis 3 then go down 5 in the y-axis. (Quadrant III x is negative ,y is negative)

Using Cartesian Coordinates, mark a point on a graph by how far along and how far up it is; See Fig 5. The point (12,5) is 12 units along the x-axis, and 5 units up on the y-axis.

Fig 5

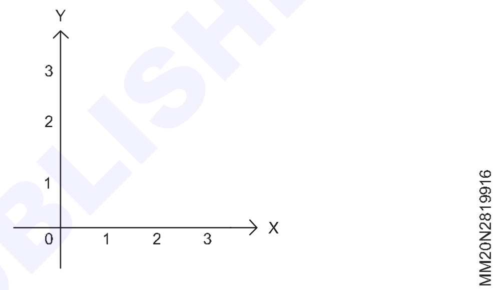


X and Y Axis

The horizontal line is called x-axis and vertical line is called y-axis; both line runs through zero origin,(0,0) put them together on a graph ... See Fig 6.

It is basically, a set of two real Number lines.

Fig 6



Axis: The reference line from which distances are measured.

Example: (Fig 7)

Point (6,4) is

Go along the x direction 6 units then go up 4 units up in the y direction then "plot the dot".

And you can remember which axis is which by:

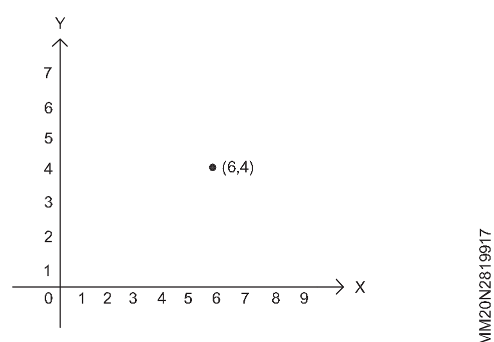
- the horizontal distance first,
- then the vertical distance.

Ordered pair

The number are separated by a comma, and parentheses are put around the whole thing like this: (7,4)

Example: (7,4) means 7 units to the right (x-axis), and 4 units up(y-axis)

Fig 7



Cartesian coordinates of three dimensional space

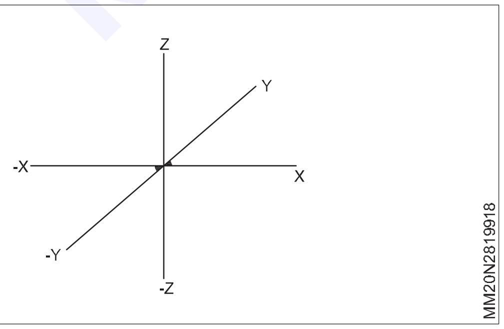
In three-dimensional space (xyz space), oriented at right angles to the xy-plane. The z axis, passes through the origin of the xy-plane. Coordinates are determined according to the east-west for x-axis north-south for y-axis, and up -down for the z-axis displacements from the origin. The Cartesian coordinate system is based on three mutually perpendicular coordinate axes: the x-axis, the y-axis, and the z-axis, See Fig 6 below. The three axes intersect at the point called the origin. You can imagine the origin being the point where the walls in the corner of a room meet the floor. The x-axis is the horizontal line along which the wall to your left and the floor intersect. The y-axis is the vertical line along which the wall to your right and the floor intersect. The z-axis is the vertical line along which the walls intersect. The parts of the lines that you see while standing in the room are the positive portion of each of the axes. The negative part of these axes would be the continuations of the lines outside of the room.

Three-dimensional cartesion coordinate axes. A representation of the three- dimensional cartesion coordinate system. The positive x-axis, y-axis, and positive z-axis are the sides labelled by x,y,z. The origin is the intersection of all the axes. The branch of each axis on the opposite side of the origin (the unlabelled side) os the negative part.

When dealing with 3-dimensional motion, is to set up a suitable coordinate system. The most straight-forward type of coordinate system is called a Cartesian system. A Cartesian coordinate system consists of three mutually perpendicular axes, the X, Y, and Z-axes. By convention, the orientation of these axes is such that when the index finger, the middle finger, and the thumb of the right -hand are configured so as to be mutually perpendicular, the index finger, the middle finger, and the thumb can be aligned along the X,Y,Z-axes respectively. Such a coordinate system is termed right-handed. See Fig 7. The point of intersection of the three coordinate axes is termed the origin of the coordinate system.

The Cartesian coordinates of a point in three dimensions are a triplet of numbers (x,y,z). The three numbers, or coordinates, specify the signed distance from the origin along the x,y, and z- coordinate axis respectively. They can be visualized by forming the box with edges parallel to the coordinate axis and opposite corners at the origin and the given point.

Fig 8

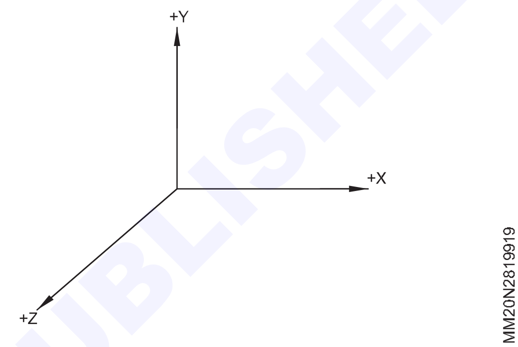


The points may now be defined in a three dimensional volume or space. This permits to define points in three dimensions from the origin. The Cartesian coordinates (x,y,z) of a point in three-dimensions specify the signed distance from the origin along the x,y, and z-axes, respectively. Z-axis points become the third entry when defining coordinate locations.

Given the above corner-of-room analogy, we could form the Cartesian coordinates of the point at the top of your head,as follows. Imagine that you are five meters tall the z-axis, and that you walk two meters from the origin along the x-axis, then turn left and walk parallel to the y-axis four meters into the room. The Cartesian coordinates of the point at the top of your head would be (2,4,5).

For example, a notation of (2,4,5) corresponds to the value of X2, Y4, and Z5. See Fig 9.

Fig 9

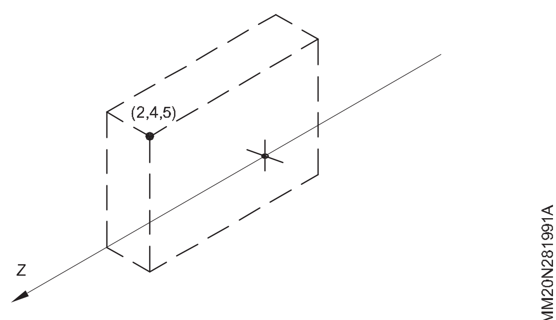


3 DIMENSIONS

Cartesion coordinates can be used for locating points in 3 dimensions as in this example:

Figure 10. The point (2,4,5) is shown in three-dimensional Cartesian coordinates

Fig 10

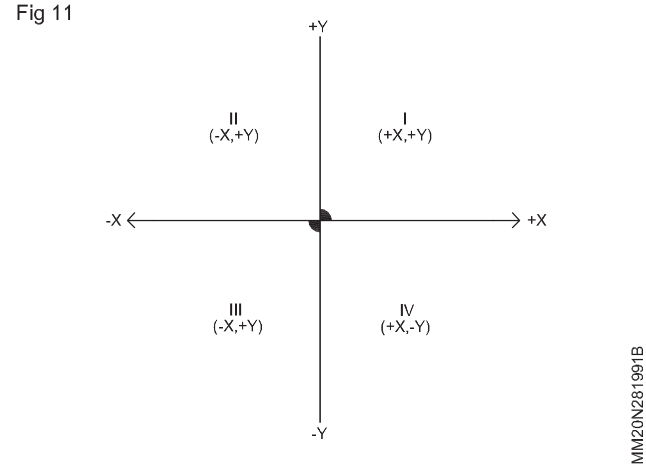


QUADRANTS

The coordinate axes divide the plane into four parts, called quadrants (See Fig 11). The quadrants are number counter clockwise,starting from the upper right,labelled I,II,III,IV with axes designations as shown in illustrations below.

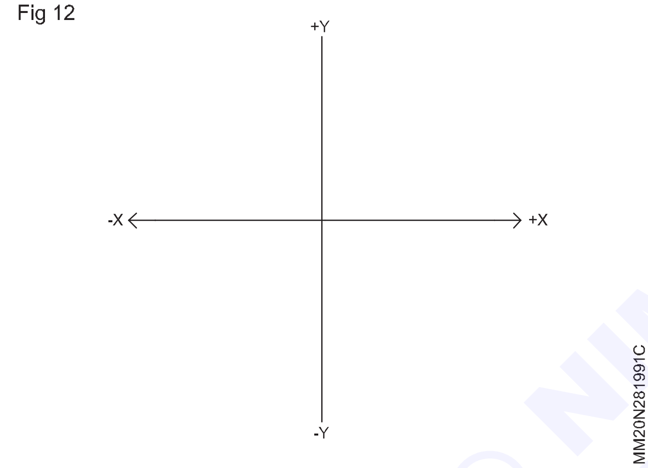
When we include negative values, the x and y divide the space up into 4 pieces:

Fig 11



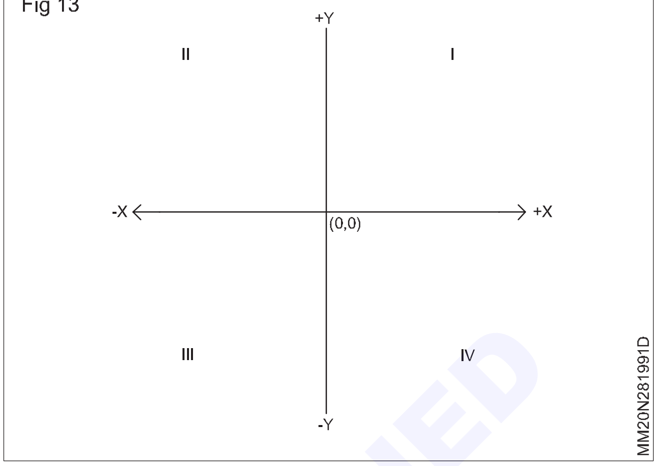
(They are numbered in a counter clockwise direction)

Fig 12



In Quadrant I : both x and y are positive
In Quadrant II : x is negative (y is still positive)
In Quadrant III : both x and y are negative
In Quadrant IV : x is positive again, while y is negative.

Fig 13



Quadrant	X(Horizontal)	Y(Vertical)	Example
I	Positive	Positive	(3,2)
II	Negative	Positive	(-5,2)
III	Negative	Negative	(-2,-1)
IV	Positive	Negative	(2,-5)

Example: the point “A” (3,2) is 3 units along the x-axis, and 2 units up the y-axis.

Both x and y are positive, so that point is i “Quadrant I”

Example: The point “C” (-2,-1) is 2 units along the axis in the negative direction, and 1 unit down the y-axis in the negative direction.

Both x and y are negative, so that point is in “Quadrant III

DIMENSIONS: 1,2,3 AND MORE...

1 The Real Number Line can only go:
   - Left-right
   - So any position needs just one number.

2 Cartesian coordinates can go:
   - Left-right, and
   - Up-down
   - So any position needs two numbers

3 3 Dimensions
   - Left-right,
   - Up-down, and
   - Forward-backward
   - So any point can be located with (x,y,z) coordinates.

Axis convention of CNC machine

Objectives: At the end of this lesson you shall be able to
- **identify CNC machine by number of axes**
- **identify CNC machines by orientation of axes**
- **understand axes convention on CNC lathes.**

Types of CNC milling machines

Milling machines can divided into three categories

1 by the no of axes

(two, three or more)

2 by the orientation of axes

(vertical or horizontal)

3 by the presence or absence of a tool changer.

The spindle motion is up and down in vertical milling/ machining centre.

The spindle motion is in and out in horizontal milling/ machining centre.

These machines are capable to perform the following operations:

Drilling, Reaming, boring, tapping, profiling, thread cutting and many other operations.

ATC: Automatic Tool changer.

APC: Automatic pallet changer

CNC: Computer Numerical Control

With the above advanced features built in milling machines become the new breed of machine tools called machining centres.

Machine axes

The machining centres are provided with minimum three axes of 'X','Y'&'Z' axis and fourth axis machines become more flexible i.e the fourth axis 'A' for vertical model and 'B' of horizontal model. The machine with five or more axes is of higher level of capacity.

In aircraft industry 5 axes profile milling machine is used for complex shapes and to reach cavities and various angles.

Meaning of half / full axis in NC language (what is half / full axis machine)

A full axis vertical machine has X,Y,Z as primary axes and indexing table designated as 'A' axis which can position but cannot rotate simultnesously is called 3 1/2 axes machine. If the machine is equipped with full rotating table, simultaneously then it is called four axis machine tool.

In the milling systems, three most common machine tools are

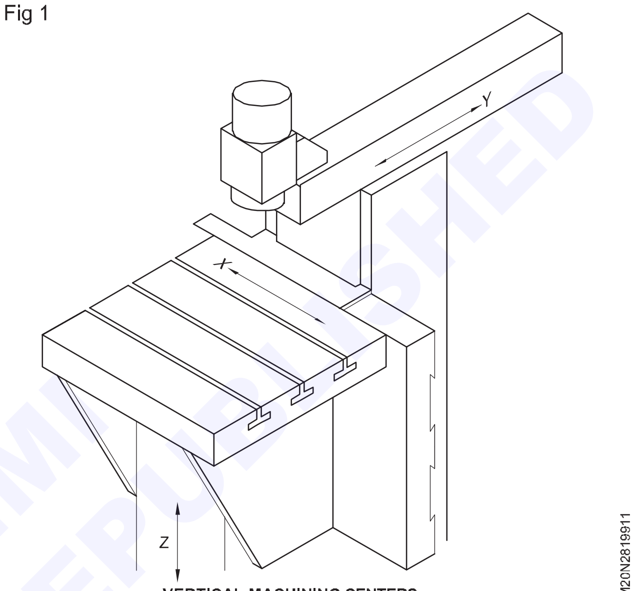
CNC vertical machining centre - VMC

CNC horizontal machining centre - HMC

CNC horizontal boring mill

Vertical Machining Centres (Fig 1)

Fig 1



VERTICAL MACHINING CENTERS

VMC is for flat type of work where the machining is done on only one face of the part in single set up.

An optional fourth axis can be provided by mounting rotary table to the main table either vertically or horizontally depending on the desired results and the model type.

In the combination with a tailstock (usually supplied) the fourth axis in the vertical configuration can be used for machining long parts,which need support at both ends.

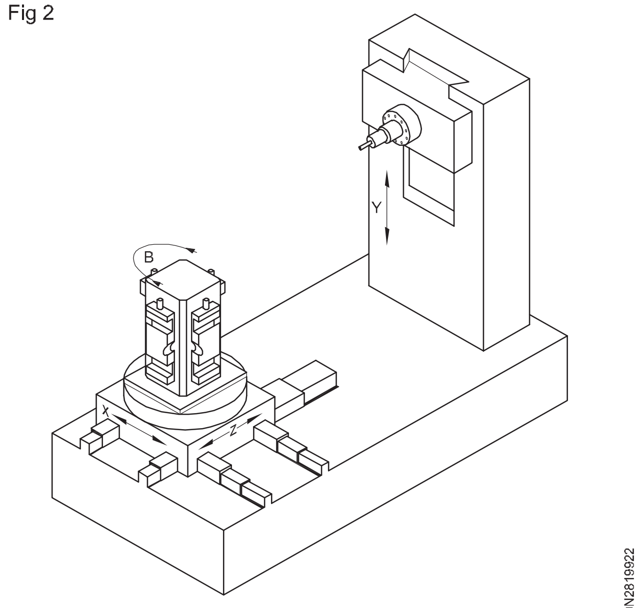
For programming two types of systems are followed. In one type programming always takes place form the view point of the spindle, not the operators eye, view as if looking straight down at 90° towards the machine, for development of the tool motion.

In the second type, various markers located some where in the machine itself, show the positive and negative motion of the machine axes. For programming,these markers should be ignored. The programming directions are exactly opposite to the markers on the machine tool.

Horizontal machining centers (Fig 2)

Horizontal CNC machining centres are also categorized as multi - tool and versatile machines, and are used for cubical parts, where the majority of machining has to be done on more than one face in a single setup.

Fig 2



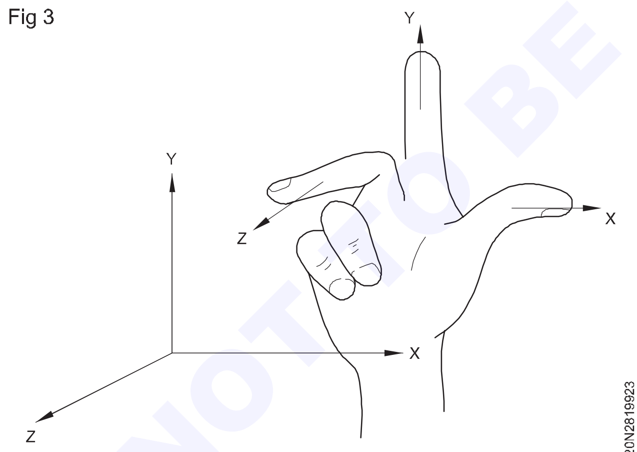
HMC SHOWING THE AXIS DIRECTIONS

There are many applications in this area. Common examples are large parts, such as pump housings, gear cases, manifolds, engine blocks and so on. Horizontal machining centres always include a special indexing table and are typically equipped with a pallet changer and other features.

Axis - nomenclature

The basic designation of the axis (i.e.), in Fig 3 which is X, Y, Z, is decided by the right hand thumb rule and the main spindle axis. The thumb indicates X - axis, fore finger indicates Y - axis and the middle finger indicates Z - axis.

Fig 3



RIGHT HAND THUMB RULE

Auxillary axes on NC machine

Apart from each side movement axes on the machine, some other auxillary axes can exist. E.g. Rotary table. This rotary table axis is designed as A axis if it is parallel to X direction. Similarly B and C axes for Y and Z respectively.

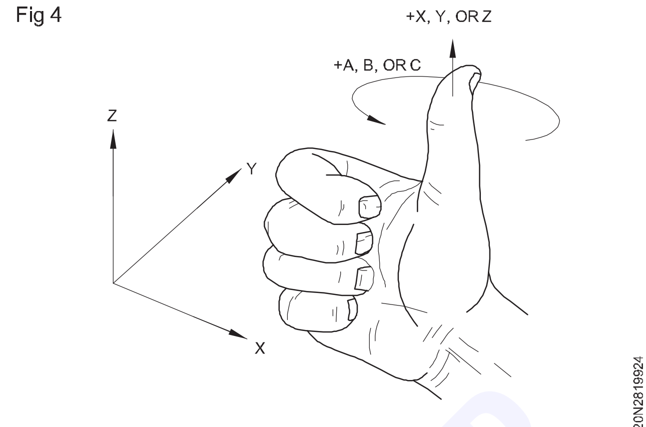
Right hand rule

The rotary movements about X, Y and Z are designated as A, B and C respectively. The right hand rule is used to define the positive direction of the coordinate axes as per the Fig 4.

Z - axis (Fig 5)

The axis of the main (i.e. principle) machine spindle,

Fig 4

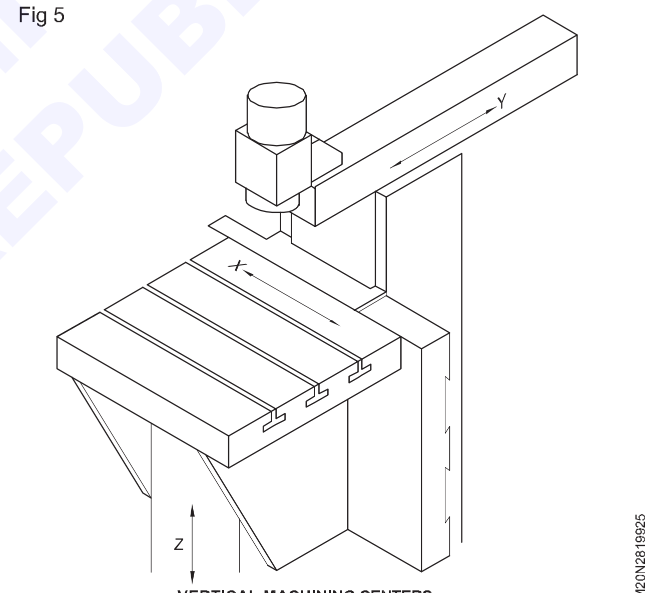


RIGHT HAND RULE

whether it be the axis of the tool spindle or the axis about which the work piece rotates, is denoted as the Z axis. On machine tools, which do not possess principle spindle (e.g. planning machines) the Z - axis is perpendicular to the work holding surface.

X - axis

Fig 5



VERTICAL MACHINING CENTERS

The X - axis is always horizontal, parallel to the work holding surface and perpendicular to the z - axis.

Y - axis

The Y - axis is perpendicular to both Z and X axis.

Milling tool coordinate system (Fig 6)

Classification of machines.

CNC machines can be classified by various ways,

a) According to number of axis

CNC machine can be classified as

- 2 axis machine

- 3 axis machine
- 4 axis machine

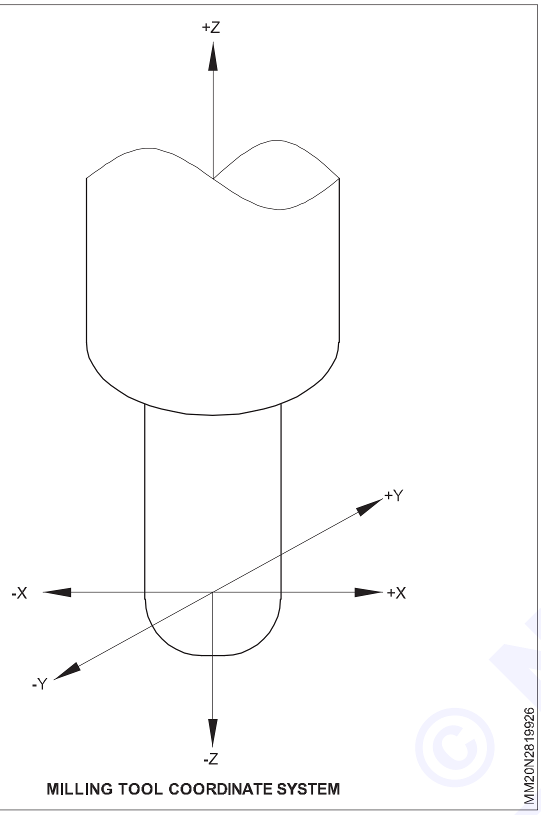
It should be noted that each axis has it own drive motor.

b) According to CNC system

There are three types of CNC systems based on their capability in providing feed in different axes.

- 1 Point -to- point control

Fig 6



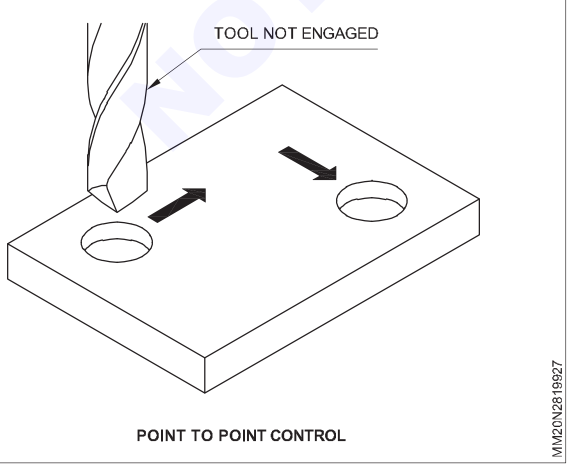
MILLING TOOL COORDINATE SYSTEM

- 2 Straight cut control
- 3 Contouring control

Point-to-point control

Machines with point-to-point control provide only one feed axis while the other two axes can perform only rapid motion. Machines with point-to-points control are suited only for drilling operations. (Fig 7)

Fig 7

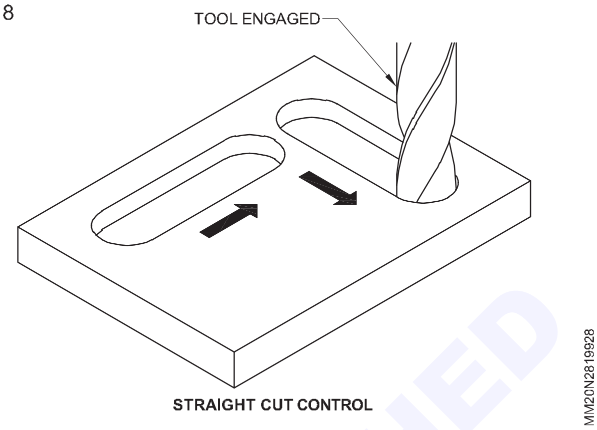


POINT TO POINT CONTROL

Straight cut control

The system provides feed motion in two axes (but not simultaneously) and hence their capability is limited to performing milling either along X axis or along Y axis. (Fig 8)

Fig 8



STRAIGHT CUT CONTROL

Contouring control

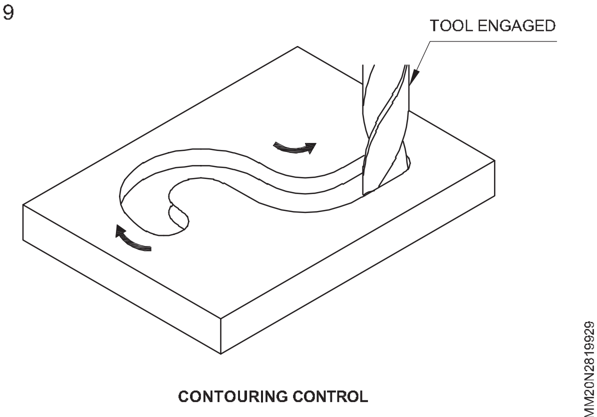
This can provide feed control in 3 axes. They are also capable of providing simultaneous feed in 2 or 3 axis.

Milling machine with contouring control can mill contours made up of straight lines and arc/circular elements.. Depending on the number of axes that can be simultaneously fed, contouring controls are further classified as 2D control, 2 1/2D control and 3D control.

i 2D control

Machines with 2D control can be simultaneous feed only in two of the 3 axes. They can mill only contours with constant depth that too in just one plane (X-Y) (Fig 9 & 10)

Fig 9

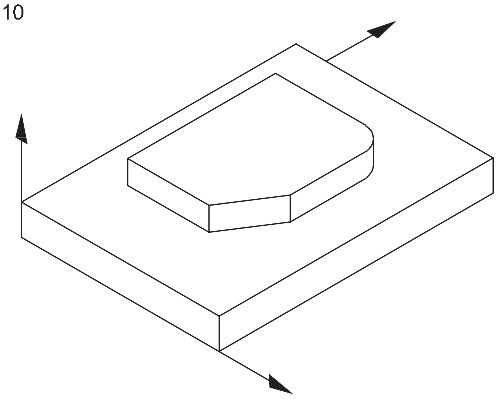


CONTOURING CONTROL

ii 2 1/2D control

Machines with 2 1/2D control can have simultaneous feed of any of the two axis X-Y, X-Z,Y,Z and, hence they can mill contours (of constant depth) in any one of the 3 planes. (Figs 11 & 12)

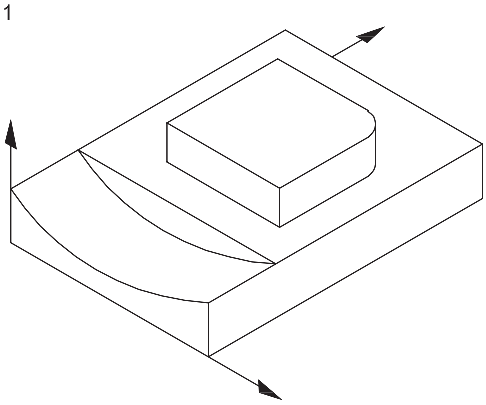
Fig 10



2-D CONTOURING CONTROL

MM20N281992A

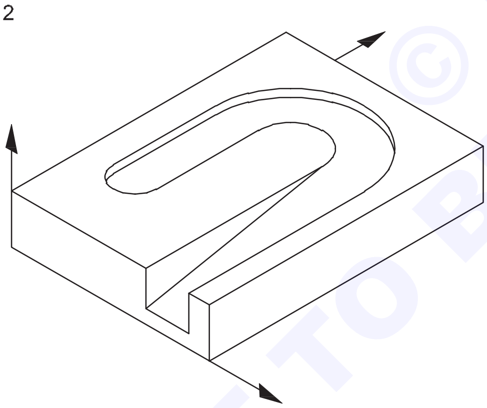
Fig 11



$2\frac{1}{2}$-D CONTOURING CONTROL

MM20N281992B

Fig 12



3-D CONTOURING CONTROL

MM20N281992C

Machine axis identification

NC coordinates system

All the NC machine toolmaker's use of Cartesian coordinate system for the sake of simplicity. The guiding coordinate system followed for designating the axes is the well known as right hand coordinate system.

Designation of axes

First axes to be identified is the z axis .This is then followed by x and y axes respectively. (Fig 13)

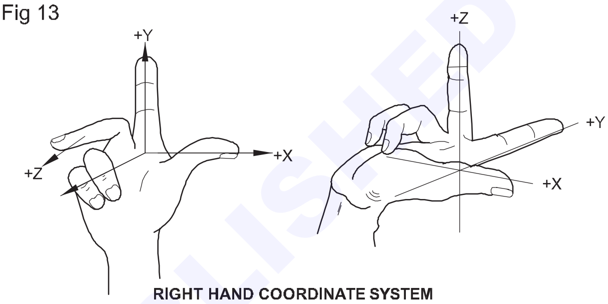
Part programming for turning centers

Diameter programming

The dimensioning of a turned component is generally specified by its diameters. However, in turning operation, the tool should approach the work piece in radial direction for matching. Hence, for the sake of simplicity, most of the turning centers are provided with diameter programming facility.

This means that all the movements of the tool along X-axis should be doubled to represent the diametral rather than radial movement. The selection of radius or diameter programming depends upon the system variable set during the integration of controller with the machine tool.

Fig 13



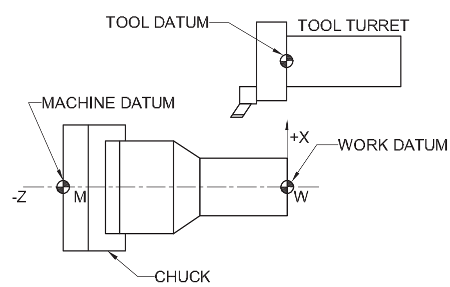
RIGHT HAND COORDINATE SYSTEM

MM20N281992D

Axis system(Fig 14)

In turning centers, the spindle axis is designated as Z. The radial axis perpendicular to the z-axis and away toward the principle tool post is termed as x-axis .The machine datum or home position may be the intersection of spindle axis and clamping plane. At the start, the controller display will show the axis position with respect to home The work piece datum is fixed by the programmer on the work piece for the convenience of part programming. The difference between the tool tip position and the turret datum is termed as offset.

Fig 14



AXES SYSTEM USED IN TURNING CENTRES

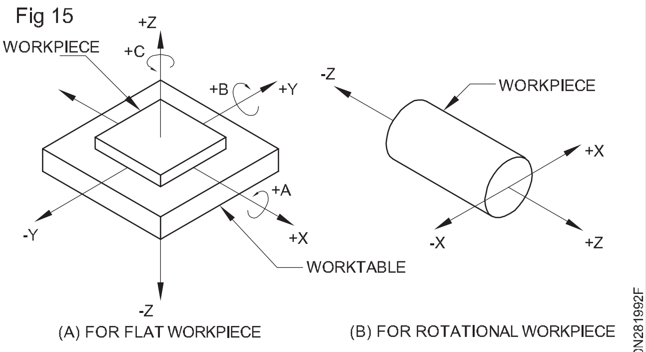
MM20N281992E

Z-axis

The z-axis motion is along the spindle axis or parallel to the spindle axis. In the case of machine without a spindle such as shapers and planers, the z-axis is perpendicular to the work holding surface.

For machines such as milling, drilling and lathe, the cutting tools move in the negative z direction to move a tool into the work piece. The positive z motion increases the clearance between the tool holder and work piece surface.

Fig 15



DESIGNATION OF AXES

When there are several spindles and slide ways, the spindle perpendicular to the work holding surface may be chosen as the principle spindle. The primary Z motion is then related to the primary spindle. The tool motions of other spindles or slides, designated as U, V, W and P, Q, R respectively.(Fig 15)

X-axis

The principle motion direction of cutting tool on the work piece is designated as x-axis .It is perpendicular to the z-axis and should be horizontal and parallel to the work holding surface whenever possible.

Reference points of CNC machines

Objective: At the end of this lesson you shall be able to
- **explain the features of reference point applied in CNC machine tools.**

Zero and reference points on CNC machine tools

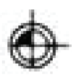
Reference zero points are the base or starting points that are chosen as the reference for calculating the coordinates of the other points. Also, reference zero points are called the zero points. CNC controls use the following zero points to facilitate the programming of tool paths.

M Machining reference zero point

W Work part zero point

R Relative point

Machine zero point


M

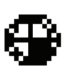
The machine zero point is the origin of the machine coordinate system. It is set by the machine tool manufacturer and cannot be changed.

The machine zero is labelled with an M and represented by the symbol shown above.

Normally the machine zero is not directly used as the reference point for writing part programs. It may be used in one of the following three applications.

- Initial set - up of the machine.
- As the reference point for other reference points such as reference return points, work zeros, and program zeros.
- As the tool change position.

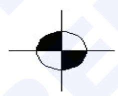
Work part zero point


W

A work part zero point is the origin of the work piece's coordinate system. It is used to determine the work's coordinate system in relation to the machine zero point. The work zero points are often referred to as set - up points because they are the location for setting up the workpiece on the machine table. Some CNC controls allow the use of multiple work zero points in one machine set up or operation. The work zero point is labelled by W and represented by the symbol above.

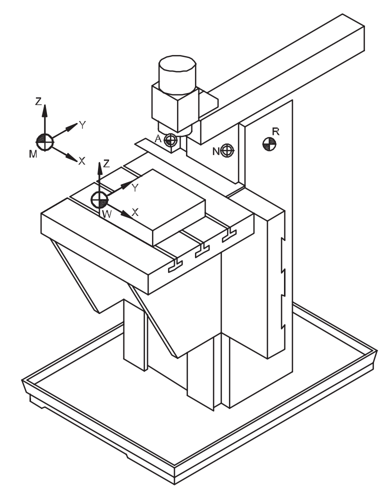
The work zero point can be chosen by the programmer at any convenient location within the working envelope of the machine. It is recommended that you place the workpiece zero point in a way that it can be easily located and measured on the workpiece.

Reference return point


R

In Fig 1 reference return points are the locations to which the machine table or the spindle is returned. They are identified by the letter R and are represented by the above symbol.

Fig 1



REFERANCE RETURN POINT

The location of the first reference return point is precisely predetermined in each moving axis in relation to the machine zero point. Because of this, it can be used for calibrating and regulating the measuring system of the slide table and spindle.

Specifically, the reference point is used in four situations

- When the control is powered up, all axes always must be positioned at the reference return point to calibrate the measuring system.
- The machine must be re-positioned to the reference return point for re-establishing the proper coordinate value in situations such as losing the current position data due to electrical failure or improper operation.
- All axes must be retracted to the reference point before the tool change can take place.
- At the end of the program, all axes must be retracted to the reference return point to reset the control system for re - running the part program or running a new program.

Absolute and incremental programming

Objectives: at the end of this lesson you shall be able to
- **understand absolute programming method**
- **understand conversion of part dimensions in absolute method.**
- **understand Incremental programming method.**
- **understand conversion of part dimensions in incremental method.**

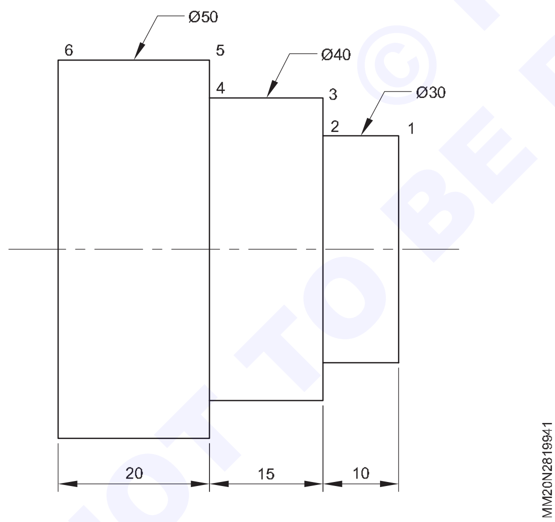
Programming method

In CNC for programming in Lathe, Absolute Command and Incremental Command are available.

Absolute method (Fig 1)

In absolute dimensions programming, all the points of the tool is coming from the datum point (or) zero point. In CNC Lathe machines "X" and "Z" is the absolute input. The "X" means diameter of work piece and the "Z" means distance from the finished end surface of work piece.

Fig 1



All the travel commands for tool are mean their co-ordinate value from the work piece zero point (XO, ZO).

position	x	z
1	30.0	0.0
2	30.0	-10.0
3	40.0	-10.0
4	40.0	-25.0
5	50.0	-25.0
6	50.0	-45.0

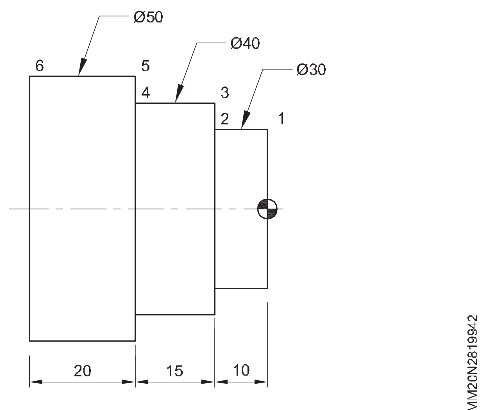
In the above figure, points 1 to 6 can be specified as follows in absolute dimension programming.

Incremental method (Fig 2)

In this system, tool move from the previous point. In the incremental programming the address "U" (diametrical) for "X" axis and the address "W" for "Z" axis are used to distinguish incremental program from the absolute program.

The incremental command should have the direction (+/ -) and distance from currently specified point to next command point.

Fig 2



In the Fig 2 the points, 1 to 6 can be specified as follows in incremental dimension programming.

position	x	z
1	30.0	0.0
2	0.0	-10.0
3	10.0	0.0
4	0.0	-15.0
5	10.0	0.0
6	0.0	-20.0

Part programming

Objectives: At the end of this lesson you shall be able to
- **define the part programming**
- **state the purpose of preparatory (G codes) & Miscellaneous function (M codes)**
- **develop the part programming.**

Part programming

Definition wise "the part program is a sequence of instructions which describe the work which has to be done on a part, in the form required by a computer under the control of an NC computer program".

Actually, part programming for NC production consists of the collection of all data required to produce the part, the calculation of the tool path etc. in a standard format. The methods of part programming can be of two types depending upon the two techniques employed to produce a punched tape

- Manual part programming
- Computer aided part programming.

Manual part programming

In manual part programming, the data required for machining, is written in a standard format known as program manuscripts. Each horizontal line in a manuscript represents a 'block' of information.

Computer aided part programming

If the component requires a great deal of machining such as in case of milling machines or contouring applications, calculation of cutter paths requires more calculations and sometimes if a machining centre is used then selecting different tool for drilling, tapping, boring and milling makes all this part programming more tedious and time consuming. More mistakes are also likely to occur Thus, we use general purpose computer as an add, to reduce labour involved in part programming. Also one of the high level.

Language such as APT (Automatically Programmed Tools), ADAPT, SPLIT, 2CL, romance, auto stop is used for writing a computer programme.

Procedure for developing manual part program

The part programming requires an NC programmer to consider some fundamental elements before the actual programming steps of a part takes place. The elements to be considered are as follows.

Types of dimensioning system

- Axis designation
- NC words
- Standard G and M Codes
- Tape programming format
- Machine tool zero point setting

Type of dimensioning

After deciding what NC machines is best suitable and available for the application, we determine what type of dimensioning system "he machine uses i.e., whether an absolute or incremental dimensional system. (Explained in previous chapter).

Axis designation

Another consideration is designation the axis of the machine tool. In most cases the programmer already known this fundamental element when he select the NC machine tool for his job. The most important factor in axis designation is the location and position of the spindle.

The part programmer also determines how many axes are available on machine tool i.e. X, Y, Z, a, bar c and so on. Also whether machine tool has a continuous path and point to point control system.

NC words

In order to understand the language of NC information processing the following definitions should be understood

A 'bit' is the basic unit of information represented by either the absence or the presence of a hole punched on the tape. Bit is an abbreviation of "Binary digit", which can be '0' or'1'.

A code or character is the series of combination of '1' s and '0' s. It represents a number of an alphabet or any symbol.

An NC word is a unit of information, such as a dimension (e.g. X01 000 or Y1 0025) or feed rate (e.g. F1000 and so on.

A block is a collection of complete group of NC words representing a single NC instruction (e.g. N1G01 X100 Z100 F100). An end of block (EOB) symbol is used to separate the blocks.

Block number/sequence number (N - words)

Each block of the program has a sequence number which is used to identify the sequence of a block of data in it which is in ascending numerical order. This enables the operator to know which sequence of block is being preformed practically by the tool. It consists of a character 'N' followed by a three digit number raising from '0' to '999'.

Preparatory functions (G - words)

The preparatory function is used to initiate the control commands, typically involving a cutter motion i.e. it prepares the MCU to be ready to perform a specific operation and interpret, the data which follows the way of this function. It is represented by the character ‘G’ followed by a two digit number i.e. ’00 to 99’. These codes are explained and listed separately.

Dimension words (X,Y and Z words)

These dimension words are also known as ‘co - ordinates’. Which give the position of the tool motion. These words can be of two types.

Linear dimension words

- X,Y,Z for primary or main motion.
- U, V, W for secondary motion parallel to X, Y, Z axes respectively.
- p, q, r for another third type motion parallel to X, Y, Z axes respectively.

Angular dimension words

- a, b, c for angular motion around X,Y, Z axes respectively.
- I,J, K in case of thread cutting is for position of arc centre, thread lead parallel to X, Y, Z axes.

These words are represented by an alphabet representing the axes followed by five or six digits depending upon the input resolution given.

Feed rate word (F - word)

It is used to program the proper feed rate, to be given in mm/ min or mm/rev as determined by the prior ‘G’ code selection G94 and G95 respectively.

It is represented by ‘F’ followed by three digit number e.g. F100 represents a feed rate of 100 mm/ min.

Spindle speed/cutting speed word (S) - word)

It specifies the cutting speed of the process or the rpm of spindle. It is also represented by ‘S’ followed by the three digit number. If the speed is given in meter per min. Then the speed is converted in rpm rounded to two digit accuracy, e.g. S - 800 represents the 800 rpm of spindle.

Tool selection word (T - word)

It consists of ‘T’ followed by max five digits in the coded number Different numbers are used for each cutting tools. When the T number is read from the tape, the appropriate tool is automatically selected by ATC (Automatic Tool Changer). Hence this word is used only for machines with ATC or programmable tool turret. e.g. T01, T02, T03…….. represents the tool selection word.

Miscellaneous words (M - words)

It consists of character M followed by two digit number representing an auxiliary function such as turning ON/ OFF spindle, coolant ON/OFF.

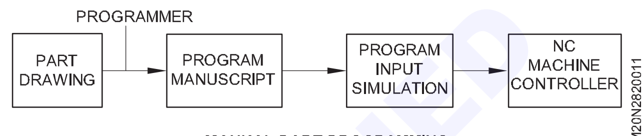
End of Block (EOB)

It identifies the end of instruction block.

G and M codes (G, codes)

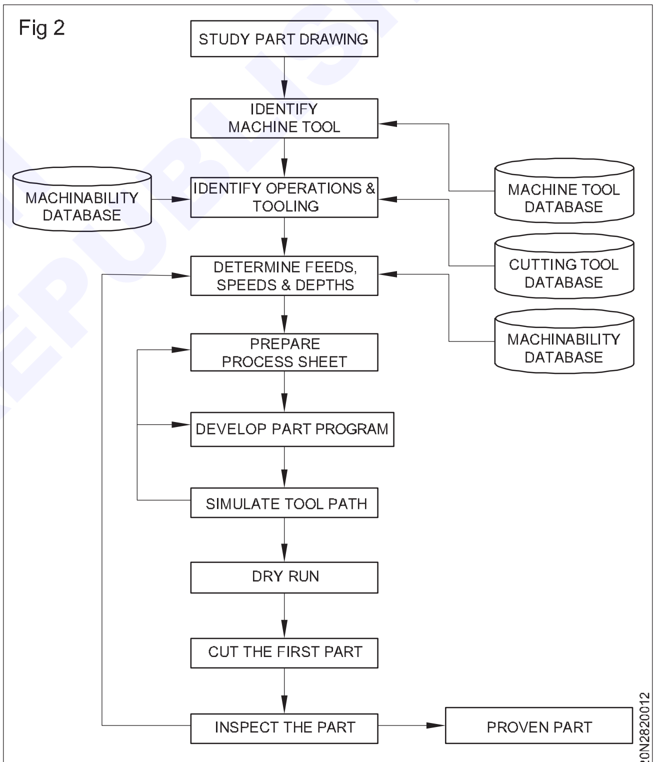
This is the preparatory function word, consists of the address character G followed by a two digit code number, known as G - code. This comes after the sequence number word and a tab code. There are two types of G - codes model and non - model. Model codes remain active until cancelled by a contradictory and code of same class. E.g. G70 is a model code which defines that the dimensional units are metric. It will remain active until cancelled by G - 71, which tells that the dimensional units are in inches now. Non - model G codes are active only in the block in which they are programmed. G04 is non- model code.

Fig 1



MANUAL PART PROGRAMMING

Fig 2



CNC PROGRAM PROCEDURE

CNC program procedure (Figs 1 & 2)

The following are the steps involved in the development of a part program and its proving.

Process planning: The programmer carryout a careful study of part drawing to prepare the process plan. It includes the following

- Machine tools used
- Fixtures required
- Sequence of operations
- Cutting tools required
- Process parameters

Axes - selection: The reference axes should be chosen so that the coordinates for various features can be determined easily.

Tool selection: Various tools are feasible for a given operation, but some of them would be more economical than others So it is essential to chose the right tool for the job.

Cutting process parameters planning: For a given tool and the operation, the appropriate process parameters such as speed, feed and depth of cut are to be selected. These may be taken from the handbooks supplied by the cutting tool manufacturer or based on the shop experience.

Job and tool setup planning: The initial position of job and tool are defined carefully.

Tool path planning: A careful planning of the tool path ensures that the required manufacturing specifications are achieved at the lowest cost.

Part program writing: This involves the actual writing of the part programs undertaking the format and syntax restrictions into account

Part program providing: Once the part program is created, ‘it should be verified before it can be loaded on the machine controller for the manufacture of the component. A trial run can be carried out with or without the tool or work piece to enable visualization of movements taking place, and any collision possible between the tool, the work piece and the clamping device.

Definition of character, word and block

Bit: A binary digit is called a bit. In includes 0 or 1. In punched tape, the values 0 or 1 are represented by the absence or presence of a hole in a certain row and column position.

Character: A character is formed from a row of bits. A character is a combination of bits representing a numerical digit (0 to 9), an alphabetical letter (A - Z and a - z), or a symbol.

Word: Award is formed from a sequence of characters. A word specifies a detail about the operation, such as X - position, Y - position, feed rate, or spindle speed.

Block: A block is formed from a collection of words. A block is one complete NC instruction. It specifies a destination for the move, the speed and feed of the cutting operation, and other commands that determine what the machine will do.

Block format

The order in which words appear in a block of instruction is called the format. The following are the block formats used in NC programming.

Fixed sequential format: This formal was used on many of the first commercially available NC machines. Each instruction block contain five words in only numerical data and in a very fixed order.

Example

00100703003

00200706003

Fixed sequential format with tab ignored: This is the same as the fixed sequential format except that TAB codes are used to separate the words for easier reading.

Example

001	00	70	30	03
002	00	70	60	03

Tab sequential format: This is same as fixed sequential format with tag ignored except that words with the same value as in the preceding block can be omitted in the sequence.

Example

001	00	70	30	03
002	00		60	

Word address format: This format uses a letter prefix to identify the type of word. Repeated words can be omitted. The words run together, which makes the code difficult to read.

Example

N001G00X70Y30M03

N002Y60

Word address format with tab separation and variable word order: This is the same format as word address format except that words are separated by TAB, and the words in the block can be listed in any order. It is the block format used on all modern CNC controllers.

Example

N001 G00 X70 Y30 M03

N002 Y60

Structure or format of a part program

The complete part program for a given component consists of a beginning code of %. A part program consists of large number of blocks each representing an operation to be carried out in the machining of the part. The words in each block are usually given in the following order.

- Sequence number (N - word)
- Preparatory word (G - word)
- Coordinates (X -, Y-,Z- words for linear axes; A-, B-,C- words for rotational axes)
- Feed rate (F -word)
- Spindle speed (S - word)
- Tool selection (T·· word)
- Miscellaneous command (M - word)
- End - of - block (EOB symbol)

The structure of part program used in fanuc controller is given below. .

%; (program start)

03642 (program number)

N010

Blocks ....

N100 M02; (program end)

M30 (program rewind)

Program number

Each of the program that is stored in the controller memory requires an identification. It is used while running and editing of the programs directly from the control console. This identification is specified in terms of a program number with 0 word address. The number can be a maximum off our digits.

Sequence number (N - word)

Each block in a part program always starts with a block number, which is used as identification of the block. It is programmed with a N word address.

Coordinate function

The coordinate values are specified using the word address such as X,Y, Z, U, V, W, I, J, K, etc. All these word addresses are normally signed along with decimal point depending upon the resolution available in the machine tool.

Comments

Parentheses are used to add comments in the program to clarify the individual functions that are used in the program. When the controller encounters the opening parenthesis, it ignores all the information till it reaches the closing parenthesis.

Example

N010 GOO Z50 M05 (Spindle stops and rapidly moves up) Table - common word addresses used in word address format

Address	Function
N	Sequence number to identify a block.
G	Preparatory word that prepares the controller for instruction given in the block.
X,Y,Z	Coordinate date for three linear axes.
U,V,W	Coordinate data for incremental moves in turning in the X, Y and Z directions respectively
A,B,C	Coordinate data for three rotational axes X, Y and Z respectively.
R	Radius of are, used in circular interpolation.
I,J,K	Coordinate values of arc centre, corresponding to X,Y and Z-axes respectively.
F	Feed rate per minute or revolution in either inches or millimeters.
S	Spindle rotation speed.
T	Tool selection, used for machine tools with automatic tool changer or turrets.
D	Tool diameter word used for offsetting the tool.
P	It is used to store cutter radius data in offset register. It defines first contour block number in canned cycles.
Q	It defines last contour block number in canned cycles.
M	Miscellaneous function.

G - codes and M - codes

Objective: At the end of this lesson you shall be able to
- **Identify various 150G codes and M Codes for CNC turning.**

Modal and non - modal G - codes

Some of the G - codes are modal, which means that they behave as settings to the control. Once given they remain operational till cancelled by another G codes from the same group. A few other G - codes are non - modal, which means that they remain operational in the block in which they are programmed.

For example, G20 (Inch input) is a modal command, which can be cancelled by G21 (Metric input) command.

Table G codes

Number	Operation	Definition
G00	Point - to - point positioning	Point - to - point positioning at rapid rate.
G01	Linear interpolation	A mode of contouring control to produce a straight line in which the velocity is held constant.
G02	Arc clockwise (Two - dimensional)	An arc generated by the coordinated motion of two axes in which curvature of the path of the tool with respect to the workpiece is clockwise.
G03	Arc counterclockwise (Two - dimensional)	An arc generated by the coordinated motion of two axes in which curvature of the path of the tool with respect to the workpiece is counterclockwise.
G04	Dwell time	A time delay programme used in drilling operation.
G06	Parabolic interpolation	A mode of interpolation used to produce a segment of a parabola. Velocities used to generate this curve are varied by the control.
G08	Acceleration	The velocity increase to programmed rate starting immediately.
G09	Deceleration	The velocity decrease to a fixed percent of the programmed rate starting immediately.
G13 - G16	Axis selection	Used to direct the axis or axes as specified by the format.
G17 - G19	Plane selection	Used to identify the plane for functions like circular interpolation cutter compensation and others as required.
G33	Thread cutting with constant lead	Mode selection for machines equipped to perform thread cutting.
G34	Thread cutting with increasing lead	Mode selection for machines equipped for thread cutting when a constantly increasing lead is desired.
G35	Thread cutting with decreasing lead when a constantly decreasing lead is desired.	Mode selection for machines equipped for thread cutting
G40	Cutter radius compensation/offset	Command which will cancel any cutter radius compensation/off cancel set.
G41	Cutter radius compensation left	Cutter will be on left side work surface looking from
		Cutter in the direction of relative cutter motion with dis placement normal to the cutter path to adjust for the difference between actual and programmed cutter radius or diameters.
G42	Cutter radius compensation right	Cutter will be on right side of work surface looking from cutter in the direction of relative cutter motion with displacement normal to the cutter path to adjust for the difference between actual and programmed cutter radius.
G43	Cutter offset inside corner	Displacement normal to cutter path to adjust for the difference between actual and programmed cutter radii or diameters. Cutter will be on inside corner.
G44	Cutter offset outside corner	Displacement normal to cutter path to adjust for the difference between actual and programmed cutter radii. Cutter will be on outside corner.
G50 - G59	Adaptive control	Reserved for adaptive control requirements.
G70	Inch programming	Made for programming in inch units. It is recommended that control turn on establish this mode of operation.

Number	Operation	Definition
G71	Metric programming	Mode or programming in metric units. This mode is cancelled by G70, M02 and M30.
G72	Arc clockwise (three dimensional)	An arc generated by the coordinated motion of three axes in which the arc of the tool path with respect to the workpiece is anticlockwise.
G73	Arc counter clockwise (three dimensional)	An arc generated by the coordinated motion of three axes in which the arc of the tool path with respect to the workpiece is counterclockwise.
G72 - G73	Circular interpolation (three dimensional)	A mode of contouring control used to produce an arc on a sphere. The velocities used to generate this arc are varied by the control.
G75	Multiquadrant circular	Mode selection required for multiquadrant circular cancelled by G74.
G80	Cancel cycle	Commanded that will cancel any of the fixed cycles G81- G89.
G81 - G89	Fixed cycle	A preset series of operations which direct machine movement and/or cause spindle operation to complete operations like boring drilling, tapping, etc.
G90	Absolute mode	A control mode in which the inputs given is in absolute dimensions.
G91	Incremental mode	A control mode in which the input is in given incremental data.
G92	Preload of registers	Used to preload registers to desired values. No machine operation is initiated. Examples would include preload of axis position registers, spindle speed constraints, initial radius, etc. Information within this block shall conform to the character assignments of the preceding table.
G93	Inverse time feed rate	The data following the feed rate address is equal to the reciprocal of the time in minutes to execute the blocks and is equivalent to the velocity of any axis divided by the corresponding programmed increment.
G94	Inches/mm per minute feed rate	The feed rate units are inches or millimeters per minute.
G95	Inches/mm per revolution	The feed rate code units are inches or millimeters per revolution of the spindle.
G96	Constant surface speed per minute	The spindle speed code units are surface feed (meters) per minute and specify the tangential surface speed of the tool relative to the workpiece. The spindle speed is automatically controlled to maintain the programmed value.
G97	Revolutions per minute or constant surface speed cancel	The spindle speed is defined by the spindle speed word.

Miscellaneous functions or auxiliary functions (M - codes)

These functions actually operate some controls on the machine tool and thus affect the running of the machine. The particular machine tool must have the function that is being called.

Miscellaneous commands are normally placed at the end of the block. The common M - codes and their functions are given in Table.

Table miscellaneous functions (M codes)

Number	Operation	Definition
M00	Program stop	A miscellaneous function command to cancel the spindle, coolant functions and terminate further program execution.
M01	Optional (Planned)	A miscellaneous function command similar to a program stop except that stop the control ignores the command unless the operator has previously vali dated the command.
M02	End of program	A miscellaneous function indicating completion of workpiece. Stops spindle coolant and feed after completion of all commands in the block. Used to reset control and/or machine. Resetting control may include rewind of tape to the end of record character or progressing a loop tape through the splicing leader.
M03	Spindle CW	Start spindle rotation in clockwise direction.
M04	Spindle CCW	Start spindle rotation in counter clockwise direction.
M05	Spindle OFF	Stop spindle in normal manner; brake if available applied; coolant turned OFF.
M06	Tool change	Stops spindle and coolant and retracts tool to full retract position. It should be coded in last block of information in which a given tool is used.
M07 - M08- M09	Coolant, ON, OFF	Mist (No.2) Flood (No.1) tapping coolant or dust collector.
M10- M11	Clamp, unclamp	Can pertain to machine slides, workpiece, fixtures, spindle, etc.
M12	Synchronization code	An inhibiting code used for synchronization of multiple sets of axes.
M15 - M16	Motion +, Motion -	Rapid traverse of feed direction selection where required.
M19	Oriented spindle stop	A miscellaneous function which causes the spindle to stop at a predetermined or programmed angular position.
M26	Pseudo tool change	Retracts tool from gage height to tool change position. Used primarily to avoid clamps or part obstructions.
M30	End of data	A miscellaneous function which stops spindle coolant and feed after completion of all commands in the block. Used to reset control and/ or machine. Resetting control will include rewind of tape to the end of record character progressing a loop tape through the splicing leader or transferring to a second tape reader.
M31	Interlock by - pass	A command to temporarily circumvent a normally provided interlock.
M47	Return to program start	A miscellaneous function which continuous program execution from the start of program unless inhibited by an interlock signal.
M49	Over ride by - pass	A function which deactivates a manual spindle or feed override and re turns the parameters to the programmed value. Cancelled by M48.
M59	CSS by - pass	A function which holds the RPM constant at its value when M59 is initiated/updating cancelled by M58.
M90 - M99	Reserved for user	Miscellaneous function outputs which are reserved exclusively for the machine user.

CNC control system & machining operations and tool path

Objectives: At the end of this lesson you shall be able to
- **explain about feedback system**
- **state the closed loop and open loop control**
- **define the interpolation**
- **state the purpose of interpolation**
- **explain various interpolation used in CNC lathe.**

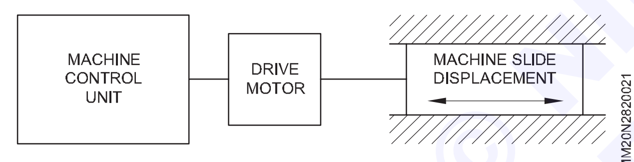
Feedback system

- The feedback system is also referred to as the measuring system.
- It uses position and speed transducers to continuously and monitor the position at which the cutting tool is located at any particular instant.
- The MCU uses the difference between reference signals and feedback signals to generate the control signals for correcting position and speed errors. (Fig 1)

Open loop control system (Fig 1)

In an open loop control system (Fig 1) in which there is no arrangement for detecting or comparing the actual position of the cutting tool on the job with the commanded value.

Fig 1



Therefore, this system is not providing any check to see that the commanded position has actually been achieved There is no feedback of information to the control also These systems are not good where extremely accurate positioning is required.

Closed loop control (Fig 2)

Closed loop control (Fig 2) is a term which is used very often when we talk about CNC machines. This term signifies, that the control system has provisions to ensure that the tool reaches the desired position, at the correct feed rate, even if some errors creep in due to unforeseen reasons.

For instance, in the previous example 60,000 pulses sent in 2 minutes by the control should cause a tool travel of 60 mm at 30 mm/min, but even if the control sends these may pulses it cannot be ensured that the tool has really travelled exactly 60 mm.

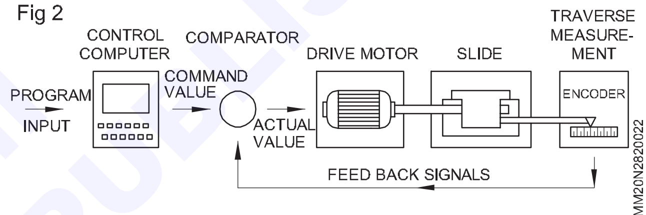
A closed loop control has a device called encoder and this can continuously ascertain the distance actually travelled by the tool and then monitor the same, in the form of feedback signals to the control. The control studies this feedback information and takes corrective action in case any error is detected in the tool position/ feed rate.

Interpolation

As the co-ordinates of points on the profile of the job vary continuously, it is necessary to define the path of small segment.

This tedious work is done by the computer by means of "interpolator".

Fig 2



Definition

The methods by which control system calculate the intermediate points and the speed of the motor is known as interpolation.

The parameters supplied may be

1 Radius
2 Start and end point of a curve
3 Radius and Centre of a circle
4 Gradient angle for a line.

Types of interpolations

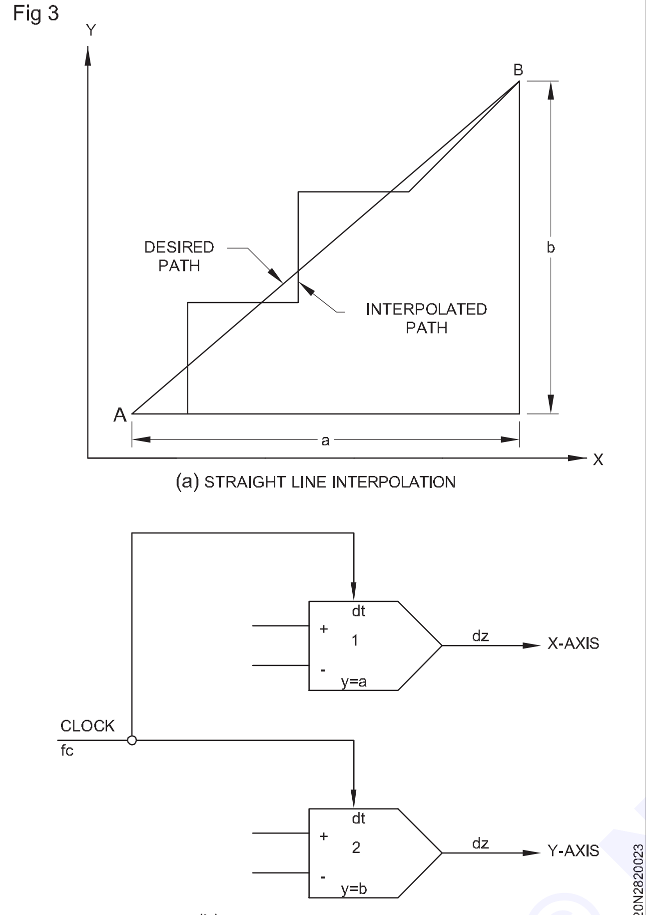
Interpolations are classified as

1 Linear interpolation
2 Circular interpolation
3 Helical interpolation
4 Parabolic interpolation
5 Logarithmic interpolation
6 Exponential interpolation of these the linear and circulate interpolators are commonly employed.

Linear interpolation

In this interpolation, the interpolated points lie on the straight line joining a pair of given points. (Fig 1a)

Fig 3



(a) STRAIGHT LINE INTERPOLATION

(b) LINEAR INTERPOLATOR

This is done in two or three dimensions.

The fast of linear interpolator is to supply velocity commands to several axes simultaneously in pps (pulses per second) (Fig 3b)

By changing the frequency of the pulses, the feed can be controlled.

The linear interpolator consists of Digital Differential Analyzer (DDA) integrators one for each axis of motion hence each integrator functions separately one for X-axis and the other for Y - axis. (Fig 4a)

Circular interpolation

In circular interpolation, the interpolated points lie on a specific circle between a pair of fixed points.

In most cases, the circular interpolation is limited to one quadrant in the machine tool system. (Fig 4b)

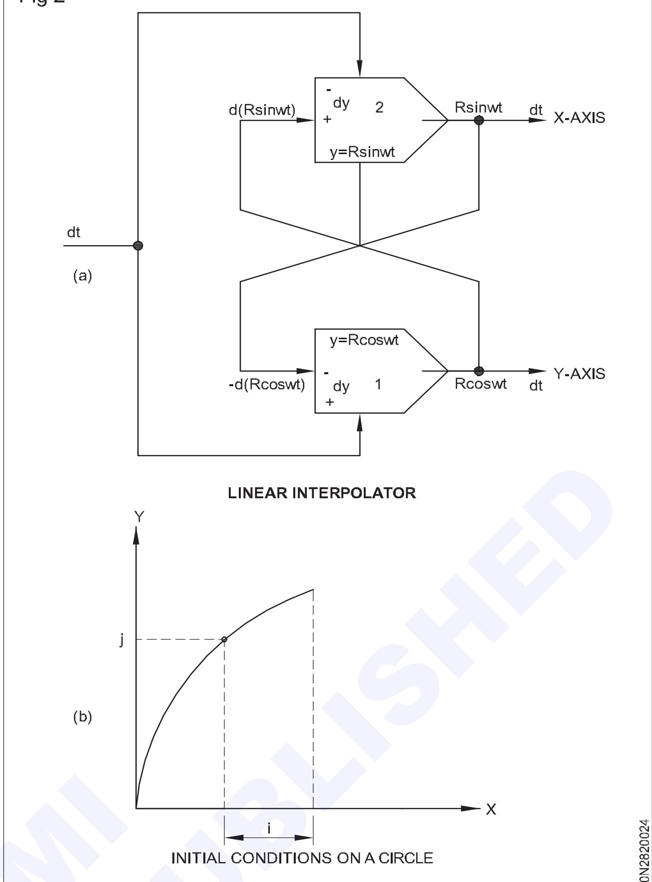
The input data should consists of the distances between the initial point and the centre of the circle.

Two Digital Differential Analyzers (DDA) are required for circular interpolation.

Advantages of circular interpolation are

Better surface finish

Fig 2



CIRCULAR INTERPOLATOR

Greater accuracy

Less total machining time

Lower working costs.

Circular interpolation

The circular interpolation

Code G02 (clockwise)

Code G03 (anti - clockwise)

A circular interpolation permits the traversing of the tool with a defined speed along a circular path from the present Start-points to the programmed destination point.

Apart from the destination points co-ordinates, the control unit here also needs statements about the sense of rotation and the centre of the circle. The centre is entered with I, J and K with incremental dimensions with the centre points as origin.

The following assignment applies

I for the X - axis

K for the Z - axis

Circular Interpolation with mixed programming

Particularly the incremental statement of the centre of the circle usually represents some difficulties to the operator in practice, since it must often be evaluated using triangle calculations.

This is a prime example of where the mixed co-ordinate programming of the interpolation parameters in absolute dimensions comes in useful.

Cutting tool materials for Turning

Objectives: At the end of this lesson you shall be able to
- **explain the properties of cutting tool**
- **state the types of tool material & its applications.**

Cutting tool materials and their properties

Tool materials are the subject of intense development. They are the product of an evolvement that has taken place almost entirely during the twentieth century, and especially since the thirties. Machining which took one hundred minutes in 1900, today takes less than one minute. It is not an exaggeration to say that the evolvement of tool materials has been one of the major contributing factors that has helped to make the modern, efficient industrial world.

Today, there is a tool material to optimize every metal cutting operation-one that will cut a certain work piece, under certain conditions in the best way. Not only have completely new materials appeared but high speed steel, which was the major break through at the beginning of the century, has been developed to machine several times faster. It is however, the introduction and continuous improvement of hard materials that have really improved metal cutting during the recent decades.

Cutting tool properties

The most important properties required by a cutting tool material are,

Toughness

Ability to withstand the various cutting forces during machining.

Hardness

Ability to retain hardness under severe working conditions.

High resistance to wear

The material must withstand excessive wear even though the relative hardness of the tool materials changes.

Frictional coefficient

The frictional coefficient must remain low for minimum wear and reasonable surface finish.

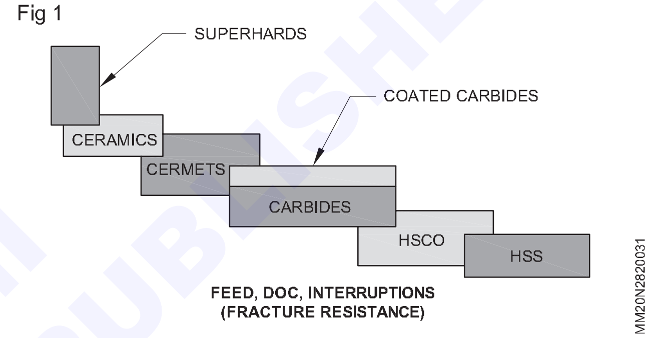
Cost and easiness in fabrication

The cost and easiness of fabrication should have within reasonable limits.

Evolution of cutting tools

- 1910-1920: High speed steel
- 1920's: Cemented carbide
- 1950's: Cermets (Tic -based)
- 1960's: Alumina-based ceramic
- 1970: CVD coated carbide
- 1980: First engineered carbide substrate (cobalt-enrichment)
- 1982: First SiAlON ceramic
- 1985: First PVD coated carbide
- Mid 80's: Modern cermets (TiCN-based)
- Late 80's: SiC whisker reinforced Al2o3 ceramic
- Early 90's: Advanced Sialons
- Mid 90's: thin film diamond coated carbide

Fig 1



- Late 90's: PVD coated PCBN
- 2000: Advanced pre-coat & post-coat treatments

Cutting tool materials

Metal cutting environment (Fig.1)

- Heat (thermal deformation)
- Pressure (deformation, fracture)
- Wear (pure abrasion, chemical wear, notching)
- Interrupted cuts (thermal & mechanical cycling)

Types of tool materials

The selection of proper tool materials depends on the type of service to which the tool is subjected. The commonly used cutting materials are:

Carbon steels

- It is basically high carbon steel with percentage of carbon in the range of 0.8 to 1.5
- It may only be used in manufacture of tools operating at low cutting speed (12m/min).
- They are comparatively cheap, easy to forge and simple to harden.
- Disadvantage of carbon tool steel is their comparatively low heat and wear resistance.

High speed steel

- It is the general purpose metal for low and medium cutting speeds owing to its superior hot hardness and resistance to wear.
- HSS can operate at cutting speeds 2 to 3 times higher than for carbon steels and retain its hardness up to 900°C.
- Tungsten in HSS provides hot hardness and form stability. Molybdenum maintains keenness of the cutting edge. Cobalt makes the cutting tool more wear resistant.

Stellites

- Stellites is the trade name of a non-ferrous cast alloy composed of cobalt, chromium and tungsten.
- The range of elements in these alloys is 40% to 48% cobalt, 30% to 35%, chromium and tungsten.
- Stellites can be operated on steel at cutting speeds 2 times higher than for HSS.
- They are used for non metal cutting application such as rubbers, plastics etc.,

Carbides

- They are composed principally of carbon mixed with other elements.
- The basic ingredient of most carbides is tungsten carbide, which is extremely hard. Pure tungsten powder, is mixed under high heat(1500°C) with pure carbon in the ratio of 94% and 6% weight.
- The two types of carbides are the tungsten and titanium and both are more wear resistant.

Coated carbides

- The coated carbide has substrate and coating layer
- Substrate-for toughness having hard material and soft material (cobalt + carbide)
- Coating -Layer of carbide (very hard)
- Perform well on all work material
- Better impact strength to resist fracture
- Allow good coating adhesion

Ceramics

- The latest development in the metal cutting tool uses aluminium oxide, generally referred to as ceramics.
- Compacting aluminium oxide powder in a mould at about 280 kg/sq.cm or more makes ceramic tools. The part is then sintered at 2200 °C. This method is known as cold pressing.
- Ceramic tool material are made in the form of tips that are to be clamped on metal shanks
- The tools have low conductivity and extremely high compressive strength, but they are quite brittle and have a low bending strength.
- They can with stand temperature up to 1200°C and can be used at cutting speeds 4 times that of carbide and up to 40 times that of HSS.
- To give them increased strength often ceramic with metal bond know as cermets is used.
- Heat conductivity of ceramics being very low the tools are generally used without coolant.

Cermets

Cermets -Ceramics and Metal

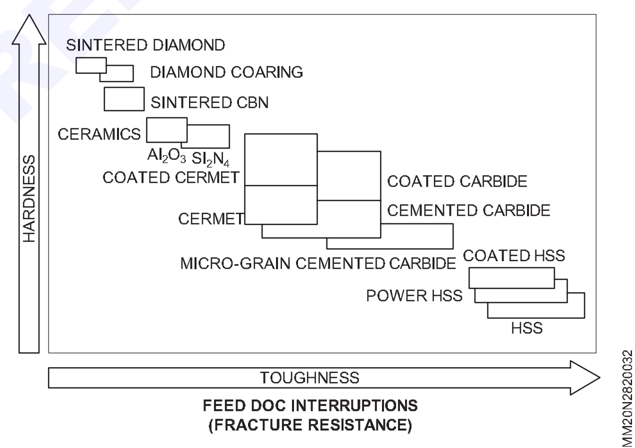
Characteristics of cermets

- High Hardness
- High Hot Hardness
- Resist oxidation
- Low Friction

Advantage of cermets

- High efficiency
- Long life
- Large batch
- Avoid Build Up Edge
- Surface Finish Control
- Cermets Have the properties of higher cutting speed and wear resistance which enables hard part turning.

Fig 2



Diamond

- The diamond is the hardest known material and can be run at cutting speed about 50 times greater than that of HSS tool and 5 to 6 times of tool life than carbide.
- Diamond is incompressible, readily conducts heat and has low coefficient of friction.
- Diamond are suitable for cutting very hard material such as glass, non-ferrous materials, plastics etc.,
- For poly crystalline diamond (PCD) the tool life is 30 times of carbide.

The following picture shows the comparison of the various materials in terms of their properties. (Fig 2)

Tool Geometry, Insert Type, Nomenclature of Inserts

Objectives: At the end of this lesson you shall be able to
- **discuss the features of tool geometry**
- **identify various tool angles**
- **state what is a negative rake angle and its features**
- **learn various types of inserts**
- **understand nomenclature of insert and ISO designation.**

Tool Geometry

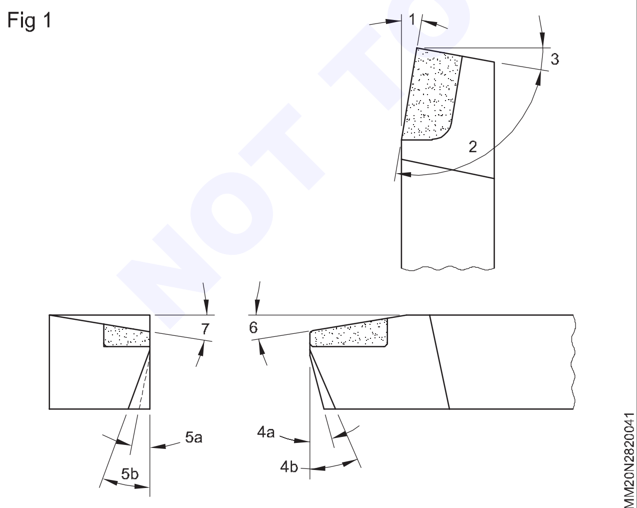
The tool geometry of cutting tool is a complicated subject. It is very difficult to determine the scope of the tool face. The straight edged tool moving with a constant velocity un the direction perpendicular to the work is known as tool geometry. The cutting tool geometry deals mainly with factors like approach angle,cutting angle, training angle, clearance angles,rake angle . The following sketches indicates various angles (tool geometry) relating to fFcinf tool,rough turning tool,finish turning tool,parting tool,boring tool. The advantages of negative rake is also explained.

The carbide turning tools generally used for various turning operations are listed below.

- Straight round nose
- Right hand and left hand roughing tool
- Facing tool
- Right and left hand knife edge tool
- Heavy duty roughing tool
- Cranked round nose tool
- Recessing tool
- Parting tool
- Screw cutting tool.

The various cutting angles provided in these tools are as follows. (Fig 1)

Fig 1



1 Approach angle
2 Cutting angle
3 Trailing angle
4a Front clearance-primary
4b Front clearance-secondary
5a Side clearance-primary
5b Side clearance-secondary
6 Top rake-negative
7 Side rake

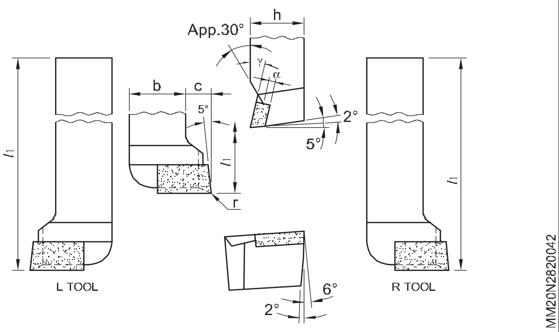
These angles for various tools are shown in the figures. (IS 2163-1973 and 2163-1976)

Generally the manufacturers of carbide tools maintain these angles while manufacturing these tools. Hence it is only needed to maintain these angles while re-sharpening.

The illustrations are as indicated below.

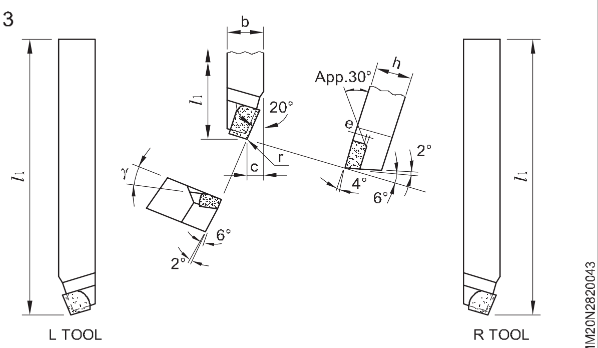
1 Facing tool (Fig 2)

Fig 2



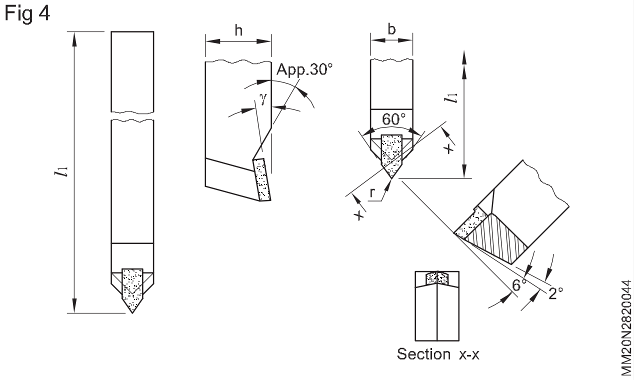
2 Rough turning tool (Fig 3)

Fig 3



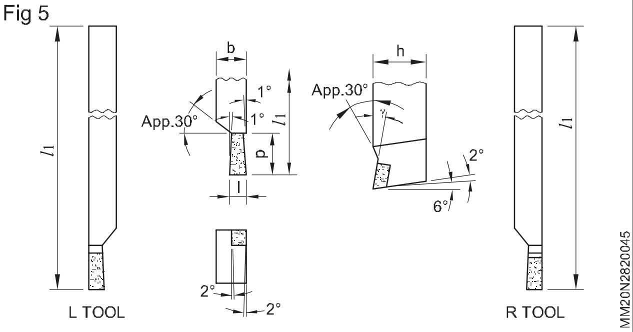
3 Finish turning tool (Fig 4)

Fig 4



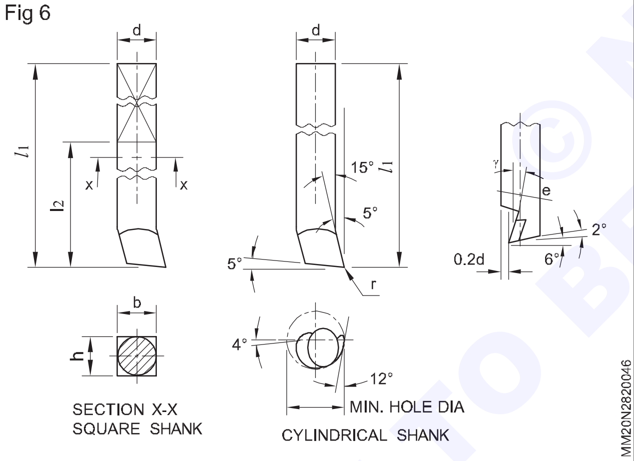
4 Parting off tool (Fig 5)

Fig 5



5 Boring tool (Fig 6)

Fig 6

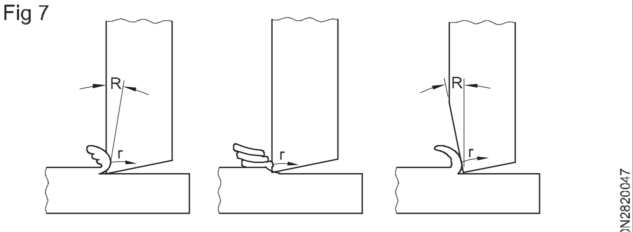


Negative rake is used in cemented carbide tip tool for rough turning.

The true rake angle is the resultant of front rake and side rake angles. The top rake may be positive, zero or negative as shown in Figure 7.

Most of the cutting tools have positive rake angles. Turning tools for brass have zero rake as the metal chips are short and do not exert excessive cutting pressure on the tool face while cutting. Zero rake increases the strength of the tool and prevents the cutting edge from digging into the work.

Fig 7



POSITIVE, ZERO AND NEGATIVE RAKE

Negative rake angle

It is used to achieve the following advantages.

– The cutting edge becomes stronger.

– It can withstand excessive compressive loads.

– The tool can be operated at higher cutting speeds.

– It decreases tool wear and increases the tool life.

– Heavier depth of cut can be given.

The limiting conditions for the applications of negative rake turning tools are:

– the machine must have a wider range of high spindle speeds

– the machine and the tool-holding devices must be quite rigid and must be free from vibrations since the cemented carbide tip may chip off under vibrations

– provision must be there for quickly dissipating the higher degree of heat generated during machining

– the power of the motor of the machine must be atleast 10 to 15% higher than that provided on machines on which positive rake tools are used under similar working conditions.

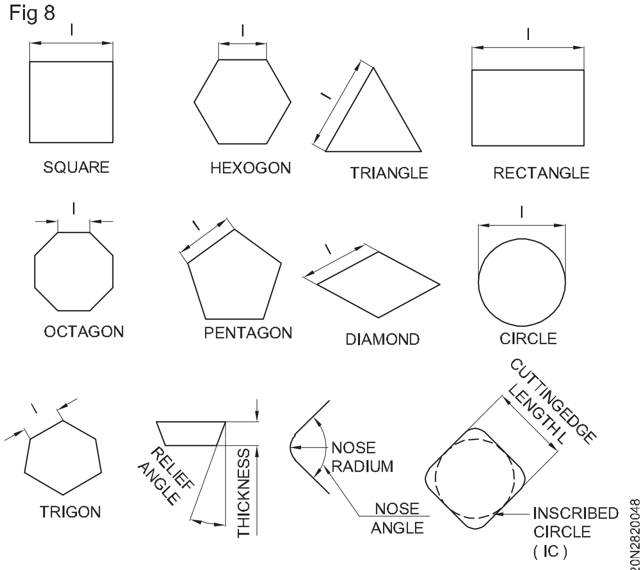
Tool inserts

Carbides and other harder tool materials are very costly. Moreover, they cannot be machined. So, only tool tips are made for such materials using powder metallurgy technique. In this method, the tool material is taken in a powder form. It is mixed with a suitable binder (in powder form) and compressed in the shape of an insert.

Inserts are available in various shapes such as triangle, square, rectangle, pentagon, hexagon, octagon, diamond shaped and circle. They cannot be resharpened, but they have a number of cutting edges. (Fig 8)

Inserts are produced in various sizes and thicknesses. Smallest possible size is chosen to produce the desired depth of cut. Thickness of an insert affects its strength. Hence, for a large depth of cut and feed, a thicker insert is chosen.

Fig 8



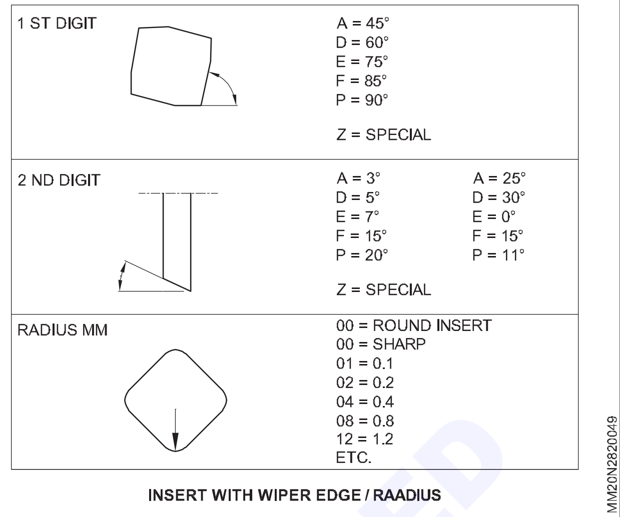
INDEXABLE TOOL INSERTS

ISO standard is commonly followed for specifying inserts. An example is CNMG120408. The first letter, C in this case , indicates the shape of the insert. The common types are:

Symbol	Shape
S	Square
T	triangular
H	hexagonal
O	octagonal
P	pentagonal
L	rectangular
R	round
A, B, K	parallelogram (nose angles 85°, 82° and 55° respectively)
C, D, E, F, M, V	Diamond shaped or rhombic (nose angles 80°, 55°, 75°, 50°, 86°, 35 ° respectively)
W	Trigon (nose angle 80°)

The second letter specifies the relief angles (Fig 9).

Fig 9



INSERT WITH WIPER EDGE / RAADIUS

Symbol	Relief Angle
N	0°
A	3°
B	5°
C	7°
P	11°
D	15°
E	20°
F	25°
G	30°

The third letter specifies tolerances on various dimensions (Fig.4) (e.g., thickness) of the insert. The different tolerance classes are A, F, C, H, E, G (absolute values) and J, K, L, M, N, U (tolerance values depend on the diameter of the inscribed circle of the insert).

Tool holders and inserts for radial grooving, face grooving, threading and drilling

Objectives: At the end of this lesson you shall be able to
- **understand the ISO designation of tool holders for CNC machine**
- **learn about various shapes of tool inserts**
- **learn about the type of clamping for tool holder**
- **understand the clearance angle and included angle of inserts.**

Tool holders

For CNC machine tool, we need special tool holders, and the conventional holders used in ordinary lathe and other machine tool may not fit. The tool holders for CNC machines are specified under ISO designation holders. It can be clamp type, screw type, locking pin via the bore etc;

The shape of the tool holder can be either straight shank type or off-set shank type. Another classification of the tool holder is Right hand (R), left hand (L) and neutral type (N) The tool holders are so designed to suit the various shapes of available inserts.

ISO designation for lathe tool holders (Contd.)

1st character	2nd character	3rd character	4th character	5th character
Insert holding method	**Insert shape**	**Tool holder style**	**Insert relief (clearance)**	**Hand**
M=top clamp and lock pin via the bore	A-85° parallelogram	A = 0° side cutting striaght shank	N = 0°	R = right -hand
P = lock pin via the bore only	B = 82° parallelogram	B = 15° side cutting cutting straight shank	A = 3°	L = left-hand
C=top clamp only	C=80° diamond	C = 0° end cutting	B = 5° straight shank	N - neutral
S=centre screw lock only	D=55° diamond	D = 45° side cutting, 45° end cutting, straight shank	C = 7°	
X = other methods	E = 75° diamond	E = 30° side cutting, straight shank	P = 11°	
	H = hexagon	F = 0° end cutting, offset shank	D = 15°	
	K = 55° parallelogram	G = 0° side cutting, offset shank	E = 20°	
	L = rectangle	H = -17.5° side cutting, offset shank	F = 25°	
	M = 86° diamond	J = -3° side cutting,offset shank	G = 30°	
	O = octagon P = pentagon	K = 15° end cutting, offset shank L = 5° side cutting, 5°end cutting, offset shank		

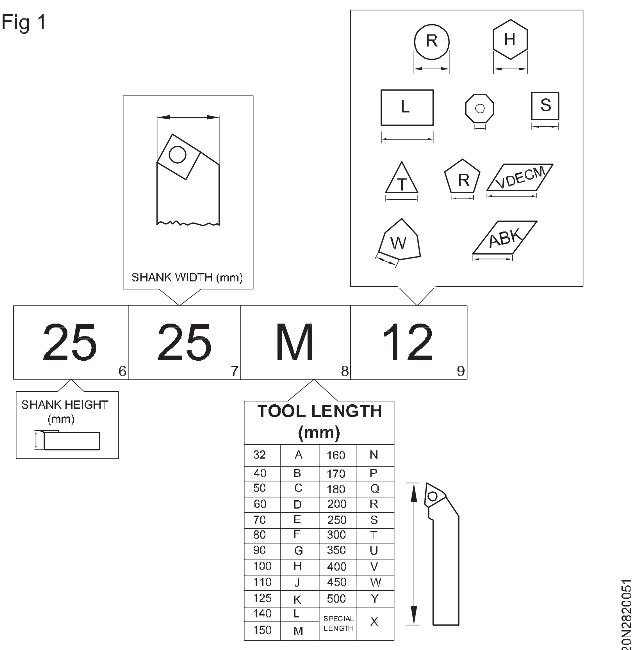
The nomenclature and ISO designation of lathe tool holder is shown in Table1.

The included angle of the tool inserts generally varies 55° to 85°. The inserts can be rectangular pentagonal, hexagonal, triangular, circular, diamond shape etc.

There is a special tool holder used in CNC machines for boring bars, Which is generally steel shank type, with a length of 350 mm, retained through central screw, with offset shank. The clearance angle for boring bar tool is around 7°.The details of boring bar is shown in

Shank height (25)	25 mm
Shank width (25)	25 mm
Tool length (M)	150 mm
Cutting edge length (12)	12 mm
Manufacturer specific information	None

Fig 1



ISO DESIGNATIOM FOR LATHE TOOL HOLDERS

CNC Simulation Process

Objectives: At the end of this lesson you shall be able to
- **understand the function of a CNC simulation**
- **learn the benefits of simulator.**

Simulation process in a CNC machine system is a program verification activity. Most of the CNC machines come with suitable simulation software installed.

This software simulates the tool movement on a graphic screen. The software first checks the program syntax.

When the program is found correct, the simulation starts.

In simulation, the dimensions of the given component is shown on the screen and the chosen tool start moving with respect to the program command. (Fig 1)

The resulting shape that will be obtained on completion of simulation represents the final size & shape of component.

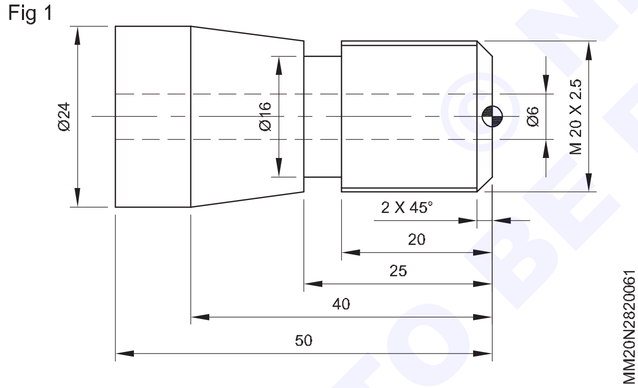
Simulation (verification of program) can be done block by block.

With this software, it is easily possible to analyse the tool path, during the turning process.

Purpose of Simulator

The purpose of CNC Simulator Pro is to provide the CNC community with a versatile Full 3D simulator with CAD/CAM capability. In the simulator you may find different type of machines like milling machines, router, lathes, cutter, 3D printer etc,.

Fig 1



It automatically adapt your part programmes to different CNC machines. The simulator solution provides the break down of the details of tools used during the job, the positioning of fixtures & part for multi-setup operation; through providing a shop floor documentation.

The traditional APT-based simulation system, only simulate the planned tool-path where as modern advance control Enulator, delivers a more meaning simulation, recreating how the machine will react the G-code generated by your post-processor. It provides powerful validation method allowing users to determine the association between G-code & specific operations inside the NC program.

Ex:	G04	X2.0 [Dwell at 2 second]	
	X30.25		Y5.00
	G03	X35.25	Y10.00
	G01	**X35.25**	**Y50.10 - Toolpath**
	G03	X5.00	Y50.10
	G03	X35.25	Y10.00

Most common used of simulator:-

- Technical Training for programmers & operators in Training center.
- Editing/simulation in design dept.
- Machining time estimate.
- In preparing equation processing.

Process and tool selection (CNC)

Objectives: At the end of this lesson you shall be able to
- **understand selection of tool for CNC**
- **understand the factors contributing for tool selection**
- **learn about MachiningCloud APP.**

The main factors that should be considered while writing a CNC programme, is what type of tooling should be selected for a specific job. Making the right selection depends on how well one understand the vital factors that may have impact on the job.

The selection of tool is based on:

- The machine being used for the manufacture.
- The material used for the job.
- The quantity of machining parts.
- The requirement of the customer.
- The specification of the tool to be used.

All the above five factors are related and interlinked. All the information are avaliable in Router of Tool Directory.

The tool used for CNC mainly depends on the type of material used, type of workdone, quality of finish needed the no.of components to be run etc,.

CNC machine may have different tool configuration. One should know which tool configuration is suitable for hard material or a typical raw material. The Direction of cut, is another factor which affects the tool life, and quality of the cut based on customer specification, the cutting speed, spindle speed & feed are important in the manufacturing process.

The tool selection has to be done following the steps shown below:

step 1: What type of machining is needed?

Collect the machine drawing of the finished part and collet important information such as size,shape, stock material,speed & feed for various operation, namely turning, facing, boring etc.

step 2: What is the work piece material?

Ascertain the workpiece material & the parameters like chip forming, material hardness, alloy elements.These information have significant influence on the spindle speed & feed rates.

step 3: What are the Capabilties of your machine?

This includes machine HP, stability, horizontal or vertical type, spindles type & size, no.of axes, workpiece clamping. Similarly tool holding details such as Holding strength, axis/radial runout, tool overhang etc needs to be considered.

step 4: What Machining Operation needed?

The operation can be face turning, OD turning, ID turning (Boring), grooving/profiling, threading of the components. Geometry & tolerances permissible such as dimensional accuracy, surface finish, part distortion, surface integerity etc.

step 5: In what order should operations to be performed?

This includes minimising tool changes, travel distance between operations, achiving shortest cycle time, maintaining consistency etc,.

spet 6: What type of tool are needed?

Parameters such as part material/tool mateial, depth of cut to be given, smallest concave radius etc are to be taken into consideration to decide the tool material, inserts, shape, tolerance etc,.

C & W inserts are used for rough machining

D & V inserts are used for finish machining.

Square or round shape inserts used for grooving.

3 point inserts are used for threading.

step 7: Are the required tools available?

MachiningCloud APP is an independent provider of CNC cutting tool product data. This provides most up-to-date information, directly obtained from the manufacturer. Information can be obtained by download Machining Cloud APP.

step 8: What feeds & speeds should I use?

Material run better at specific SFM. The recommended SFM for cutting aluminium is 150 to 400. SFM is the combination of cut diameter & RPM. SFM is constant for a material. RPM mode G97 is useful for centre cutting operations (drilling) CSS mode (G96) is useful for good surface finish, better tool life. (SFM- Surface Feet / Minute, CSS- Common Surface Speed)

Part programe for Grooving

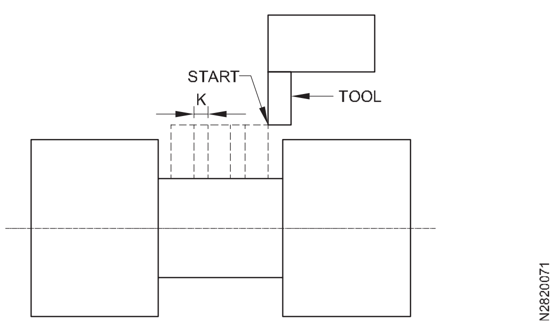
Objectives: At the end of this lesson you shall be able to
- **learn about G75 grooving cycle**
- **understand that grooving linking with parting**
- **follow the part programme of a grooving cycle.**

Introduction

Grooving is an important & complicated operation in turning. G75 is the grooving cycle in 'X' in a CNC machine. (Fig 1)

Grooving is an operation in which the tool is plunged into surface of the work piece until the proper depth is reached. The grooving has to be done step by step and grooving cycles have been developed which allows for wide grooves to be cut with multiple passes by a specific shift value with a Q-word, and P word for depth of cut.

Fig 1



GROOVING CANNED CYCLE

In grooving, the grooving tool is positioned to the start point, then call the canned cycle. The tool will take an initial cut to the finished diameter. Then it will retract to the starting X-position & move over in the Z axis by the amount specified with the P-word. The tool will make several passes until it reaches the programmed Z cooridnate. If the X coordinate is programmed to zero grooving will become parting.

The syntax of G75 code is as follows:

G75 R___;

G75 X___Z___P___Q___F___;

Where,

R = Reliving the tool

X = Groove diameter (mm)

Z = Groove length (mm)

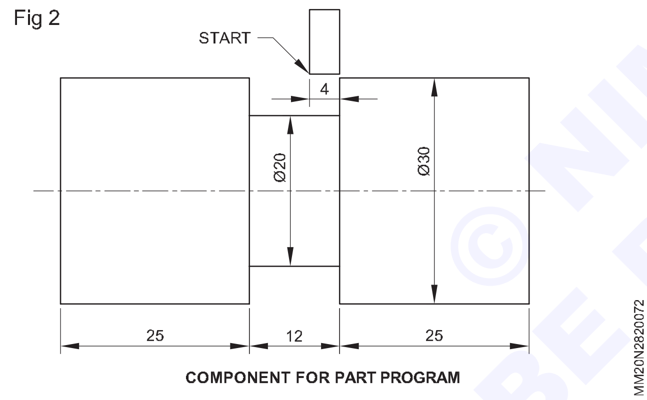
P = Depth of cut in ‘x’ axis in microns (radial value)

Q = Shift value in Z axis microns

F = Feed

Grooving canned cycle [G75] (Fig 2)

Fig 2



COMPONENT FOR PART PROGRAM

Grooving cycle (G75)

```
%
O0013
N1;
G28   U0     W0;
G97   S600   M03;
T0303; [4mm groove width]
G00   X31.0  Z5.0   M08;
G01   Z-29.0 F0.1;
G75   R1.0;
G75   X20.0  Z-37.0 P500  Q4000  F0.08;
G00   X35.0;
Z5.0  M09;
G28   U0     W0;
M05;
M30;
```

Part Programming for Drilling

Objectives: At the end of this lesson you shall be able to
- **understand the part programme for drilling in CNC machine.**

The part program is a sequance of instructions, which decribe the work, which has to be done on a component in the form as required by a computer under the control of a NC computer program. All data is fed into numerical control system using standard format.

In manual part programming: The programmer first perpares the manuscripts which is typed on flexo writer, and carried out in the machine.

Important details for a part programming:-

- Machining sequence, tool start up point, cutting depth, tool paths.
- Cutting conditions, spindle speed, feed rate, coolant etc.
- Selection of cutting tool.

In drilling operation in CNC, a special program of G74 is used, Known “Peck” cycle and a part programme for drilling using the above G74 cycle is given below:

G74 - Peck drilling cycle (Fig 1)

Format

G74 R__;

G74 Z___Q___F___;

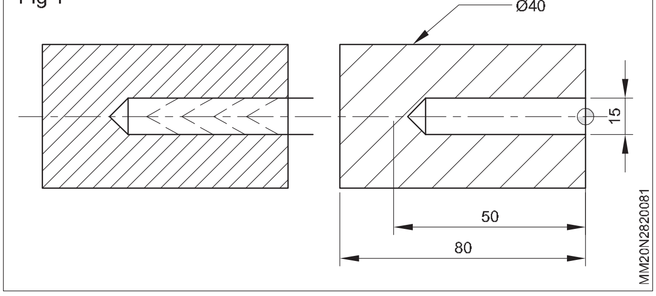
R : Retract value

Z : Depth of the hole

Q : Depth of cut per pass in Microns

F : Feed rate

Fig 1



%

O0029

N1; (C.D)

G28 U0 W0;

T0200;

G97 S1500 M04;

G00 X0.0 Z5.0 T0202 M08;

G01 Z-6.0 F0.12;

G00 Z5.0 M09;

G28 U0 W0 M05;

M01;

N2;

G28 U0 W0;

T0700;

G97 S1500 M04;

G00 X0.0 Z5.0 T0707 M08;

G74 R4.0;

G74 Z-50.0 Q8000 F0.05;

G00 Z5.0 M09;

G28 U0 W0 M05;

M30;

Part Programme for Boring

Objective : At the end of this lesson you shall be able to
- **understand the programme for boring in CNC machine.**

Boring operation in CNC is preceeded by a drilling operation. Hence the component should be initially programmed for drilling either manual or G74 canned cycle (Fig 1). The important factors to be considered for part programming for boring operation includes:

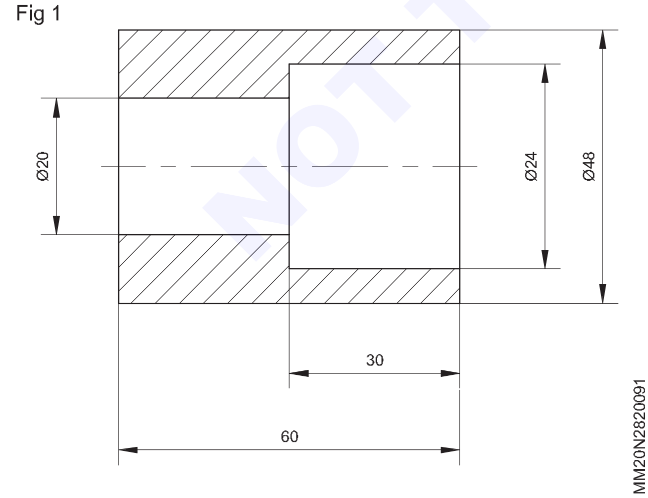
1 Boring sequence, tool start point, cutting depth, tool path.

2 Cutting parameters, spindle speed, feed rate, coolant, utting condition ect.

3 The boring is carried out in steps with 4 operation with initial heavy cuts followed by lesser feed.

4 Selection of correct cutting tool, and cutting speed suitable for the component should be done.

Fig 1



The part programming for the sbove component is indicated, with normal boring operation.

(Boring)

N51; S1200 M03$_{LF}$

N52 T6 D6 M06$_{LF}$

N53 G0 X17 Z2 M08$_{LF}$

N54 G0 X19$_{LF}$

N55 G01 Z-62 F100$_{LF}$

N56 G0 X17 Z2$_{LF}$

N57 G0 X19.7$_{LF}$

N58 G01 Z-62 F100$_{LF}$

N59 G0 X17 Z2$_{LF}$

N60 G0 X20.7$_{LF}$

N61 G01 Z-30 F100$_{LF}$

N62 G0 X17 Z2$_{LF}$

N63 G0 X22.7$_{LF}$

N64 G01 Z-30 F100$_{LF}$

N65 G0 X17 Z2$_{LF}$

N66 G0 X22.7$_{LF}$

N67 G01 Z-30 F100$_{LF}$

N68 G0 X17 Z2$_{LF}$

N69 G0 X23.7$_{LF}$

N70 G01 Z-30 F100$_{LF}$

N71 G0 X17 Z2$_{LF}$

N72 G0 X24$_{LF}$

N73 G01 Z-30 F100$_{LF}$

N74 G01 X20 F100$_{LF}$

N75 G01 Z-62 F100$_{LF}$

N76 G00 X17 Z2 M09$_{LF}$

N77 G0 G90 G53 Z180 Z0$_{LF}$

N78 D0$_{LF}$

N79 M05$_{LF}$

N80 M30$_{LF}$

2nd Operation:

%8

N1 G0 G90 G53 X180 Z0$_{LF}$

N2 S1500 M03$_{LF}$

N3 T1 D1 M06$_{LF}$

N4 G0 X52 Z5 M08$_{LF}$

N5 G0 Z0$_{LF}$

N6 G01 X0 F100$_{LF}$

N7 G00 X49 Z2$_{LF}$

N8 G01 Z-25 F100$_{LF}$

N9 G00 X48 Z2$_{LF}$

N10 G01 Z-25 F100$_{LF}$

N11 G00 X55 Z10 M09$_{LF}$

N12 G0 G90 G53 X180 Z0$_{LF}$

N13 D0$_{LF}$

N14 M05$_{LF}$

N15 M30$_{LF}$

Part Programme for Threading

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

- **understand the programme for external and internal threading in CNC machine.**

The threading operation in a CNC machine is preceded by a turning operation. The threading programme will therefore have rough turning G73 and finish turning G72 operation. The external threading is represented in N29 and internal threading in N48 blocks of the part program for the component shown below. (Figs 1,2)

Fig 1

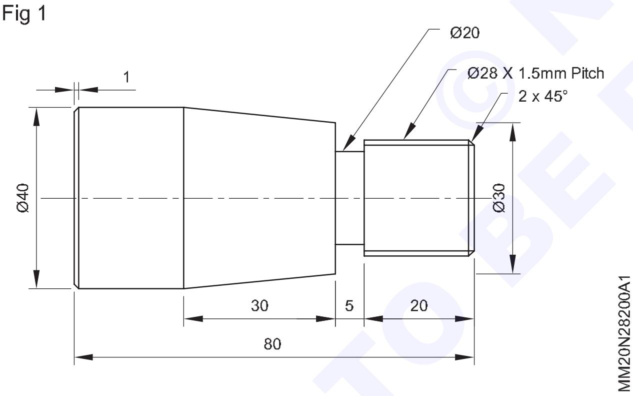
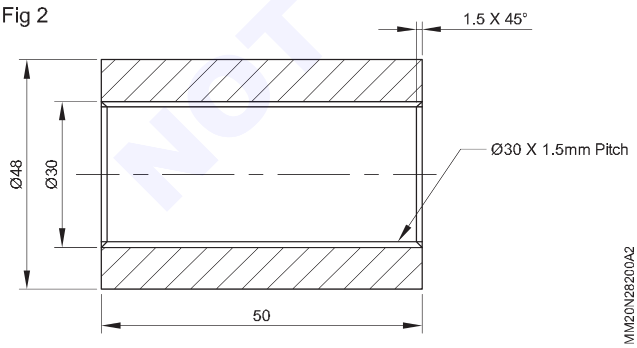


Fig 2



(Threading)

N26 S900 M04 $_{LF}$

N27 T5 D5 M06 $_{LF}$

N28 G0 X33 Z5 M08 $_{LF}$

N29 R20=1.5 R21=28 R22=0 R23=3 R24=-0.97 R25=0.02 R26=3 R27=2 R28=5 R29=30 R31=26.05 R32=-22 $_{LF}$

N30 L97 P1 $_{LF}$

N31 G0 X50 Z10 M08 $_{LF}$

N32 G0 G90 G53 X180 Z0 $_{LF}$

N33 D0 $_{LF}$

N34 M05 $_{LF}$

N35 M01 $_{LF}$

N36 M30 $_{LF}$

(ID Threading)

N45 S1000 M04 $_{LF}$

N46 T8 D8 M06 $_{LF}$

N47 G0 X28 Z5 M08 $_{LF}$

N48 R20=1.5 R21=280.53 R22=0 R23=2 R24=-0.973 R25=0.03 R26=3 R27=2 R28=5 R29=30 R31=30 R32=-52 $_{LF}$

N49 L97 P1 $_{LF}$

N50 G0 X25 $_{LF}$

N51 G0 Z10 M09 $_{LF}$

N52 G0 G90 X53 X180 Z0 $_{LF}$

N53 D0 $_{LF}$

N54 M05 $_{LF}$

N55 M30 $_{LF}$

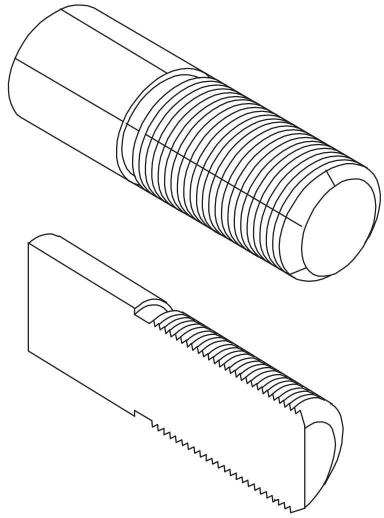
G76 - Multiple therad cutting cycle (Fig 3)

Format:

G76 P____Q____R____;

G76 X____Z____P____Q____F____;

Fig 3



MM20N28200A3

Explanation for the cycle:

P : NCA

N: Number of finishing passes

C : Chamber amount

A : Included angle

Q : Minimum depth of cut in microns (radial value)

R : Finishing depth of cut in microns (radial value)

X : External threading (minor dia) internal threading (minor dia)

Z : Thread length

P : Height of thread (microns)

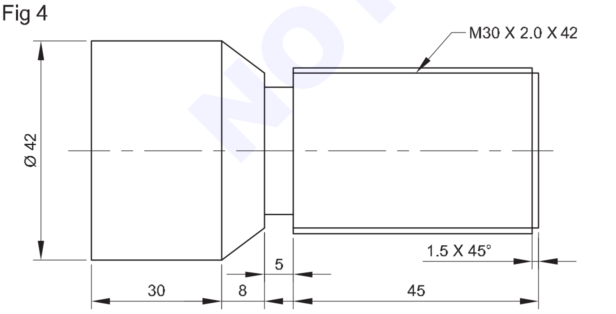
Q : Firast depth of cut in microns (radial value)

F : Feed (pitch of the thread)

Example

OD Threading (Fig 4)

Fig 4



OD THREADING

MM20N28200A4

```
%
O0031
G28   U0     W0;
T0400;
G97   S600   M04;
G00   X32.0  Z5.0    T0404  M08;
G76   P0300  Q150    R20;
G76   X27.404        Z-42.0 P1238  Q300  R20;
G00   X32.0;
Z5.0  M09;
G28   U0     W0      M05;
M30;
```

Threading calculation

Minor dia, d = D - (2h)

(h = 0.649 p, for metric thread)

h = 0.649   2.0 = 1.298 mm.

d = 30 - (2 1.298)

= 27.404 mm.

ID Threading (Fig 5,6)

```
%
O0032
G28   U0     W0;
T0500;
G97   S600   M04;
G00   X38.0  Z5.0    T0505  M08;
G76   P030060        Q150   R20;
G76   X40    Z-110.0 P1298  Q300  F2.0;
G00   X38.0;
Z5.0  M09;
G28   U0     W0      M05;
M30;
```

Threading calculation

Minor dia, d = D - (2h)

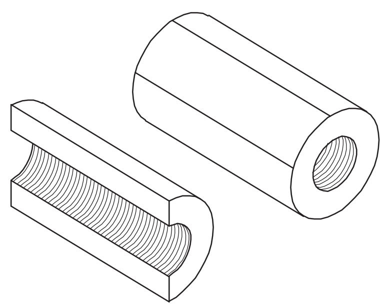
(h = 0.649 p, for metric thread)

h = 0.649   2.0 = 1.298 mm.

d = 40 - (2 1.298)

= 37.404 mm.

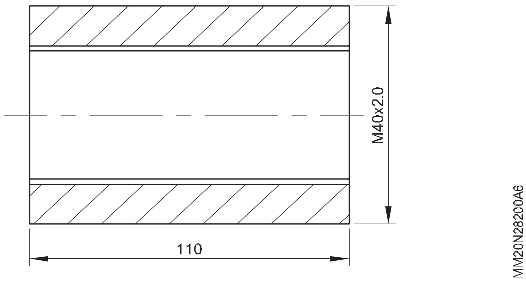
Fig 5



ID THREADING

MM20N28200A5

Fig 6



Collisions due to improper machine setup and operation

Objectives : At the end of this lesson you shall be to
- **identify the collision reason**
- **identify to axis of collision**
- **recover from collision.**

Collisions due to program error, tool brackage

Full collision avoidance can be provided in the machine design phase, the full cycle simulation is combined with real - time monitoring of all moving and stationery components on the machine. This has particular importance when tomb stone fixturing devices, rotary toll trunnions and other hardware are present inside the cutting theater.

STL files to model all the machine assemblies and structures relevant to determine full collision avoidance plus this can be done in all operating modes, including JOG/MDI and AUTO.

In the shop using the operating program on the CNC can further identify potential collisions when altering a program changing a rotary table dimension, resetting fixture or simply monitoring the tooling changes Basic machining areas and limits can be defined by modeling those protected areas. Head stock, rotary table trunnions, tombs stone fixturing or a simple clamp position can be monitored in this real time collision.

All of the stationary and moving elements, as well as the cutting edges, are effectively monitored for potential collision. The affected area or machine components are quickly Identified on screen during a cycle simulation or in real time.

Human error can also be factored in so that the resulting collision that would have been caused by - a change in a program or a set-up error can be anticipated, triggering an alert that is high light the affected area on screen.

Faulty CNC Machine Programming

CNC machining is not exactly a foolproof process. In some instances, either a work piece or the machine itself could be directed in a harmful way. When this happens, a crash might occur, whereby tools or machine parts end up broken. The tools that could get damaged by a crash may include the vices or clamps that hold the work piece in place. When damage occurs within the machine, it could range from minor screw breakage to serious structural deformity.

The fact is, CNC equipment lacks the sentience to know exactly which distances are too far. Therefore, the tools must be exactly programmed in order to work without fault. If a program code is miscalculated, a CNC machine could be driven outside its physical bounds and cause an internal collision. Even though most of today's CNC machines are manufactured with parameter boundaries, these inputs can be manipulated by operators.

Likewise, CNC tools are oblivious to a given environment. While certain CNC machines are equipped with spindle load sensing, others lack this feature. In the latter case, the software must be coded properly to ensure nothing goes off parameter, otherwise a crash would be the likely outcome. Even if a CNC machine is equipped with load sensors, a crash could still occur. When a tool function goes astray, it's up to the operator to rectify the situation.

Crash Prevention on Different Types of CNC Machines

With the installation of encoder-disk position sensors, the possibility of a crash can be detected in advance and thwarted. Alternately, torque sensors can help determine whether a CNC machine is moving as intended and also detect unwanted cutting.

In garage CNC systems, tools are reliant on the rotational precision of stepper motors for the correct number of degrees. To monitor the tool position, the pulses that go to the stepper must be counted, because in most cases, there's no form of alternate monitoring.

On industrial CNC machines, closed-loop controls are employed, whereby the control always knows the axis position. If properly controlled, the potential for crashes is significantly lowered, though it's still the responsibility of programmers to see that codes are inputted accurately for utmost safety.

Over the last two decades, CNC software has advanced to where a vast range of machine tools-axes, clamps, fixtures, spindles, turrets-can be based precisely on 3D solid models. With those specs programmed into the code, it's easier to determine whether a crash will occur with a particular cycle.

Find alarm codes and meaning of those codes

Objective: At the end of this lesson you shall be able to
- **state classification of CNC alarm**
- **define the alarm code**
- **state various alarm list in fame system**

CNC alarms classified into system alarm and custom alarm.

1 System alarm are related to CNC control system

2 Custom alarm are related to machine tool manufacturer.

An alarm code may indicator a problem with the CNC machine (Mechanical or Electrical) or with the G- code program the machine has loaded.

Alarm code also called as error code or fault codes.

Alarm list - (CNC)

- Alarms on program and operation (PS alarm)
- Back ground edit alarms (BG alarm)
- Communication alarms (SR alarm)
- Parameter writing alarm (SW alarm)
- Servo alarm (SV alarm)
- Over travel alarm (OT alarm)
- Memory file alarm (IO alarm)
- Alarms requiring power to be turned OFF (PW alarm)
- Spindle alarm (SP alarm)
- Over neat alarm (OH alarm)
- Other alarms (DS alarm)
- Malfunction prevention function alarm

Alarm list (PMC) programmable machine control

- Message that may be displayed on the PMC
- PMC system alarm messages.

Alarm list (serial spindle)

Error codes (Serial spindle)

Alarm numbers are common to all these alarm types

Depending on the state, an alarm is displayed in the following examples

PS alarm number Example PS 0003

BG alarm number Example BG 0085

SR alarm number Example SR 0001

Number	Message	Description
003	Too many disit	Data entered with more disits than permitted in the NC interesting word. The number of permissible ditits varies according to the function and the word.
0010	Improper G - code	An usable G code is specified.

Simivelling for other alarms refer machine tool catalogue.

Edit and MDI mode functions

Objectives : At the end of this lesson you shall be to
- **program execution line MDI, single block and auto**
- **canned cycle - turning / facing, grooving, threads external and internal**
- **tool nose radius - find geometry page.**

Edit mode

program edit, insert/delete word, alter and save program can be done in edit mode.

MDI mode

Manual data input key and functions.

MDI and single block mode.

MDI mode

- When the machine is not running a part program the operator may use this mode.
- Only one block is executed at a time.
- Once it is executed, it is gone from the computer in memory.
- An operator can use MDI mode to change cutting tool, spindle ON/OFF, Coolant ON/OFF, etc.

Automatic mode

Selection of this mode enables automatic machining. This should be attempted only after the program has been proved to be correct in all aspects. It is very important that there should be no mistake in the programme and one should satisfy himself during the trial run. It is also important to realise that once a program is proved, we should not make even minor or innocent looking changes in it. In case any change is warranted, we may incorporate the same, but we should again do the trial run of the changed version of the programme in single block mode.

Procedure

- Power on.
- Auxiliary on.
- Reference points.
- Mount the job and measure zero offsets.
- Mount the tool and measure tool offsets.

Single block mode

Single block mode allows an operator to check the program by executing only one program block at a time.

Example

```
N1   G01   X50   Z5    F0.1 ;
N2   S1200 M03 ;
N4   M08 ;
N5   G01   X48   F0.1 ;
N6   G01   Z-25  F0.1 ;
N7   G00   X60   Z10 ;
N8   M09 ;
N9   M05 ;
N10  M30 ;
```

- Enter the zero offsets and tool offsets.
- Select automatic mode.
- Enter the number of program to be executed.
- Ensure that default settings displayed are correct.
- Start execution by pressing the relevant button on the control panel.
- Inspect the part for dimensions and geometry.

Process planning & sequencing tool layout & selection and cutting parameter

Objectives : At the end of this lesson you shall be able to
- **state what is process planning**
- **name the types of process planning**
- **state what is machining sequence**
- **state what us tool layout**
- **selection of cutting parameters.**

Process planning is a preparatory step before manufacturing, which determines the sequence of operations or processes needed to produce a part or an assembly. This step is more important in job shops, where one - of - a kind products are made or the same product is made infrequently.

The manufacturing process begins with the process planning and ends with actual product. Process planning is considered the back bone of manufacturing, since it attempts to determine the most efficient sequence to produce the product quickly and inexpensively as possible.

A process planner must be aware of the various aspects of manufacturing to plan properly. The planner works typically with blue prints and may have to communicate with the design department of the company to clarify or request changes in the final design to fit manufacturing requirements. The outcome of process planning is a production plan, tools procurement, material order and machine programming. Other special manufacturing needs such as design of jigs and fixtures are planned.

Numerical control is concerned with controlling the operation of a single machine, but process planning considers the sequence of production steps needed to make a part from start to finish, generally using successive operations on several machines. The planning describes the routine of the work piece through the shop floor and its state at each work station.

Flow diagrams and other information such as part specifications, tooling requirements and machining conditions can be used to develop a production sequence for fabricating the part in the fastest, most economical manner.

Once the process planning phase is completed, the actual production of the product begins. The produced parts are inspected and usually must pass certain standard quality control (assurance) requirements. Parts that survive inspe ction are assembled, packaged, labeled and shipped to customer.

An important part of process planning is a concept called " group technology" (GT). This is a manufacturing philosophy, that takes advantageof the similarities among parts and processes. Instead of treating each part as unique, group technology organizes the parts in to families according to either similar shape or common manufacturing operation.

Types of process planning

The Types are

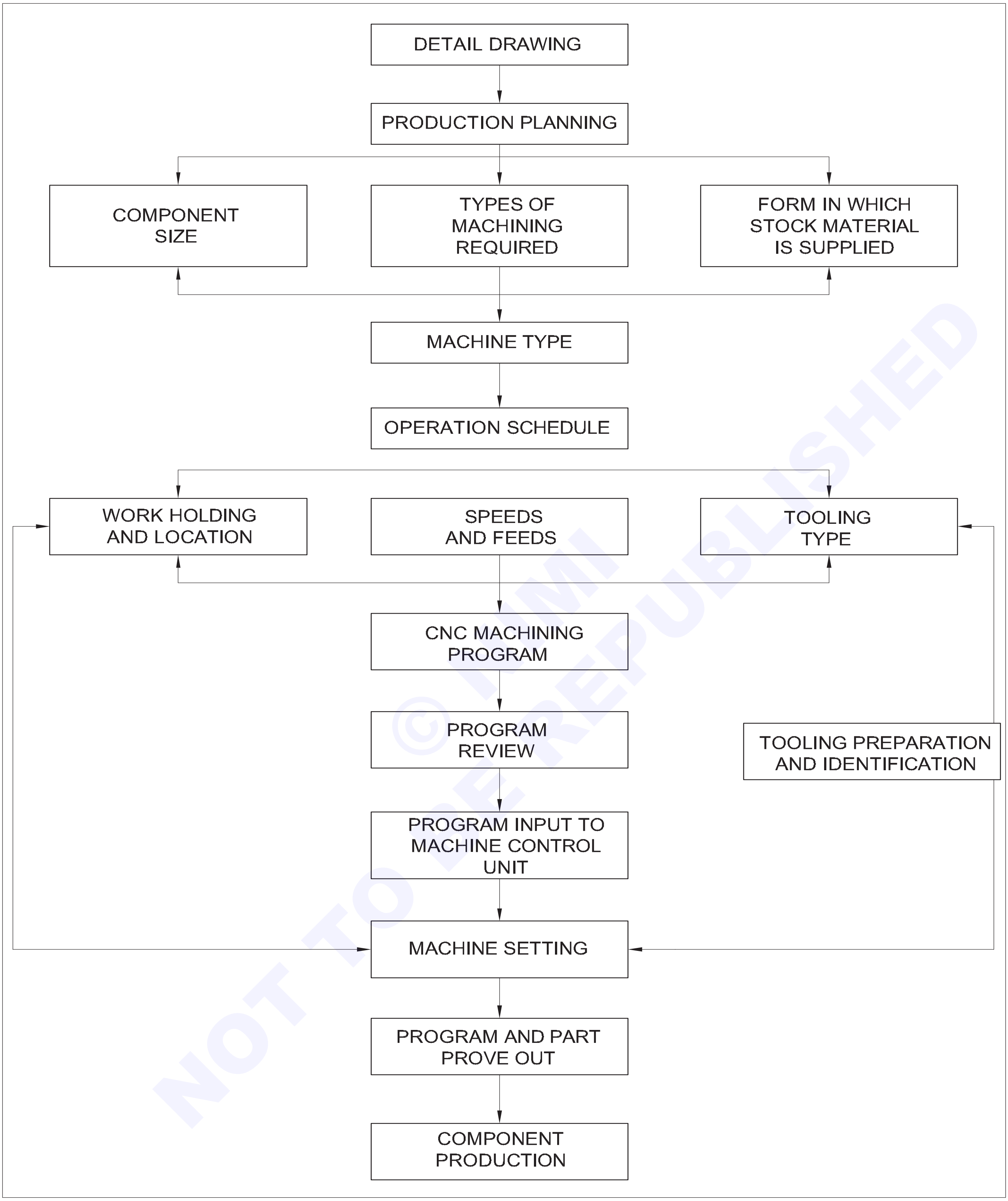
1 Manual process planning

2 Automated process planning

3 Generative process planning.

Process planning

Process planning flow chart



Machining sequence

Machining sequence defines the order of machining operations. Technical skill and machine shop experience does help in program planning, but some common sense approach is equally important. The sequence of machining must have a logical order - for example, drilling must be programmed before tapping, roughing operations before finishing, first operation, before second etc. With in this logical order, further specification of the order of individual tool motions is required for a particular tool. For example in turning, a face cut may be programmed on the part first,and then roughing all material on diameters will take place. Other example is, to program a roughing pass for the dameter, then face and continue with the remainder of the diameter roughing after wards. In drilling, a center drill before drilling may be useful for some applications, but in another program a spot drill may be a better choice. There is no fixed rule, on which method is better - each CNC programming assignment has to be considered individually, based on the criteria of safety and efficiency.

The basic approach for determining the machining sequence is the evaluation of all related operations. In general, program should be planned in such a way that the cutting tool, once selected, will do as much work as possible, before a tool change. On most CNC machines, less time is needed for positioning the tool than for a tool change. Another consideration is in benefits gained by programming all heavy operations first, then the lighter semi finishing or finishing operations. It may mean an extra tool change or two, but this method minimizes any shift of the material in the holding fixture while machining. Another important factor is the current position of a tool when a certain operation is completed. For example, when drilling a pattern of holes in the order of 1-2-3-4, the next tool (such as a boring bar, reamer or tap) should be programmed in the order of 4-3-2-1 to minimize unnecesary tool motions.

T01- Spot drill	T02- drill	T03- Tap
Hole - 1	Hole - 4	Hole - 1
Hole - 2	Hole - 3	Hole - 2
Hole - 3	Hole - 2	Hole - 3
Hole - 4	Hole - 1	Hole - 4

Typical machining - sequence (Spot drill, drill and tap shown as an example).

Typical turning - sequence (facing, rough turining, finish turning, grooving threading etc.

This machining sequence may have to be changed after the final selection of tools and the set up method. The reverse sequence may not be practical in sub programs.

Tool layout

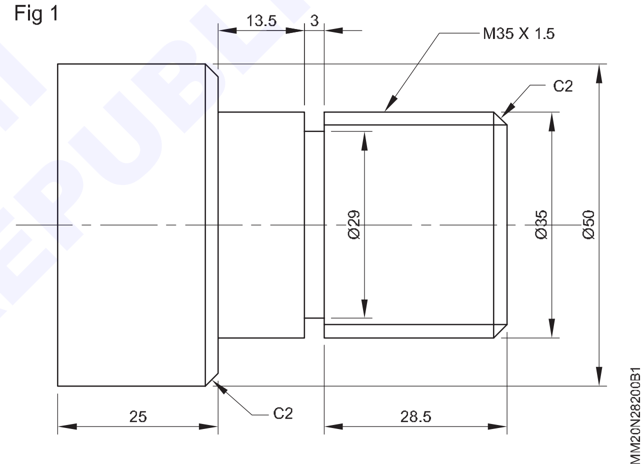
The tool layout for a job constitutes the predetermined plan for machining operation of a particular component the layout is dependent upon the number of pieces to be manufactured in lot size.

As a general rule, standard tools should be used as much as possible and also for small batches of work, the layout should be simple for large quantities and long run special tools should be used. The accuracy and cost of component largely depends upon th tool layout.

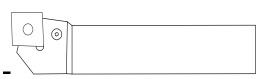
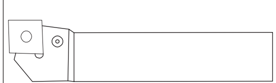
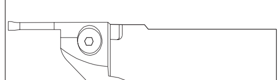
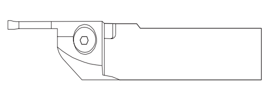
For preparation of the tool layout, it is necessary to have the finished drawing of the part to be machined and if is a forging or casting will determine how much machining has to be done. (Fig 1)

Example of tool layout

Fig 1



Tool layout

No	Operation	Tool	Tool geometry name	Cutting speed	Depth of cut	Feed
1	OD Rough	PCLNL 2525 M12 Turning CNMG 120408 - Insert		180	2	0.2
2	OD Finish Turning	PCLNL 2525 M12 CNMG 120404 - Insert		180	1	0.2
3	OD Grooving	Groove tool holder LH		150	3	0.15
4	OD Threading	LH thread holder 25x25x150mm lenth DEG., DEPTH 3.0, LH		100	0.2	Pitch 1.5

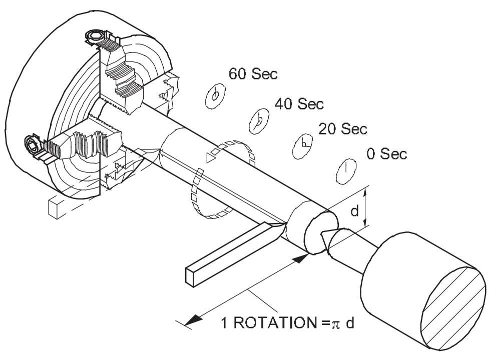
Cutting parameters selection

Objectives: At the end of this lesson you shall be able to
- **differentiate between cutting speed and feed**
- **state select the recommended cutting speed for different materials from the chart**
- **state the factors governing the cutting speed**
- **state the factors governing feed.**

Cutting speed (Fig 1)

Cutting speed is the speed at which the cutting edge passes over the material, and it is expressed in metres per minute. When a work of a diameter 'd' is turned in one revolution the length of the portion of work in contact with the work in contact with the tool is πxdxn. This is converted into metres and expressed in a formula form as

Fig 1



CUTTING SPEED FOR TURNING OPERATION

$$V = \frac{\pi \text{ x dn}}{1000} \text{ metre /min.}$$

Where V = cutting speed in m/min

π = 3.14

d = diameter of the work in mm

n = RPM

When more material is to be removed in lesser time, a higher cutting speed is needed. This makes the spindle to run faster but the life of the tool will be reduced due to more heat being developed. The recommended cutting speeds are given in a chart. As far as possible the recommended cutting speeds are to be chosen from the chart and the spindle speed calculated before performing the operation. (Fig 2) correct cutting speed will provide normal tool life under normal working condition.

Example

Find out the rpm of a spindle of a 50mm bar to cut at 25m

Factors governing the cutting speed

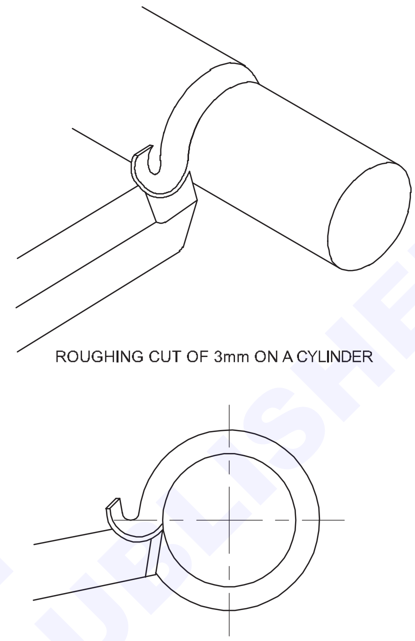
$$\text{min. V} = \frac{\pi \times DN}{1000}\ ;\ \ n = \frac{1000\ V}{\pi \times D}$$

$$\frac{1000 \times 25}{3.14 \text{ x } 50} = \frac{500}{3.14} = 159 \text{ r.p.m}$$

Finish required

depth of cut

Fig 2



DEPTH OF CUT

tool geometry

properties and rigidity of the cutting tool and its mounting

properties of the workpiece material

rigidity of the workpiece

type of cutting fluid used

rigidity of the machine tool

Feed (Fig 3)

The feed of the tool is the distance it moves along the work for each revolution of the work, and it is expressed in mm/rev.

Factors governing feed

Tool geometry

surface finish required on the work

rigidity of the tool

coolant used

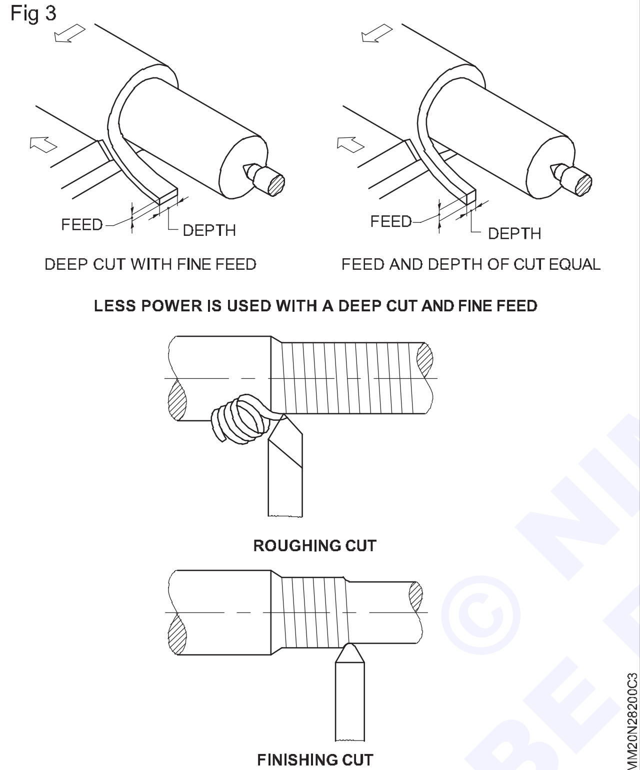
Rate of metal removal

The volume of metal removal is the volume of chip that is removed from the work in one minute, and is found by multiplying the cutting speed, feed rate and the depth of cut.

For super HSS tools the feeds would remain the same, but cutting speeds could be interested

Cutting speed 120m/min	length of metal passing cutting tool in 1 revolution	Calcualted r.p.m. of spindle
	____ 78.56mm	1528
	____ 157.12mm	756
	____ 235.68mm	509.3

Fig 3



For super HSS tools the feeds would remain the same, but cutting speeds could be intersted by 15% to 20%.

A lower speed range is suitable for heavy, rough cuts.

A higher speed range is suitable for light, finishing cuts.

The feed is selected to suit the finish required and the rate of metal removal

Cutting speeds and feeds for H.S.S. tools

Depth of cut

The depth of cut is the difference between machined and un machined surface.

If $D1$ = initial diameter

$D2$ = Final diameter

Depth of cut $= \frac{D1 - D2}{2}$

TABLE 1

Material being turned	Feed mm/rev	Cutting speed m/min
Aluminium	0.2-1.00	70-100
Brass (alpha)-ductile	0.2-1.00	50-80
Brass (free cutting)	0.2-1.5	70-100
Bronze(phosphor)	0.2-1.00	35-70
Cast iron(grey)	0.15-0.7	25-40
Copper	0.2-1.00	35-70
Steel(mild)	0.2-1.00	35-80
Steel		
(medium-carbon)	0.15-0.7	30-35
Steel (alloy high		
tensile)	0.08-0.3	5-10
Thermosetting plastics	0.2-1.00	35-50

The relationship between limiting spindle speed and constant cutting speed

When cutting in the constant cutting speed mode, as the tool moves towards the axis, the spindle speed increases.

The spindle speed N in RPM is calculated using this equation , where V is the cutting speed and D is the diameter at which the tool is cutting.

$$V = \frac{\pi \times D \times N}{1000} \quad \text{hence } N = \frac{1000 \times V}{\pi \times D}$$

At a cutting speed of 250, at 30 mm. Diameter thee RPM would be 2652. At 20 dia. The RPM would be 3978. At 1 mm. dia. The RPM would be 79,577.

At a certain diameter the spindle speed goes beyond the machine's capability. At the axis of the part, in fact, the RPM would theoretically be infinity (D is zero). The machine however has a certain maximum spindle RPM, so in the CNC program we need to specify what this maximum is. This is specified as Limiting spindle speed. When the spindle speed reaches this value, the controller clamps it at this speed and the rest of the motion is done at a constant spindle speed equal to the limiting speed.

E.g., if we want to cut at a constant cutting speed of 250 m/min and limit the RPM to 3000, for Fanuc we would write this

G96 S250

G92 S3000

So what should I program as the limiting spindle speed? If the part is held rigidly in the chuck and is circular, just set the limiting spindle speed to the machine's maximum spindle RPM. If the part is non-circular or is held in a fixture that is not balanced, centrifugal forces might cause the part to fly off or damage the fixture.

Operational modes

- Auto mode
- Edit mode
- MDI mode (Manual data input)
- Jog mode
- MPG mode (manual pulse generation) data
- Input/output mode
- Zero return mode

I) Selection of tools, speed feed & depth of cut

D =	work piece diameter	mm
V =	cutting speed	m/min
S =	Feed	mm/r
N =	RPM	r/min
A =	Depth of cut	mm
N =	Efficiency	for example 0.75
Ks =	Specific cutting force	N/mm2
V =	Metal removal rate	cm3/min
P =	power required	kW
R =	nose radius	mm
K =	Constant	for example 1.4
Rt =	Profile depth	μm
Ra =	Surface finish	μm

II) Approximate value for power required

The above formula for power is exact but the specific cutting force ks is included. The ks-value is hard to set because it is dependent on many factors. Such as work piece materials, chip breaker, cutting rake, feed setting angle chip thickness.

RPM	$n = \frac{v.1000}{\pi D}$ =r/min
Cutting speed	$v = \frac{\pi.D.n}{1000}$ m/min
Metal removal rate	V = v.s.A cm^3/min
Power required	$P = \frac{v.s.A.ks}{6000\eta}$ kW

A simplified formula for approximate power required is shown below, Based on the most common type of application-medium rough to rough turning of normal steel, with a light-cutting edge-a specific cutting force. Ks=1800 N/mm^2 and a machine efficiency factor=0.75 are used.

$$P = \frac{v.s.A}{25} \text{ kW}$$

III) Approximate value for surface finish

$$\text{Profile depth } R_t = k\frac{s^2\ 1000}{8r}$$

The constant k is depends on two factors, the work piece material and how well the cutting edge profile is reproduced on the work piece. In normal machine steel k=1.4, Surface finish Ra = Rt/3.5.

Surface Ra = s^2.50/R

IV) Effect of nose radius and feed rate on the surface finish requirements

The table below gives the recommended maximum values of feed rate for finishing normal steels, when turning materials which give rise to edge build-up, the cutting speed must be sufficiently, high to avoid such tendencies, if possible When turning highly abrasive materials, the feed rates should be reduced by about 20% .To convert Ra to CLA multiply by 40.

	Nose radius, mm					
	0.2	**0.4**	**0.8**	**1.2**	**1.6**	**2.4**
Ra value	**Feed rate, mm/rev**					
0.6	0.05	0.07	0.10	0.12	0.14	0.17
1.6	0.08	0.12	0.16	0.20	0.23	0.29
3.2	0.12	0.26	0.23	0.29	0.33	0.40
6.3		0.23	0.33	0.40	0.47	0.57
8.0		0.40	0.49	0.57	0.69	

A large nose radius will usually result in a better surface finish, provided that the cutting edge is sufficiently sharp and that the larger nose radius does not give rise to vibrations. It is recommended that the depth of cut for finishing should be more than the nose radius of the chosen insert. Filets, etc on the component often restrict the choice of nose radius on finishing.

V) Cutting speed-wear life

Providing the machining conditions are good i.e. stability of the work piece and tool, it is possible to increase the wear life of the insert.

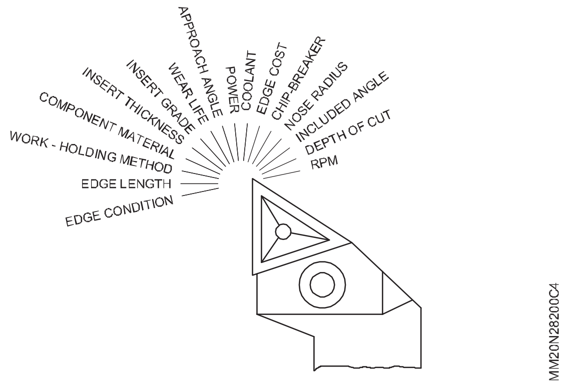
To achieve longer wear life, the cutting speed must be reduced. Multiply the recommended cutting speeds by the following factors.

The cutting speeds given in this guide are for 30 min. wear life. If higher surface speeds are required that wear life will decrease.

Approx. wear life Mm	Factor
* 15	1.25 x V
* 30	1.0 x V
45	0.89 x V

VI) Edge condition factors (Fig 4)

Fig 4



- Fixed conditions
- Material specification
- Amount of material to be removed
- Component dimension
- Component shape
- Hardness
- Surface condition
- Operation
- Finish requirement
- Type of machine
- Condition of machine
- Power available
- Chucking or clamping method

Once the fixed conditions have been considered, the tooling and data parameters can be variable conditions

- Select carbide grade
- Select radius
- Select insert shape
- Select insert size
- Select insert rake
- Select tool size
- Select tool-holder shank size
- Select tool-holder style

Now the cutting speed, depth of cut and the feed over revolution can be selected.

Cutting parameters for CNC turning applications

Speed / feed /depth of cut for general turning							
	Part Material	Cutting speed	Feedrate /mm/rev			Depth of cut mm	
		Vc m/min	Rough	Finish	Rough	Finish	
						0.4 R	0.8R
Steel	Steel 130 - 180 BHN	240 - 320	0.2 - 0.35	0.1 - 0.2	1 - 3	0.25 - 0.4 Radial	0.3 - 0.5 Radial
Steel	Steel 180 - 250 BHN	160 - 240	0.2 - 0.35	0.1 - 0.2	1 - 3	0.25 - 0.4 Radial	0.3 - 0.5 Radial
Steel	Cast Steel 180 - 250 BHN	140 - 200	0.2 - 0.35	0.1 - 0.2	1 - 3	0.25 - 0.4 Radial	0.3 - 0.5 Radial
SS	Stainless steel Bar/ Forged 200 BHN	100 - 140	0.2 - 0.3	0.1 - 0.2	1 - 3	0.2 - 0.4 Radial	0.3 - 0.5 Radial
SS	Stainless steel Casting 200 - 330 BHN	75 - 140	0.2 - 0.3	0.1 - 0.2	1 - 3	0.2 - 0.4 Radial	0.3 - 0.5 Radial
C I	Grey CI 180 - 260 BHN	180 - 250	0.2 - 0.3	0.15 - 0.2	1 - 3	0.2 - 0.4 Radial	0.3 - 0.5 Radial
C I	Nodular CI 250 BHN	160 - 220	0.18 - 0.25	0.15 - 0.2	1 - 3	0.2 - 0.4 Radial	0.3 - 0.5 Radial
AL	Aluminium 60 - 100 BHN	500 - 1000	0.25 - 0.5	0.1 - 0.2	2 - 5	0.25 - 0.6 Radial	0.4 - 1.0 Radial
AL	Aluminium Cast 75 - 130 BHN	400 - 800	0.2 - 0.4	0.1 - 0.2	2 - 5	0.25 - 0.6 Radial	0.4 - 0.8 Radial

Speed / feed / width of cut for grooving

	Part Material Vc m/min	Cutting speed	Feedrate /mm/rev		Width of cut for plunge type Rough
		Rough	Finish	%	
Steel	Steel 130 - 180 BHN	120 - 180	0.08 - 0.2	0.05 - 0.1	
	Steel	100 - 150 180 - 250 BHN	0.08 - 0.2	0.05 - 0.1	
	Cast Steel	80 - 120 180 - 250 BHN	0.08 - 0.2	0.05 - 0.1	
SS	Stainless steel Bar/ Forged	70 - 120 200 BHN	0.08 - 0.2	0.05 - 0.1	
	Stainless steel Casting 200 - 330 BHN	60 - 110	0.06 - 0.15	0.05 - 0.1	70 - 80% of tool width
CI	Grey CI 180 - 260 BHN	80 - 150	0.08 - 0.2	0.05 - 0.15	
	Nodular CI 250 BHN	60 - 110	0.06 - 0.15	0.05 - 0.15	
AL	Aluminium 60 - 100 BHN	250 - 400	0.15 - 0.3	0.05 - 0.15	
	Aluminium Cast 75 - 130 BHN	200 - 350	0.15 - 0.3	0.05 - 0.15	

Threading

	Part material	Cutting speed Vc m / min	No cutting passes pitch						Thread depth	I st DOC Pitch			
			0.75	1	1.5	2	2.5	3		1	1.5	2	3
Steel	Steel 130 - 180 BHN	60 - 120	5	6	8	10	13	15					
	Steel 180 - 250 BHN	50 - 90	6	6	9	11	14	17		0.16	0.2	0.22	0.25
	Cast steel 180 - 250 BHN	40 - 70	7	7	10	12	15	19					
SS	Stainless steel Bar / Forged 200 BHN	30 - 60	7	8	10	12	16	19	0.65 X Pitch	0.16	0.2	0.22	0.25
	Stainless steel Casting 200 - 330 BHN		7	8	11	14	18	20					
C I	Grey CI 180 - 260 BHN	60 - 110	5	6	8	10	13	15					
	Nodular CI 250 BHN	50 - 90	6	7	10	12	14	16		0.18	0.22	0.25	0.28
	Aluminium 60 - 100 BHN	150 - 220	5	6	8	10	12	15					
AL	Aluminium cast 75 - 130 BHN	120 - 200	5	6	8	11	14	16		0.18	0.22	0.25	0.3

Note: Feed rate mm/ min should not cross 2500 - 3000 mm/min on machine

To check: Use this formula: calculated RPM X (Pitch X No. of starts)= mm/min on machine

Speed / feed for drilling									
Cutting speed m/min									
	Para material	**HSS**			**Solid carbide**			**Insert type**	
			F /rev			**F/rev**			
		Vc	**Dia <10**	**Dia >10**	**Vc**	**Dia <10**	**Dia >10**	**Vc**	**F/rev**
Steel	Steel 130 - 180 BHN	25-35	0.05-0.12	0.12-0.25	50 - 80	0.05 - 0.12	0.12 - 0.25	120 - 180	0.08 - 0.15
Steel	Steel 180 - 250 BHN	20 - 30	0.05-0.12	0.12-0.25	40 - 70	0.05 - 0.12	0.12 - 0.25	100 - 150	0.08 - 0.15
Steel	Cast steel 180 - 250 BHN	20 - 30	0.05-0.12	0.12-0.25	40 - 65	0.05 - 0.12	0.12 - 0.25	80 - 120	0.06 - 0.12
SS	Stainless steel bar/Forged 200 BHN	15 - 25	0.05-0.12	0.12-0.20	35 - 50	0.05 - 0.12	0.12 - 0.2	80 - 100	0.06 - 0.12
SS	Stainless steel casting 200 - 300 BHN	15 - 20	0.05-0.12	0.12-0.20	30 - 50	0.05 - 0.12	0.12 - 0.2	70 - 100	0.06 - 0.12
C I	Grey CI 180 - 260 BHN	25 - 40	0.05-0.12	0.12-0.30	60 - 90	0.05 - 0.12	0.12 - 0.3	180 - 250	0.1 - 0.2
C I	Nodular CI 250 BHN	25 - 35	0.05-0.12	0.12-0.25	50 - 80	0.05 - 0.12	0.12 - 0.25	150 - 220	0.1 - 0.2
AL	Aluminium 60 - 100 BHN	50 - 80	0.08-0.15	0.15-0.30	150 - 250	0.08 - 0.15	0.15 - 0.3	250 - 350	0.12 - 0.2
AL	Aluminium cast 75 - 130 BHN	50 - 80	0.08-0.15	0.15-0.30	150 - 250	0.08 - 0.15	0.15 - 0.3	250 - 350	0.12 - 0.2

Tool offsets adjustment in first part

Objectives: At the end of this lesson you shall be able to
- **list the types of offsets used in CNC machine**
- **trace the tool path from the given program.**

Types of offsets

There are three types of offsets used in CNC machine operation.

They are :

i Work offset (or) zero offset

ii Geometrical offset

iii Wear offset

work offset (or) zero offset.

Every manufacturer fix a reference point on the spindle of the machine according to the design of manufacturing.

The tool will take the command and move with reference to this machine reference point.

To make the tool to move with reference to the job, work offset or zero offset has to be taken.

Procedure for taking work offset

Clamp the job in the chuck of the machine.

Set the tool in the required order set in the machine turret.

Set the jog mode or the tool and touch the face of the job.

With the use of a paper check the proper contact of tool with the face.

Now select the work co-ordinate system from G54 to G59.

Enter the z value in the selected work co-ordinate system

Now touch the diameter with the same tool.

Check the contact of the tool with the job using a paper.

Now enter the diameter of the job in the tool contact point in the x value in the selected work co-ordinate system.

This particular work co-ordinate system should be mentioned in the part program.

Geometrical offset

The tools used in CNC machine are of different geometry. The length of the tools vary accordingly.

Even if the work offset is taken for a tool it will not suit the other tools

So for every tool offset is taken and entered in tool offset value in work co-ordinate system

Because of this every tool will take the work zero point as origin

The procedure for geometrical offset is given below

Clamp the job in the chuck of the machine

Set the tool in the required order in the machine turret

Select the jog mode or MPG mode

Select the first tool and touch the face of the job

Check with a piece of paper whether the contact of tool with the job is proper

Now take the geometrical offset page and enter under the tool number the command MZ 0 (zero)

This command will clear any previous values and will measure the current tools tool offset in Z axis

Now touch the tool to a known diameter on the component

Again in the tool-geometry page enter the command MX (The value of the diameter) for example if the diameter is 50mm then MX50

Follow the same procedure for the remaining tools

enter the MZ and MX commands for various tools in the under respective tool number.

Tool offsets adjustment in first part

Objectives: At the end of this lesson you shall be able to
- **state necessity of wear offset**
- **entering wear offset value in system.**

Wear offset necessity

It is used to help with sizing adjustments during production due to tool wear and to achive required drawing dimensions.

Entering wear OFFSET in Offset /wear page

- Press offset/menu button.
- Geometry /wear offset page screen will display in monitor
- Press wear offset soft key.
- Then offset / wear page will display in monitor (Refer Ex no 3.4.160).
- Bring the cursor to the required tool offset number for wear correction.
- Bring cursor horizontally 'X' or 'Z' for wear correction.
- Type wear value.
- (Ex) - 0.1.
- Press + input soft key.
- Dimension - 0.1 input ok ? will display of bottom.
- Press "Exec" soft key.
- Wear value enter in teh required tool offset number.
- Run the auto cycle.
- Check the dimension of the corrected value.

Work and tool offsets input value to the offset / geometric page into machine

Objective : At the end of this lesson you shall be able to
- **know the method of inputting the offset values into the offset pages of CNC machine.**

Work offset

Program coordinates are specified with reference to a workpiece zero position, which is usually a point on the workpiece. The machine, however, internally only understands coordinates with reference to a fixed machine zero point. The work offset is the distance from the work zero to the machine zero. It is fed into the machine's memory, and enables the machine to translate the program coordinates into machine coordinates.

Work offset values can be input into the work co ordinate page of the CNC lathe given below (G54 To G59)

Work coordinates (G 54)

No		**Data**	**No**		**Data**
000	X	0.000	002	X	0.000
EXT	Z	0.000	G55	Z	0.000
001	X	0.000	003	X	0.000
G54	Z	0.000	G56	Z	0.000

Tool offset

Tool offset is used to compensate for the difference when the tool actually used differs from the imagined tool used in programming usually, standard tool.

Tool offset valves can be input into the offset/ geometry page of the CNC lathe given below in Table - 1

Geometry **Table 1**

Tool	X	Z	R	T
No	X offset value	Z offset value	Tool nose radius	Tool type no
G01				
G02				
G03				
G04				
G05				
G06				
G07				
G08				
G09				
G10				
G11				
G12				
G13				
G14				
G15				

Wear offset

Wear values in X(U) and Z(W) are incremental displacement of tool from the actual offset value and can be input into the offset /wear page of the CNC lathe given below in tabe 2

Tabe 2

Tool	U	W	R	T
No	Tool wear X	Tool wear in Z	Nose radius wear	Tool type No.
W01				
W02				
W03				
W04				
W05				
W06				
W07				
W08				
W09				
W10				
W11				
W12				
W13				
W14				
W15				
W 16				

Program checking in single block and dry run mode

Objectives : At the end of this lesson you shall be to
- **check the program in Dry run**
- **check the program in single block mode.**

Program check in dry run, single block mode

Dry run is to be carried out to check :

- To perform trial option of the part programming
- The path or profile of the job and
- The error in the program
- To avoid any Accidental incident
- The effectiveness of the program.
- It is used to check the program for correctness. After entry of the program it should be checked through simulation
- Single block mode is used to allow the operator, to execute the part program at a time on the single block.
- It is also used to execute the first job.

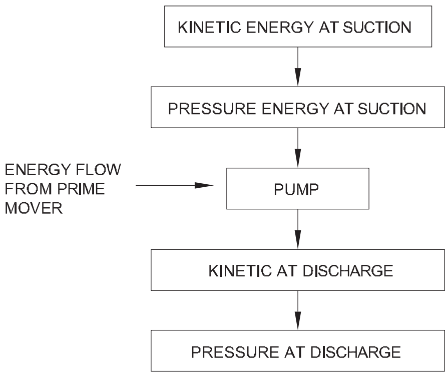
The instructor demo the 'Dry Run' to the students

Press **Simulation** → **Reset** → **START**

Classification of pump

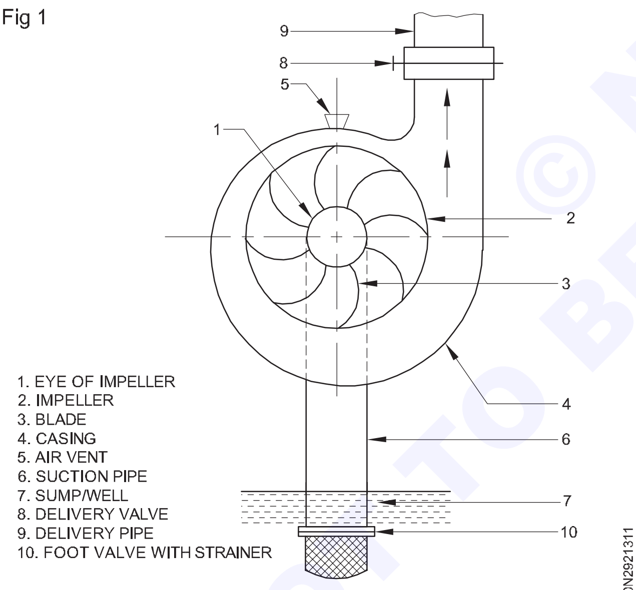
Objectives: At the end of this lesson you shall be able to
- **know about pumps and its need**
- **explain different types of centrifugal pump.**

A pump is a device used to move fluids, such as liquids, gases or slurries. It increases the mechanical energy of the fluid. The additional energy can be used to increase velocity (flow rate), pressure, elevation.



Centrifugal pump (Fig 1)

Fig 1



CENTRIFUGAL PUMP

Liquid is suck through suction pipe. Dirty particles are protected by foot valve & strainer. Through eye or the impeller liquid is suck and passes through the vanes and pressurised liquid comes out between impeller and casing to the delivery pipe and controlled by delivery valve, priming of pump is check by priming cock. Foot valve is one type of non return valve/one way valve. Liquid goes through it from sump to suction pipe but does not come back.

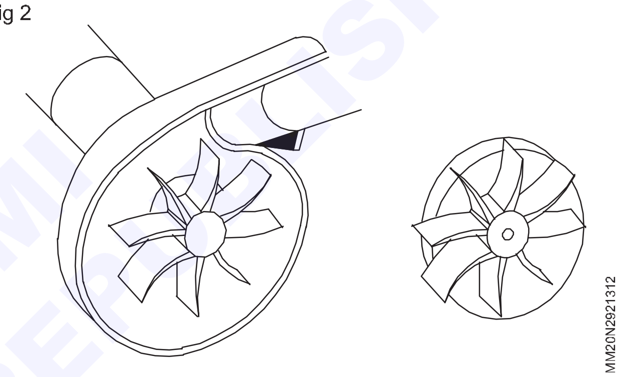
Need of pump

- Pump a liquid from lower pressure area to a high pressure area.
- To increase flow rate.
- To move liquid from lower elevation to higher elevation.

Dynamic pump

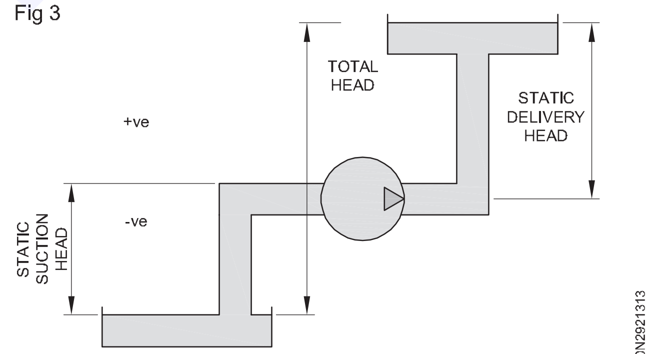
In dynamic pumps, energy is added to the fluid continuously through the rotary motion of the blades. This increase in energy is converted to a gain in pressure energy when the liquid is allowed to pass through an increased area. (Fig 2)

Fig 2



Basic terms (Fig 3)

Fig 3



PUMP HEAD

Volumetric flow rate : Flow rate/capacity of a pump is the amount of liquid delivered by the pump per unit of time (m^3/hr).

Total head : It is term that defines how high the pump can lift a liquid / pressure in terms of high.

Hydraulic power : Power transferred by the pump to the liquid.

Vacuum : Pressure lower than the atmospheric pressure.

Construction and working principle of centrifugal pump

Objectives : At the end of this lesson you shall be able to
- **explain construction of centrifugal pump**
- **describe working principle of centrifugal pump**
- **state advantages and disadvantages of centrifugal pumps.**

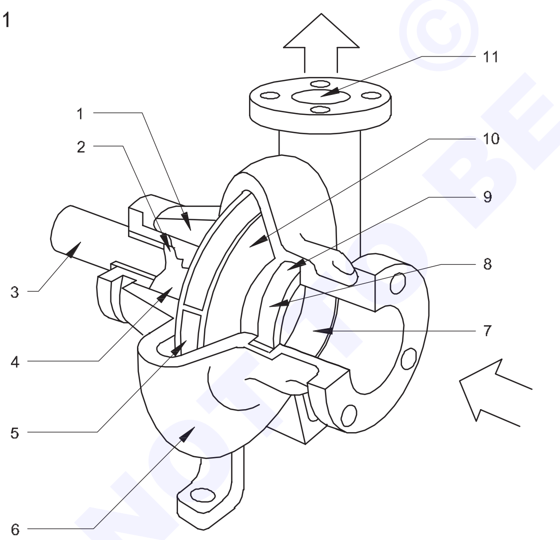
Introduction

Hydraulic systems employ centrifugal pumps **to** move fluid through a piping system. These pumps are worked centrifugal force as the fundamental principle. Centrifugal force affects an object or material moving in a circular pattern by causing it to pull away from the central axis or center point of the path along which it travels. This within a pumping unit.

Generally a centrifugal pump is based around a casting filled with fluid, usually water. A special unit within the casting exerts fast rotary motion that causes the water to spin, generating centrifugal force that channels it through a discharge outlet. Discharged water create a vacuum for atmospheric pressure to force more water out of the casting. It is a continuous process, dependent mostly on continued rotary motion and a constant supply of water Most centrifugal pumps are rotating of impellers to provide for rotary motion.

Constructional details (Figs 1 and 2)

Fig 1



1.STUFFING BOX
2.PACKING
3.SHAFT
4.SHAFT SLEEVE
5.VANE
6.CASING
7.EYE OF IMPELLER
8.IMPELLER
9.CASING WEAR RING
10.IMPELLER
11.DISCHARGE NOZZLE

PUMP HEAD

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A centrifugal pump consists of the following parts.

Impeller

It is circular disc. It is provided with a number of blades or vanes. It is fitted to a shaft. The shaft is driven by the power from an external source. The impeller rotates in a casing. The central part called the eye of the impeller connects with the sump, through the suction pipe, foot valve and strainer.

Casing

The impeller is surrounded by a chamber known as casing. It is an air tight chamber. The casing provides a gradually increasing area of flow. One end of the casing is connected to the suction pipe. The other end is connected to the delivery pipe. A priming funnel is provided on the top of casing.

Suction pipe

Top end of the suction pipe is connected to the casing. Bottom end is dipped inside the liquid.

Delivery pipe

Bottom end of the delivery pipe is connected to the outlet of the casing. The top end is connected to the required level the liquid from the outlet of the pump is conveyed to the required level by the delivery pipe.

Foot valve and strainer

It is a single unit performing the functions of a valve and strainer. Foot valve is a non-return valve. It allows the water from sump to pump. It will not allow the water from pump to sump.

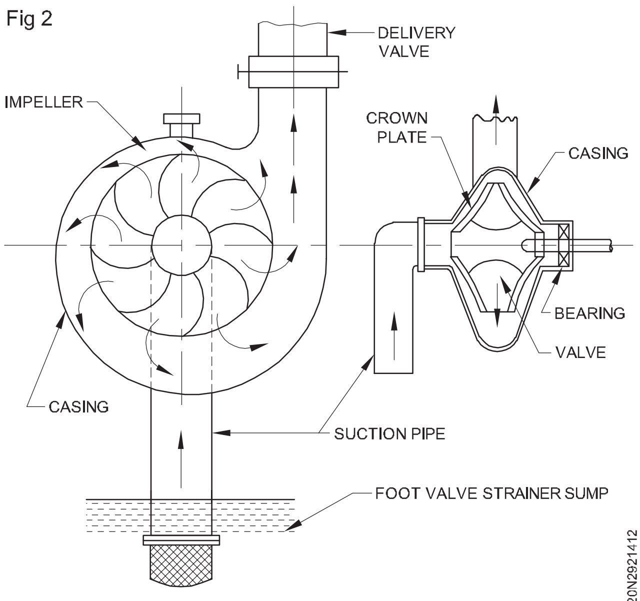
The strainer is used to prevent debris prevent in the liquid to enter into the pump. Both are fitted to the lower end of the suction pipe.

Uses of foot valves and strainers

The lower end of the suction pipe is fitted with a foot valve and strainer. It is submerged in water a few centimeters above the bottom water level. The water first enters the strainer. The strainer is used to keep the debris such as leaves,wooden pieces and other rubbish away the pump. (Fig 2)

In the absence of strainer, the foreign materials will pass through the pump and choke it thus hindering the work. Then the water passes through the foot valve to the suction pipe. The foot valve is a non-return valve or one-way valve. It allows the water from sump to pump but not from pump to sump.

Fig 2

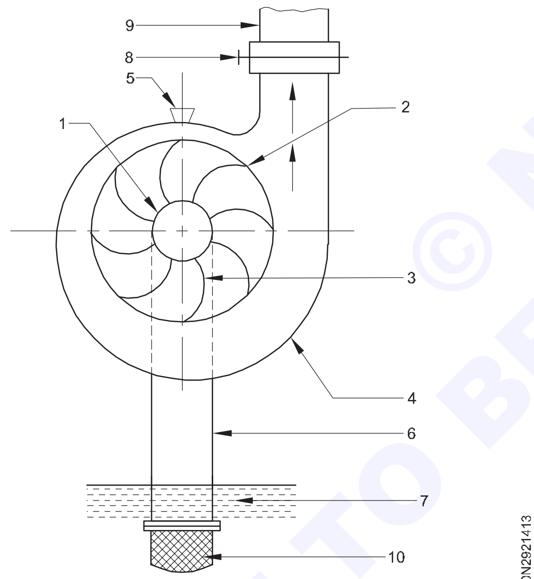


CENTRIFUGAL PUMP

Centrifugal pumps working principle (Fig 3)

These pumps work on the principle of centrifugal force and are called centrifugal pump. Water is forced up in the delivery pipe due to the centrifugal force produced.

Fig 3



CENTRIFUGAL PUMP

The Fig 3 shows the arrangement of various components of a centrifugal pump.

Before staring the pump , initially the air present in the casing and suction pipe is to be removed through air vent(5). This done by priming. Priming means filling of water in the casting,suction pipe and in delivery pipe up to delivery valve to remove air. During the priming,the delivery valve(8) is kept closed.

Then the prime mover is started to rotate the impeller(2). When the impeller rotates,the liquid between the blades(3) of the impeller is also rotated. The rotary motion imparted to liquid causes a centrifugal force to act on it.

The centrifugal force pushes the liquid towards between the outer periphery of the impeller(2) and casing(4). After the pump attains a constant speed,the delivery valve is gradually opened and the water flows radially outward by delivery pipe(9). When once the flow is commenced, a partial vacuum is continuously produced at the eye(1) of the pump. Hence water is continuously sucked through suction pipe(6) and foot valve(10) from the sump or well(7).

The liquid leaving from the impeller has a very high velocity. The kinetic energy is converted into pressure head when it flows through a suitable shape of the casing.

Advantages of centrifugal pumps

- Due to compact design, they require very small space.
- They can be fixed to high-speed driving mechanism.
- They have rotary motion due to which there is no noise.
- They are cheap in cost.
- They have simple mechanisms due to which they can be easily repaired.
- They have very simple operation.
- They cannot be damaged due to high pressure.

Disadvantages of centrifugal pumps

- The rate of flow of water cannot be regulated.
- They cannot be operated without prime movers.
- Their speed cannot always be adjusted to the prime mover without speed regulating mechanism.
- For operation they have restricted suction.
- Any air leakage on suction side will affect the efficiency of the pump.
- They have high efficiency only for low head and discharge.
- The pump will run backward, if it is stopped with the discharge valve open.

Priming, cavitation and aeration

Objectives: At the end of this lesson you shal be able to
- **describe priming and its methods**
- **state cavitation and its reason**
- **state aeration in pump.**

Priming

Priming means filling of water in the suction pipe and casing up to delivery valve of centrifugal pump. This is done for the removal of air before starting the pump. The pressure developed by the impeller of a centrifugal pump is proportional to the density of the fluid in the impeller.

Hence if an impeller runs in air having very low density,it will produce only a negligible pressure. That pressure may not be sufficient to suck water through the suction pipe. Therefore the centrifugal pump is primed. Reciprocating pump does not require priming because it is self -priming in its action.

If air is present in the cylinder and pipe, it will be sucked and delivered by the action of piston. This happens until the air is removed along with some water.

After a few stroke, When all the air has thus been removed, the pump delivers water only. Thus a reciprocating pump is self priming in its action.

The pumps can be primed in several ways. They are

- Manual priming
- Priming by vacuum and
- Self priming

In manual priming water is poured through the priming cock by a funnel and the air vent in the casing is opened. When all the air has been displaced from the suction-pipe and casing, the cock is then closed and the pump can be started.

In large pumps, priming is done by evacuating the casing and suction pipe with the aid of an air pump or ejector. Thus the water is drawn into the suction pipe from the sump. This is called priming by vacuum.

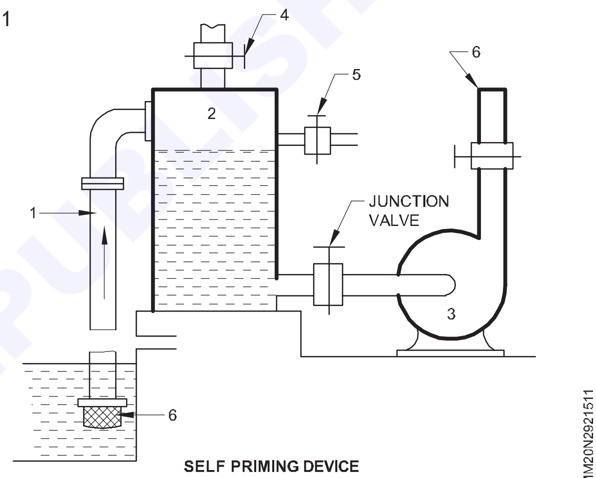
In self priming the priming is done automatically by having a special reservoir containing water between suction line and pump. Self priming devices are used with big size pump only as it requires large expenses.

Self priming device (Fig 1)

A self priming device help to avoid priming every time the pump is stopped and then started. The figure illustrates one of the types of self priming devices. In this type,a tank (2) is provided between suction pipe (1) and pump (3). The pump is connected to the bottom of the tank(2) and the suction pipe at the top.

First, water is filled in the tank through priming valve(4)up to air valve. During this time, the air valve(5) is opened. Then priming valve and air valve are closed and the pump is started. The pump draws the water from the tank and produce partial vacuum in the tank. Therefore water is sucked from the well to the tank continuously if the pump works continuously. Even if the pump stops,its casing is always filled with water. Therefore it does not require priming for restarting.

Fig 1



SELF PRIMING DEVICE

Cavitation

When a pump runs for high suction lifts,large vacuum is developed at the pump inlet. If the vacuum pressure exceeds 77 metres of water. Water commences to vaporise and causes water bubbles. When these bubbles moves from the low pressure side to high pressure side impeller they collapse suddenly. They hit the valves and may damage the valve. This damaging action is called pitting. Because of this vibrations, knocking will occur. Because of high vacuum the formation of bubbles at low pressure side and collapsing at high pressure side of the pump is called cavitation.

Reason for cavitation

- Reduction of pressure at the suction nozzle.
- Increase in temperature of the liquid.
- Increase in velocity or flow.
- Reduction of the flow, due to change in viscosity of the liquid.

Effects of cavitation

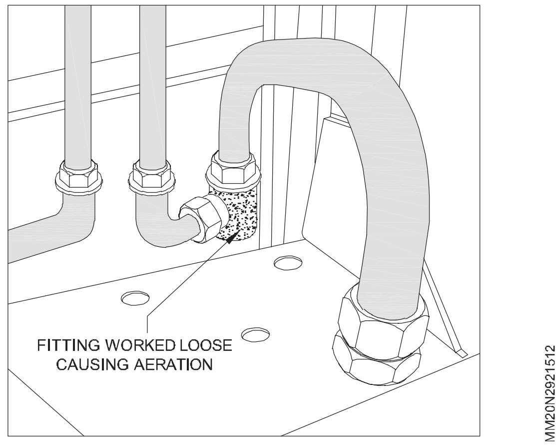
- Pitting marks on the impeller blades and on the internal volute casing wall of the pump.
- Premature bearing failure.
- Shaft breakage & other fatigue failures in the pump.
- Premature mechanical failure.

Aeration (Fig 2)

Aeration is a process where air is circulated with, mixed with or dissolved in the hydraulic fluid. It is created when air leaks into the system through the pump seals, pipe fittings and unions. These are the common areas of air leakage.

Aeration accelerates degradation of the fluid and causes damage to system components through loss of lubrication, overheating and burning of seals.

Fig 2



Charateristic, performance, gland changing procedure & mechanical Seal

Objectives: At the end of this lesson you shall be able to
- **state the pump characteristics and performance**
- **explain gland packing changing procedure**
- **describe mechanical seal.**

Characteristics of centrifugal pumps

Centrifugal pumps are specified by four characteristics.

1 Capacity

This is defined as the quantity of liquid which is discharged from the pump in a given time. Capacity is expressed in ‘m^3/hr’, ‘gal/min’, etc. The capacity of a pump is governed by the ‘head’, the ‘speed’ and the ‘size’ of the pump.

2 Total head

The total head of a pump is the difference between the pump suction and discharge pressures-expressed in terms of metres or feet head.

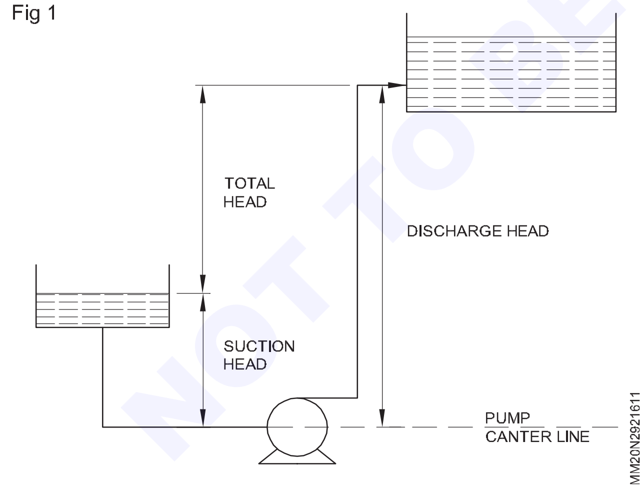
Suction head : This is the vertical distance, in feet or metres, from the centre line of the pump to the level of liquid in the vessel from which the liquid is being pumped.

If the liquid level is above the pump centre line, the suction head is positive. If below the centre line, the suction head is negative.

Discharge head : Is the discharge pressure of the pump, expressed in feet or metres of liquid.

Total head = Discharge head - Suction head (Fig 1)

Fig 1



3 Power

This is the energy used by the pump in a given time. Its unit is ‘Horsepower’ (HP). 1 HP is equivalent to 0.746 kilowatt (KW).

4 Efficiency

This is a percentage measure of the pump’s effectiveness in transferring the power used into energy added to the pumped liquid.

The formula for calculation of efficiency is,

Efficiency = (Output power)/(Input power) x 100%.

Pumps in industry, usually operate at 70% to 80% efficiency.

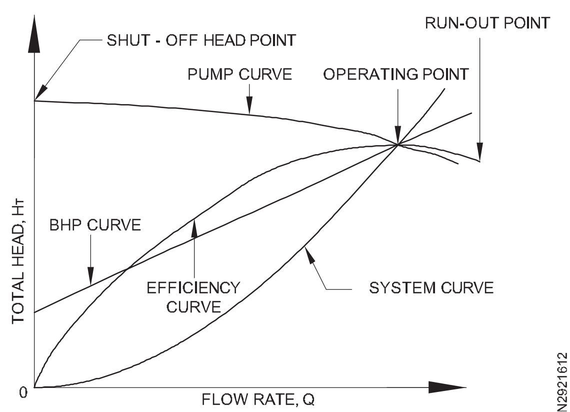
Developing a pump performance curve

A pump’s performance is show in its characteristics performance curve where its capacity i.e. flow rate is plotted against its developed head. The pump performance curve also shows its efficiency (BEP), required input power (in BHP), NPSHR, speed (in RPM), and other information such as pump size and type, impeller size, etc. This curve is plotted for a constant speed (rpm) and a given impeller diameter (or series of diameters). It is generated by tests performed by the pump manufacturer. Pump curves are based on a specific gravity of 1.0. Other specific gravities must be considered by the user.

Normal operating range

A typical performance curve (Fig 2) is a plot of Total Head vs. Flow rate for a specific impeller diameter. The plot starts at zero flow. The head at this point corresponds to the shut-off head point of the pump. The curve then decreases to a point where the flow is maximum and the head minimum. This point is sometimes called the run-out point. The pump curve is relatively flat and the head decreases gradually as the flow increases. This pattern is common for radial flow pumps. Beyond the run-out point, the pump cannot operate. The pump’s range of operation is from the shut-off head point to the run-out point. Trying to run a pump off the right end of the curve will result in pump cavitation and eventually destroy the pump.

Fig 2



TYPICAL SYSTEM AND PUMP PERFORMANCE CURVES

Understanding centrifugal pump performance curves

The capacity and pressure needs of any system can be defined with the help of a graph called a system curve. Similarly the capacity vs. pressure variation graph for a particular pump defines its characteristic pump performance curve.

The pump suppliers try to match the system curve supplied by the user with a pump curve that satisfies these needs as closely as possible. A pumping system operates where the pump curve and the system resistance curve intersect. The intersection of the two curves defines the operating point of both pump and process. However, it is impossible for one operating point to meet all desired operating conditions. For example, when the discharge valve is throttled, the system resistance curve shift left and so does the operating point.

Gland packing changing procedure in centrifugal pump

Clean and examine (Fig 3)

Fig 3

CLEAN AND EXAMINE

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Loosen gland follower nuts slowly and lift follower to release any trapped pressure under packing set.

Remove all old packing and thoroughly clean shaft/ stem and stuffing box area following plant-specified procedures.

Examine the shaft/stem for corrosion, nicks, scoring or excessive wear.

Examine other components for burrs, cracks or wear that could reduce packing life.

Check stuffing box for excessive clearances and shaft/ system for eccentricity.

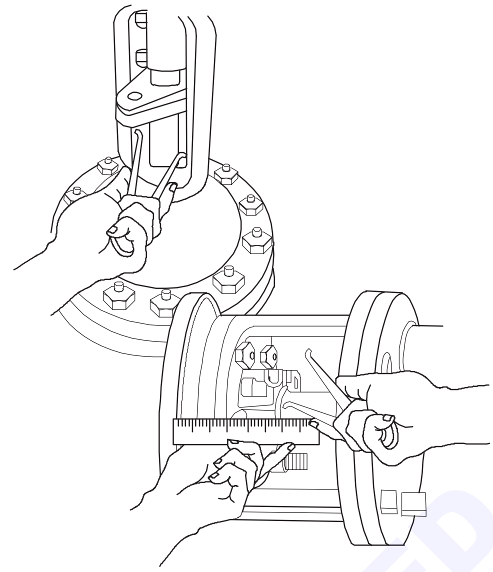
Replace any components found defective. If in doubt, seek advice.

Inspect old packing as part of failure analysis for clues to cause of premature packing failure.

Measure and record (Fig 4)

Document the shaft or stem diameter, stuffing box bore and depth, and, when using lantern rings, distance of port to bottom of stuffing box.

Fig 4



MEASURE AND RECORD

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Select packing (Fig 5)

Fig 5

SELECT PACKING

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Assure packing is as specified by packing manufacturer and/or plant engineering department to match service conditions.

Calculate packing cross section and number of rings needed from recorded measurements.

Examine packing to be sure it is free from defects.

Refer to any special installation instructions from packing manufacturer.

Ensure cleanliness of equipment and packing before proceeding.

Prepare rings (Fig 6)

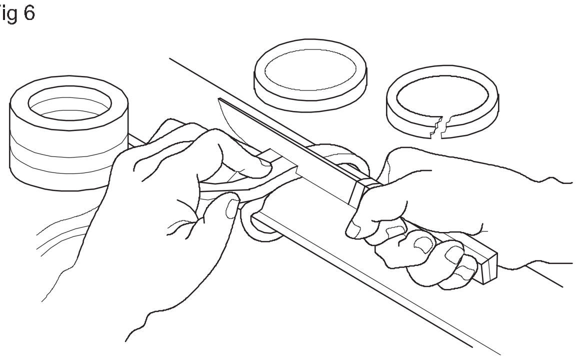
Braided

Wind packing around properly sized mandrel, or use calibrated packing ring cutter.

Cut packing cleanly,either butt (square) or skive (diagonal), per instructions from packing manufacture or plant engineering department.

Cut one ring at a time, and, using shaft or stem, check for proper sizing.

Fig 6



PREPARE RINGS

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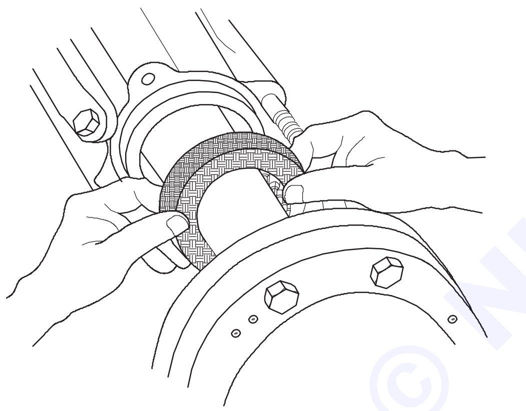
Die formed/molded

Assure that rings are sized precisely to shaft or steam. Cut rings, when necessary for installation , according to instruction from packing manufacturer or plant engineering department.

Install packing (Fig 7)

Fig 7



INSTALL PACKING

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Carefully install one ring of packing at a time.

Twist each ring over shaft/steam.

Ensure each ring is seated fully in stuffing box prior to installing next ring.

Stagger joints of subsequent rings a minimum of 90 degrees.

After last ring is installed, draw gland up evenly until nuts are finger-tight.

Check lantern ring, if used, for correct positioning relative to port.

Make sure shaft/steam turns freely.

Adjust packing pumps (Fig 8)

Take up gland nuts until finger-tight.

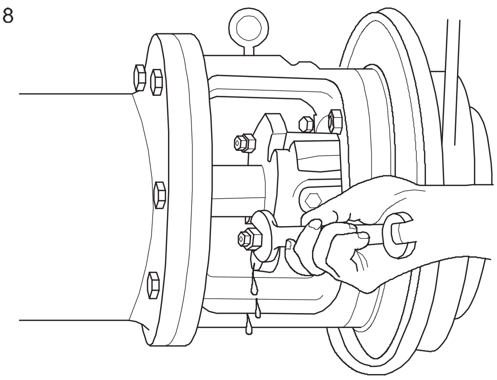
Start pump and tighteen gland nuts allowing liberal leakage.

Reduce leakage gradually by tightening gland nuts slowly until leakage reaches acceptable level.

If leakage stops abruptly, back off the gland and readjust to prevent packing from overheating.

Allow sufficient time between adjustments for leak rate to stabilize.

Fig 8



ADJUST PACKING (PUMPS)

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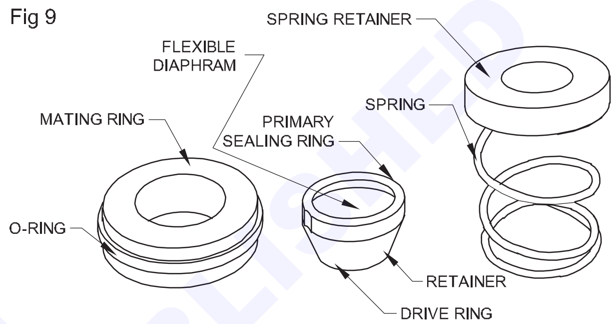
Mechanical seal (Fig 9)

Fig 9



PARTS OF MECHANICAL SEAL

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The most effective methods of preventing the leakage of the fluid from the centrifugal pump to the external surroundings is using the mechanical seals. The mechanical seals help sealing the rotating part of the shaft against the stationary part of the pump housing. Let us see more details.

What are mechanical seals in centrifugal pumps and why they are required?

In the centrifugal pumps the rotor, on which the impeller is mounted, revolves in the stationery housing of the pump and there is minor gap between the two. The centrifugal pump pumps a variety of fluids and sometimes these fluids can be highly hazardous to the humans and also the environment.

The most effective method of preventing the leakage of the fluid from the centrifugal pump to the external surrounding is using the mechanical seals. The mechanical seals help sealing the rotating part of the shaft against the stationary part of the pump housing. Thus the mechanical seals are the devices that form the packing between the rotor and the stationary part of the centrifugal pumps to prevent the leakage of the fluid being pumped by the pump. There are two main parts of the mechanical seals: one is the stationary part, which is connected to the pump housing and the other is the rotating part which is connected to the rotating shaft.

Prior to the mechanical seals, the compression packing like gland packing were used as the sealants though they are still being used in number of applications. The mechanical seals are especially used in the process applications where the pumps handle hazardous chemicals like HCL, sulfuric acid,etc. to meet the safety and the environmental standards as per the federal regulations.

Advantages of mechanical seals over glands (compression packing)

The advantages of mechanical seals over compression packing or glands are

- Mechanical seals ensures almost zero or very little (as per the regulations leakage of the fluid from the pump casing to the surroundings.
- The mechanical seals can sustain high pressures of the fluids and highly corrosive fluids. There is always some leakage from the compressible packing and sometimes they tend to fail under the deteriorating effects of the chemicals, but such problems do not occur with the mechanical seals.
- There is no friction between the moving parts of the mechanical seal so there is no extra power consumption by the pump.
- There is no wearing of the shaft or the sleeve on which the mechanical seal is mounted.
- The mechanical seals are robust components so they require very less maintenance.
- The mechanical seals are now available in wide variety of designs suitable for number of applications.

Preventive and schedule maintenance of centrifugal pumps

Objectives: At the end of this lesson you shall be able to
- **know daily maintenance**
- **know monthly maintenance**
- **know quarterly maintenance**
- **know annual inspection and maintenance**
- **prepare preventive and scheduled maintenance list.**

Maintenance of pumps

i) Daily observations and maintenance

- Daily maintenance
- Check the pump, motor and other accessories.
- Coupling bushes/rubber spider.
- Check stuffing box, gland etc.

ii) Routine observations of irregularities

Tile pump operator should be watchful and should take appropriate action on any irregularity noticed in the operation of the pumps, particular attention should be paid to the following irregularities .

- Changes in sound of running pump and motor.
- Abrupt changes in bearing temperature.
- Oil leakage from bearings.
- Leakage from stuffing box or mechanical seal.
- Changes in voltage.
- Changes in current.
- Changes in vacuum gauge and pressure gauge readings.
- Sparks or leakage current in motor, starter, switch gears, cable etc.
- Overheating of motor, starter, switch gear, cable etc.

iii) Record of operations and observations

A log book should be maintained to record the hourly observations. Which should cover the following items.

- Timings when the pumps 'are started, operated and stopped during 24 hours.
- Voltage in all three phases.
- Current drawn by each pump-motor set and total current drawn at the installation.
- Frequency.
- Readings of vacuum and pressure gauges.
- Motor winding temperature.
- Bearing temperature for pump and motor.
- Water level in intake/sump.
- Flow meter reading.
- Daily PF over 24 hours duration.
- Any specific problem or event in the pumping installation or pumping system e.g. burst in pipe line, tripping or fault, power failure.

iv) Monthly maintenance

- Check free movement of the gland of the stuffing box; check gland packing and replace if necessary.
- Clean and apply oil to the gland bolts.
- Inspect the mechanical seal for wear and replacement if necessary.
- Check condition of bearing oil and replace or lop up if necessary.

v) Quarterly maintenance

- Check alignment of the pump and the drive. The pump and motor shall be decoupled while correcting alignment and both pump and motor shafts shall be pushed to either side to eliminate effect of the end play in bearings.
- Clean oil lubricated bearings and replenish with fresh oil. If bearings are grease lubricated, the condition of the grease should checked and replaced replenished to correct quantity. An anti - friction bearing should have its housing so packed with grease that the void space in the bearing housing should be between one third to half. A fully packed housing will over heat the bearing and will result in reduction of life of the bearing.
- Tighten the foundation bolts and holding down bolts of pump and motor mounting on base plate or frame.
- Check vibration level with instruments if available, otherwise by observation.
- Clean flow indicator, other instruments and appurtenances in the pump house.

vi) Annual Inspections and maintenance

A very thorough, critical inspection and maintenance should be performed once in a year. Following items should be specifically attended.

- Clean and flush bearings with kerosene and examine for flaws developed, if any e.g. Corrosion, wear and scratches. Check end play. Immediately after cleaning the bearings should be coated with oil or grease to prevent ingress of dirt or moisture.

- Clean bearings housing and examine for flaws, e.g., wear grooving etc. Change oil or grease in bearing housing .
- Examine shaft sleeves for wear or scour and necessary rectification. If shaft sleeves are not used. shaft at gland packing should be examined for wear.
- Check stuffing box. Glands, lantern ring, mechanical seal and rectify if necessary.
- Check clearances in wearing ring.
- Check impeller hubs and vane tips for any pitting or erosion.
- Check interior or volute, casing and diffuser for pitting erosion and rough surface.
- All vital instruments i.e. pressure gauge, vacuum gauge, ammeter, voltmeter, wattmeter, frequency meter, tachometer, flow meter, etc. Shall be calibrated.
- Conduct performance test of the pump for discharge, head and efficiency.
- Measures for preventing ingress of flood water shall be examined. Ingress of flood water in sump, well, tube well or bore well shall be strictly prevented. Seal cap shall be provided above tube well/ bore well.

11 Check vibration level.

vii) Overhaul or pump

- It is difficult to specify the periodicity or interval for overhaul in the form of period of service in months/ years or operation hours, as deterioration of pump depends on nature of service, type of installation i.e. wetpit or drypit, quality of water handled, quality of material of construction, maintenance, experience with particular make and type of pump etc.
- However generally, following operational hours may be taken as broad guidelines for overhauling.

  Submersible pump - 5000 - 6000 hours

  Vertical turbine pump - 12000 hours

  Centrifugal purnp - 15000 hours

Recommended preventive maintenance checks and schedule maintenance for centrifugal pumps and drives

Interval	Routines
Daily	Check pump for noisy bearings and cavitation.
Daily	Check bearing oil for water and discoloration.
Daily	Feel all bearings for temperature.
Daily	Inspect bearings and oil rings through filing ports. Wipe bearing covers clean.
Daily	Check oil leaks at the gaskets.
Daily	Self flush pumps - Hand check the flush line temperature to determine flow through the line. External flush pumps - Determine if flow indicator and needle valve adjustment are functioning properly.
Daily	Determine if the mechanical seal conditions are normal.
Daily	Check any water cooling for effective operation. Hand test differential across coolers, jackets and exchangers. Disassemble and clean as required.
Daily	Check the operability of the heat tracing.
Daily	Determine if steam leakage at packing and glands is normal.
Daily	Check for leaks at pressure casing and gaskets. Determine if steam traps are operating properly- no continuous blow & water in casing or drain.
Monthly	Add oil to the bearing reservoirs, if required.
Monthly	Clean oiler bulbs and level windows as required.
Monthly	Make sure that the oil level is the correct distance from the shaft center line. Adjust if necessary.
Monthly	Clean out debris from bearings brackets. Drain hole must be open.
Monthly	Change oil in hydraulic governors.
Monthly	Determine if hydraulic governor heater is working.
Monthly	Check for proper oil level & leaks at hydraulic governor. Check for oil leaks at lines, fittings & power piston.
Monthly	Replace guards (repair if required).
Monthly	Determine if pump unit requires general clean by others.

Recommended preventive maintenance checks and schedule maintenance for centrifugal pumps and drives

Interval	Routines
6 Months	Machines not running – Stand by service: Overfill bearing housing to bottom of the shaft and rotate several turns by hand to coat the shaft and the bearing with oil.
6 Months	Apply a light coat of rust preventive product to expose machined surfaces to prevent rust and corrosion.
6 Months	Clean & oil governor & valve steams.
6 Months	Exercise over speed trip & valve steam linkage on turbines not running.
Yearly	Thoroughly inspect disc coupling for signs of wear & cracks in laminations. Tighten bolts.
Yearly	Using a dial indicator, Check the coupling alignment with the equipment coupled. Use special coupling indicator clamps where possible. Ensure that thermal growth allowances is correct.
Yearly	Using an indicator clamped on the coupling depress and lift on each coupling and note the dial indicator change. Determine if the deflection is normal for this machine. Refer to OEM manual.
Yearly	Using an indicator Check axial float of the pump & the driver shaft in similar manner.
Yearly	Remove turbine sentinel valve, Shop test & adjust to proper setting.
Yearly	Inspect trip and throttle valve stems and their linkage for wear. Check over speed mechanism for wear. (Turbine must be down).
Yearly	Remove mechanical the governor cover & inspect fly ball seat, spring ,bearing &plunger for wear.
Yearly	Uncouple from pump & over speed turbine. Ensure that trip valve will stop turbine with steam supply valve (throttle valve) fully open. Compare tripping speed with previous records. Adjust trip mechanism & repeat procedure. Follow manufacturers instructions when making adjustment.
Yearly	Where the process will allow it, test run the turbine coupled to the pump. When not possible, run the turbine uncoupled. With the tachometer – verify proper governor operation & control. Determine if hand (booster) valves are completely closed when required to carry load. This influences steam economy.

Seasonal	
Fall & Summer	Do a seasonal oil change out, if required by OEM lubrication guide.
Fall	Where cooling water is decommissioned ensure that no water remains in the jackets, cooler and piping.
Fall	Inspect for damaged or missing insulation.
Fall	Reestablish steam flow or electrical tracing continuity.

Fan - construction, working principle and types

Objectives: At the end of this lesson you shall be able to
- **define fan**
- **state the parts of fan**
- **explain different by types of fan.**

Fan

- Any device that produces a current of air by the movement of broad surfaces can be called a fan.
- Fans fall under the general classification of "turbo machinery" and have a rotating impeller at least partially encased in a stationary housing.
- Fans are similar in many respects to pumps. Both are turbo machines that transfer energy to a flowing fluid. It is easy to distinguish between fans and pumps; pumps handle liquids; fans handle gasses.
- Broadly speaking, the function of a fan is to propel, displace or move air or gas.

Parts of fan (Fig 1 & 2)

The list of fan spare parts are as follows: set of bearings, coupling, belts, sheaves, bushings.

Fig 1

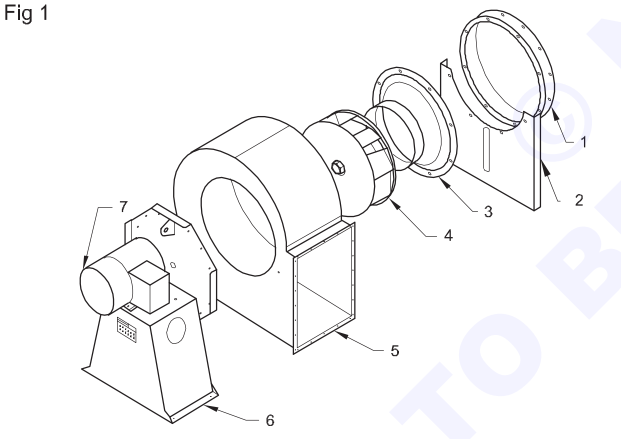
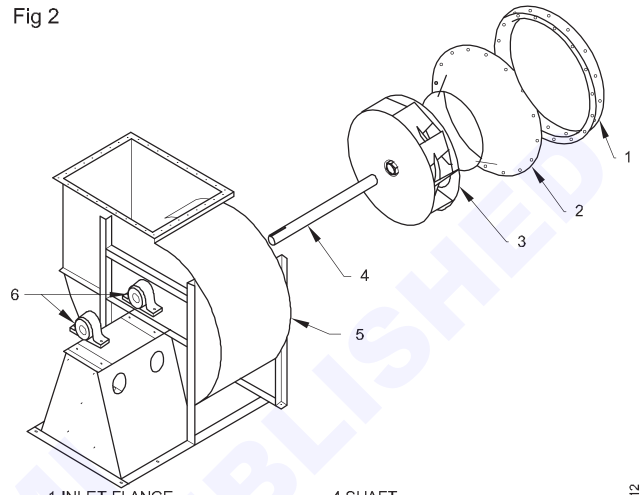


Fig 2



Fan types

Fans are classified according to the direction of flow through the impeller.

Axial flow : Air flows through the impeller parallel to, and at a constant distance from the axis. The pressure rise is provided by the direct action of the blades (Fig 3)

Centrifugal or radial flow: Air enters parallel to the axis of the fan and turns through 90^0 and is discharged radially through the blades. The blade force is tangential causing the air to spin with the blade and the main pressure is attributed to this centrifugal force (Fig 4)

Mixed flow: Air enters paralled to the axis of the fan and turns through an angle which may range from 30^0 to 90^0. The pressure rise is partially by direct blade action and partially by centrifugal action. (Fig 5)

Cross flow: air enters the impeller at one part of the outer periphery flows inward and exits at another part of the outer periphery.

Fig 3

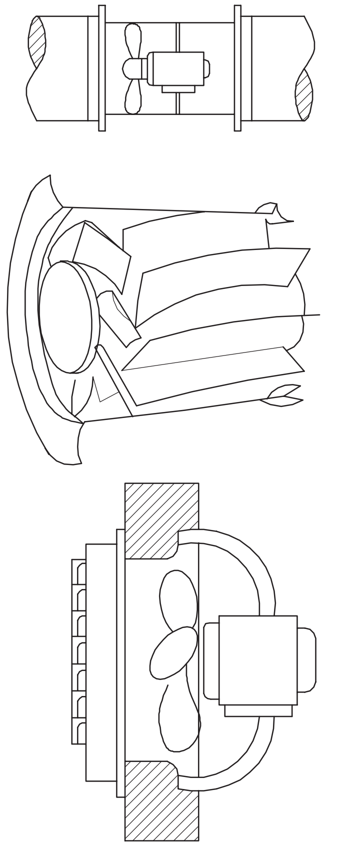


Fig 4

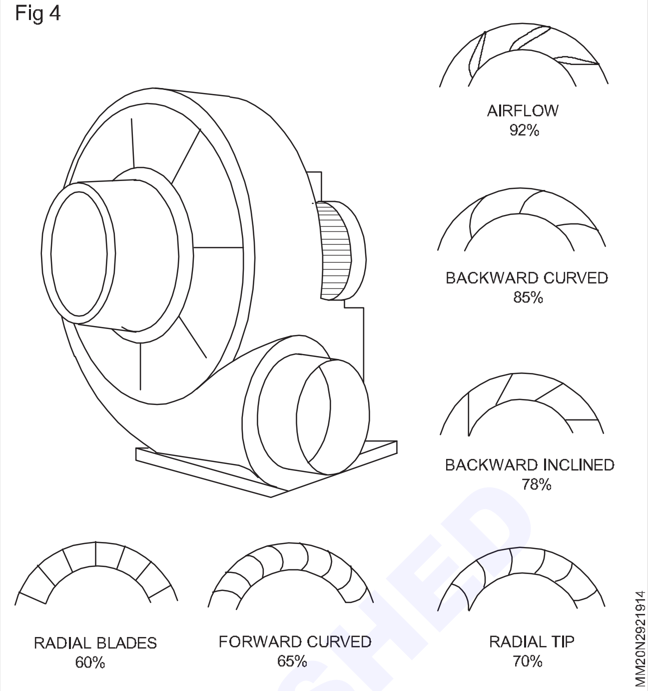
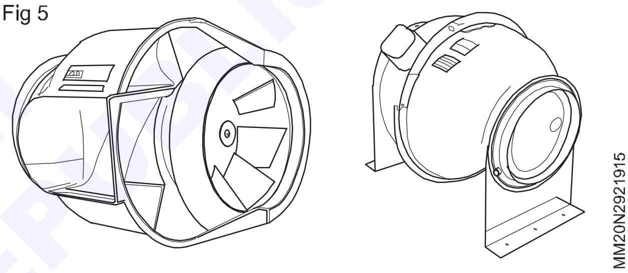


Fig 5



Type, characteristics and application of axial fans

Type	Characteristics	Typical applications
Propeller	Low pressure, high flow, low efficiency, peak efficiency close to point of free air delivery (Zero static pressure)	Air circulation, ventilation, exhaust
Tube axial	Medium pressure, high flow, higher efficiency than propeller type, dip in pressure flow curve before peak pressure point	HVAC drying ovens, exhaust systems
Vane axial	High pressure, medium flow, dip in pressure flow curve, use of guide vanes improves efficiency exhausts	High pressure applications including HVAC systems

Centrifugal fans (Fig 4)

- Rotating impeller increases air velocity
- Air speed is converted to pressure
- High pressures for harsh conditions
  - High temperatures
  - Moist/dirty air streams
  - Material handling
- Categorized by blade shapes
  - Radial
  - Forward curved
  - Backward inclined

Type, characteristics and application of centrifugal fans

Type	Characteristics	Typical applications
Radial	High pressure medium flow efficiency close to tube axial fans, power increases continuously.	Various industrial applications suitable for dust laden, moist air/gases.
Forward curved blades	Medium pressure, high flow, dip in pressure curve, efficiency higher than radial fans, power rises continuously.	Low pressure HVAC, packaged units, suitable for clean and dust laden air/gases.
Backward curved blades	High pressure, high flow, high efficiency, power reduces as flow increases beyond the points of highest efficiency.	HVAC, various industrial applications forced draft fans etc.
Airfoil type	Same as backward curve type, highest efficiency.	Same as backward curved, but for clean air application.

Mixed flow fan (Fig 5)

Mixed flow fan with barrel shaped spun housing for small diameters of inlet and outlet ducts. Direct drive the fan wheel has a conical back plate. Outlet guide vanes prevent excessive air spin at the small outlet diameter.

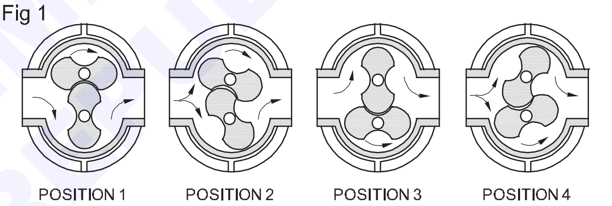
Blower - Working principle, types

Objectives: At the end of this lesson you shall be able to
- **describe the working principle of blower**
- **state the different types of blower**
- **explain the parts of blower.**

Working principle

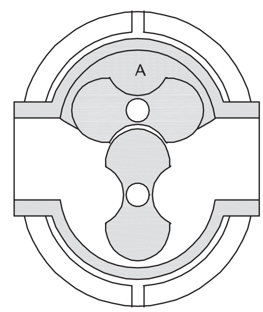
The rotary, positive displacement blower works on a very simple principle (Fig 1). As the drive shaft is rotated, the impellers turn in opposite directions with very finite clearances between each and between the rotors and the casing. As each impeller passes the inlet, a measured quantity of air is trapped between the impellers and the casing. As the shafts continue to rotate, this "pocket" of air is transported around the casing to the discharge side of the machine, where it is then expelled through the port, against the pressure prevailing in the discharge line. When this occurs, a back flow of air into the "pocket" form the higher pressure discharge line produces a constant volume pressure rise, causing a pressure pulse resulting in noise. As a "pocket" of air is expelled four times with each revolution of the drive shaft, or twice with each impeller, the fundamental frequency of the pressure pulse is four times the shaft speed. (Fig 2)

Fig 1



BLOWER OPERATING PRINCIPLE

Fig 2

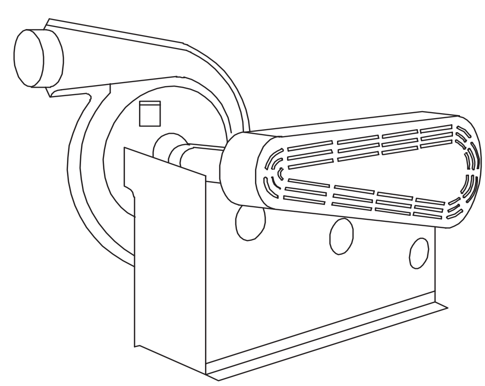


THEORETICAL VOLUME

Blower (Fig 3)

Blower are mechanical or electro-mechanical devices used to induce gas flow through ducting, electronic chassis, process stacks, etc., Wherever flow is needed for exhausting, aspirating, cooling, ventilating, conveying, and so on. Key specifications include intended application, blower type, port design, as well as the parameters of flow capacity, electrical ratings and dimensions. Blowers cool electronic enclosures, induce drafts in boilers, increase airflow on engines, and are configured in a variety of designs such as centrifugal flow or rotary lobe styles. Motors usually drive blowers, though they can be powered by other means such as engines.

Fig 3



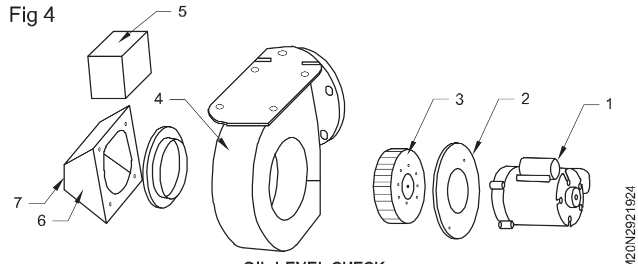
Parts of blower (Fig 4)

1 Blower motor

Blower motor act as a prime mover to rotate the blower. Generally single phase motors are used with blower having small capacity and 3 phase induction motors with starters are employed with bigger capacity blowers. Motor consists of stator and rotor. Stator is the stationary part and rotor is the rotating part.

In single phase motors mostly capacity start induction run motors are used.

Fig 4



OIL LEVEL CHECK

2 Motor mounting plate

This plate is used to mount motor in proper position with the blower. Motor mounting plate is screwed or bolted with the blower housing. It is made up of steel sheet.

3 Blower wheels

It is the heart of a blower, which helps to suck air through its centre and deliver through outer periphery of leaves or vanes. Blower wheel is fitted with motor shaft by using allen screw or small hexagonal headed bolt. Blower wheel is protected with and volute casing with is known as blower casing.

4 Blower housing

Blower housing is also known as blower casing and its main function is to provide sufficient velocity to the air flow. In order to adjust this velocity. The blower casing should be a volute casing. The blower wheel is mounted in centre portion of the casing and the area around the blower wheel is continuously varying to get required velocity energy.

5 Damper motor assembly

The main purpose of this assembly is to control the air flow through the suction side of the blower. Motor is used with sufficient mechanism to tilt the damper whenever it is needed.

6 Damper assembly

Damper assembly consists of damper with link mechanism, link mechanism is connected with damper motor. When damper motor is rotating, the damper is tilted progressively and thus the opening should varies to allow different quantities of air towards the blower. Damper assembly is fixed with suction side of the blower with hexagonal bolts.

7 Inlet cone

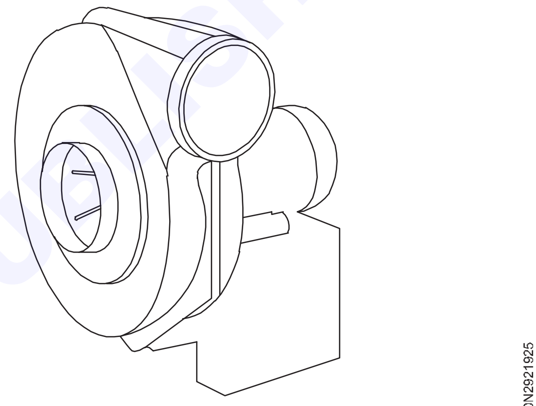
As the name denotes, it is in the shape of a cone provided at the suction end of the blower. Its function is to create sufficient inlet velocity of air.

Type of blowers

Centrifugal blowers (Fig 5)

Centrifugal blowers use high speed impellers or blades to impart velocity to air or other gases. They can be single or multi-stage units. Like fans, centrifugal blowers offer a number of blade orientations, including backward curved, forward curved and radial. Blowers can be multi- or variable speed units. They are usually driven by electric motors. Often through a belt and sheave arrangement, but some centrifugal blowers are directly coupled to drive motors. Fan speed can be changed to vary flow rates by resizing sheaves, using variable speed drives,etc., But dampers are even more common as a means of adjusting flow.

Fig 5



CENTRIGUGAL BLOWERS

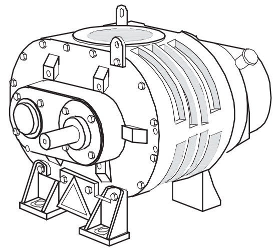
Positive displacement blowers

Positive displacement blowers are similar in principle to positive displacement pumps in that they use mechanical means to squeeze fluid and thereby increase pressure and/or velocity. Centrifugal designs, on the other hand, impart velocity and pressure to media by flinging them outward with impellers. Among positive displacement blowers,the Roots, or rotary lobe, type is common, which uses two counter-rotating lobed rotors to move fluid through the blower, much the way a gear pump moves oil or other viscous liquids. A cutaway blower (Fig 6) shows one of the two rotors. Positive displacement blowers are often driven by direct-coupled electric motors but they can be driven by gas engines, hydraulic motors,etc. in unusual circumstances.

Applications and industries

Centrifugal blowers are routinely used for combustion air suppliers, on cooling and drying systems, for fluid bed aerators, with air conveyor systems, for dust control etc. Positive displacement blowers are also used in pneumatic conveying, and for sewage aeration,filter flushing, and gas boosting,as well as for moving gases of all kinds in the petrochemical industries. Centrifugal blowers are often builts as close-coupled units, meaning that the impeller wheel is not supported by independent bearings but is cantilevered on an extension of the motor shaft and relies on the motor bearings for support. Close coupled mounting dispenses with the need for shaft couplings.

Fig 6



BLOWER

Fan / Blower - concept of surge, trouble shooting

Objectives: At the end of this lesson you shall be able to
- **describe concept of surge**
- **state the method to avoid surge**
- **describe starting and stopping of fan/ blower**
- **explain trouble shooting problems in fan/blower.**

Concept of surge and stalling

Stalling and surging are the causes for the unstable flow. This affects fan performance,blades as well as output and are thus undesirable. They occur because of the improper design, fan physical properties and, are generally accompanied by noise generation.

Stalling effect

The cause for this is the separation of the flow from the blade surfaces. This effect can be explained by the flow over and air foil. When the angel of incidence increases (during the low velocity flow) at the entrance of the air foil, flow pattern changes and separation occurs. This is the first stage of stalling and through this separation point the flow separates leading to the formation of vortices, back flow in the separated region.

Surging effect

Stalling occurs only if there is insufficient air entering into the fan blades causing separation of flow on the blade surface. Surging or the unstable flow causing complete breakdown in fans is mainly contributed by the three factors.

- System surge
- Fan surge
- Paralleling

Method to avoid surge

Some of the methods of overcome these effects are re-circulation of excess air through the fan, axial fans are high specific speed devices operating them at high efficiency and to minimize the effects they have to be operated at low speeds. For controlling and directing the flow use of guide vanes is suggested. Turbulent flows at the inlet and outlet of the fans cause stalling so the flow should be made laminar to prevent the effect.

Fan/blower startup

This startup procedure should be followed during the initial installation and after any shutdown periods or after the blower has been worked on or moved to new location. It is suggested that the steps to be followed in sequence.

1 Check the unit and all piping for foreign material and clean if required.

2 Check the flatness of the feet and the alignment of the drive. Feet that are bolted down in a bind can cause housing distortion and internal rubbing. Misaligned V-drives can cause the rotors to rub against the headplates and cause a reduction in the volumetric efficiency of the unit. Misaligned couplings can ruin bearings.

3 If the fan/blower is V-belt driven, check the belt tension and alignment. Over-tensioned belts create heavy bearing/shaft loads which lead to premature failure.

4 Be sure adequate drive guards are in place to protect the operator from severe personal injury and incidental contact.

5 Check the unit for proper lubrication. Proper oil level cannot be over-emphasized. Too little oil will ruin bearings and gears. Too much oil will cause overheating and can ruin gears and cause other damage. Insure that grease lubricated bearings are properly lubricated.

6 With motor electrical power locked out and disconnected, turn the drive shaft by hand to be certain the impellers do not bind.

7 Jog: the unit with the motor a few times to check that rotation is in the proper direction, and to be certain it turns freely and smoothly.

8 The internal surfaces of all sutorbilt units are mist sprayed with a rust preventive to protect the machine during the shipping and installation period. This film should be removed upon initial startup.

9 Start the unit and operate 15 minutes at no load. During this time, check for hot spots and other indications of interference.

10 Apply the load and observe the operation of the unit for one hour. Check frequently during the first day of operation.

11 If malfunctions occur, do not continue to operate. Problems such as knocking rotors can cause serious damage if the unit is operated without correction.

Trouble shooting

No matter how well the equipment is designed and manufactured, there may be times when servicing will be required due to normal wear, the need for adjustment, or various external cause. Whenever equipment needs attention, the operator or repairman should be able to locate the cause and correct the trouble quickly. The Trouble Shooting Chart below is provided to assist the mechanic in those respects.

Problem	Possible Causes	Solution
Knocking	1 Unit out of time.	1 Re-time impellers
	2 Distortion due to improper mounting or pipe strains.	2 Check mounting alignment pipe strains.
	3 Excessive pressure differential.	3 Reduce to manufacturer's recommended pressure. Examine relief valve,re-set if necessary.
	4 Worn gears.	4 Replace timings gears.
	5 Worn bearings.	5 Replace bearings.
Excessive blower temperature	1 Too much oil in gear case.	1 Reduce oil level.
	2 Too low operating speed.	2 Increase blower speed.
	3 Dirty air filter.	3 Clean or replace air filter.
	4 Clogged filter or muffler.	4 Remove cause of obstruction.
	5 Excessive pressure differential.	5 Reduce pressure differential across the blower.
	6 Worn impeller clearances.	6 Replace impeller.
	7 Internal contact.	7 Correct clearances.
Impeller end or tip drag	1 Insufficient assembled clearances.	1 Correct clearances.
	2 Case or frame distortion.	2 Check mounting and pipe strain.
	3 Excessive operating pressure.	3 Remove cause.
	4 Excessive operating temperature.	4 Remove cause
Lack of volume	1 Slipping belts.	1 Tighten belts.
	2 Worn clearances.	2 Re-establish proper clearances
	3 Dirty air filter	3 Clean or replace air filter.
Excessive bearing or gear wear.	1 Improper lubrication.	1 Correct lubrication level. Replace dirty oil.
Loss of oil	1 Headplate, gear case or drive cover vents plugged.	1 Clean vents.
	2 Worn seal.	2 Replace seals.

Compression theory and types of compressor

Objectives: At the end of this lesson you shall be able to
- **state the air and its characteristics**
- **describe compression theory**
- **state and explain types of compressor.**

Air and its characteristics

Air is a colourless, odourless and tasteless gas mixture. It consists of many gases, but primarily oxygen and nitrogen. Air can be considered a perfect gas mixture in most calculation contexts. The composition is relatively constant, from sea level and up to an altitude of 25 kilometers. Air is always more or less contaminated with solid particles for example , dust , sand, soot and salt crystals. The machineries and engines require air for their proper and efficient operation. Thus air plays a vital role in industries and plants. But they are usually compressed so that energy is available to perform some work.

Compressors theory (Fig 1 & 2)

The free air has some density or the given mass of gas occupies certain volume in free space. The molecules of air occupy a certain volume in free space. By compressing, the molecules of air are made to come closer, by which they occupy less space when compared to earlier (when they were free). As the number of molecules of air increases in a given volume, the mass or air also increases. As the mass of air in the given volume increases, its density also increases. As the density increases, the pressure of air increases and thus becomes compressed air.

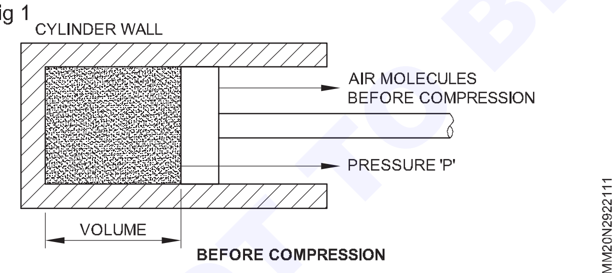
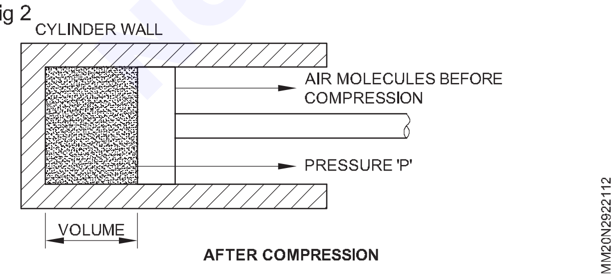
Fig 1


Fig 2


Types of air compressors

Compressors are classified in many ways out of which the common one is the classification based on the principle of operation.

1 Positive displacement and
2 Roto-dynamic compressors

Positive displacement compressors can be further divided into reciprocating and rotary compressors. Under the classification of reciprocating compressors, we have

1 Single-acting compressors. (Fig 3)
2 "V"-shaped compressors. (Fig 5)
3 In-line compressors. (Fig 4)
4 Double-acting compressors. (Fig 6)

The rotary compressors are divided into

1 Screw compressors. (Fig 7)
2 Vane type compressors. (Fig 8)
3 Lobe and scroll compressors and other types. (Fig 9)

Under the roto-dynamic compressors, we have

1 Centrifugal compressors and the
2 Axial flow compressors.

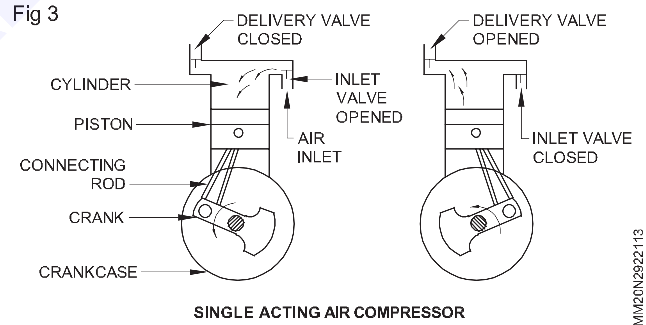
Fig 3


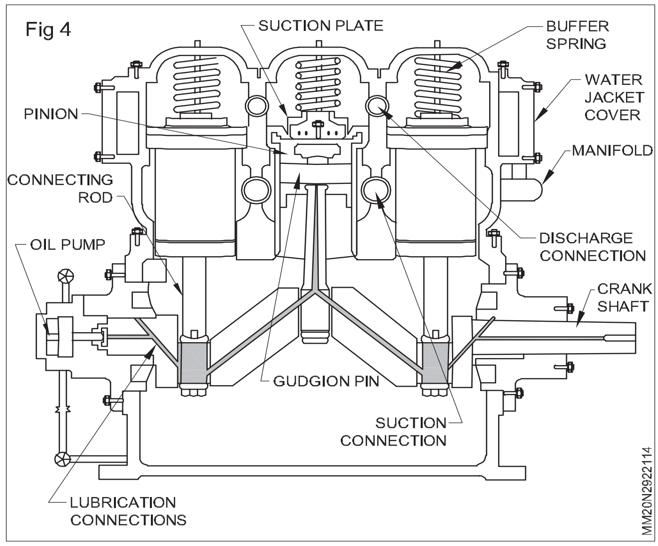
Fig 4


Fig 5

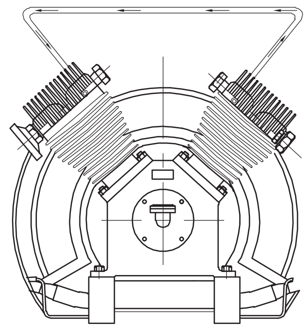
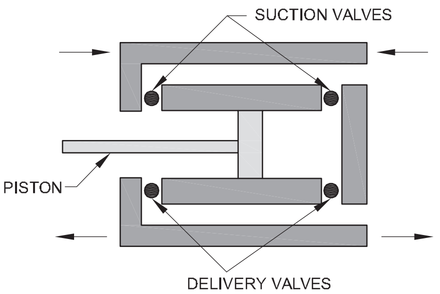


Fig 6



DOUBLE ACTING COMPRESSOR

Fig 7

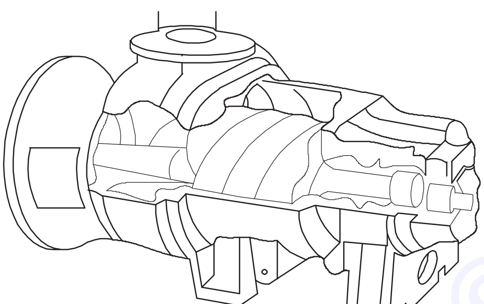
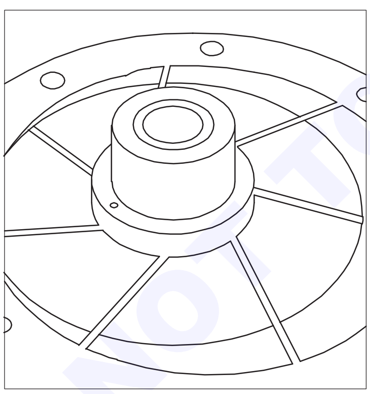


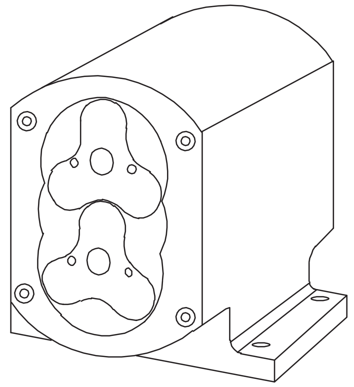
Fig 8



Reciprocating air compressors

The simple reciprocating air compressor has a piston which reciprocates inside the cylinder wall and cylinder head. The piston attached to the crankshaft with the help of a connecting rod and thus the rotation of the crankshaft causes the piston to move up and down inside the cylinder. The crankshaft is mounted on the crank case. The cylinder head contains valve pockets where the suction and delivery valve are fixed.

Fig 9



LOBE TYPE COMPRESSOR

These suction and delivery valves are of simple pressure differential types. They open and close, due to the pressure difference on either side of the valve plates.

When the compressor stops or idles for some time, it is always assumed that there is some residual compressed air left in the cylinder space. This residual air expands when the piston moves down. The pressure drops in the cylinder space at a particular point as the piston moves down, where the pressure inside the cylinder becomes lesser than the atmospheric pressure. Thus this difference in pressure makes the suction or inlet valve open. This opening of inlet valve allows fresh air to be drawn inside the cylinder space as the piston still continues to move in the downward direction. The inlet valve will remain open till there is pressure difference between the atmosphere and inside of the cylinder space. As the pressure difference starts to reduce, the inlet valve starts slowly closing.

The delivery valves starts to open when there is a pressure difference between the cylinder space and air receiver. Let us assume the air receiver is at a pressure of 7 bar. The delivery valve will not open until the pressure inside the cylinder space is slightly above 7 bar. As the piston moves in upward direction, the pressure increases and at some point the pressure grows beyond 7 bar making the delivery valve open. Thus the compressed air is delivered into the air receiver. As the piston reaches top, the pressure starts to fall and the delivery valve starts to close. The residual compressed air remaining in the space again starts to expand as the piston moves down continuing the next cycle.

Rotary compressors

These compressors are not of reciprocating nature, therefore does not have any pistons and crankshaft. Instead, these compressors have screws, vanes,scrolls, and other devices which rotate and thus compress air.

The screw compressors are efficient in low air pressure requirements. Two screws rotate intermeshing with each other, thus trapping air between the screws and the compressor casing, forming pockets which progressively travel and gets squeezed and delivering it at a higher pressure which opens the delivery valve. The compressed air delivery is continuous and quiet in operation than a reciprocating compressor.

The vane type air compressor is having a fixed casing and a rotary rotor disc which has slots for holding the sliding plates as shown in the Fig 8. As the rotor rotates, the disc also rotates, thus allowing the sliding plates to slide as the inner surface of the casing is eccentric. Thus the sliding plates moves away from the center, huge quantities of air will be trapped in, thus as the plates converge, the air gets compressed and thus results in compressed air.

The scroll type compressors are having scrolls driven by the prime mover. The scroll outer edges trap air and then as they rotate, the air travel from outwards to inwards thus getting compressed due to the reduction in area. Thus the compressed air is delivered through the central space of the scroll to the delivery air line.

The lobe type (Fig 9) air compressor is very simpler type with no complicated moving parts. There are single or twin lobes attached to the drive shaft driven by the prime mover. The lobes are displaced by 9° . Thus if one of the lobes is in horizontal position, the other at that particular instant will be in vertical position. Thus the air gets trapped in between these lobes and as they rotate they get compressed and delivered to the delivery line.

Preventive and schedule maintenance of compressors

Objectives: At the end of this lesson you shall be able to
- **state the need for preventive and scheduled maintenance**
- **prepare the check list and maintenance records for pm**
- **describe the possible causes and remedy.**

Preventive maintenance

Preventive maintenance is a schedule of planned maintenance actions aimed at the prevention of breakdowns and failures.

The primary goal of preventive maintenance is to prevent the failure of equipment before it actually occurs.

It is designed to preserve and enhance equipment reliability by replacing worn-components before they actually fail.

Scheduled maintenance

Scheduled maintenance is a stitch-in-time procedure and include.

1 Inspection

2 Lubrication

3 Repair and over haul of equipments.

It neglected can result in breakdown. Generally followed for

- Over hauling of machine
- Changing of heavy equipment oils
- Cleaning of water and other tanks etc.

Preventive Maintenance Programme

Name of the Machine/Equipment : Location of the machine/Equipment: **Annexure I**

Machine/Equipment Number :

Model No. & Make :

CHECK LIST FOR MACHINE INSPECTION

Inspect the following parameters and list the remedial measures for the defective items.

Daily preventive maintenance Inspection

Date	Parameters to be checked	Condition	Defects	Remedy
	Pressure of air Temperature of air Pressure of water Temperature of water Inter cooler air pressure Lubrication oil level Noise Vibration Any air leaks Unloader operation			
Date	**Quarterly preventive maintenance**			
	a) Compressor valve wear and dirt b) Safety valve operation c) Piston rod wear d) Crankcase sludge e) Cylinder head bolts f) Belt Tension g) Bearing wear h) Lubricator oil cups			

Yearly preventive maintenance inspection

Date	Parameters to be checked	Condition	Defects	Remedy
	1 Cylinder a) wear b) scoring c) corrosion **2 Piston rod** a) scoring **3 Piston ring** a) damage b) wear c) Tightness 4 Packing glands wear 5 Crank case wear 6 Crankshaft bearings 7 Flywheel bearings 8 Alignment of compressor with drive			

Equipment record **Annexure II**

History sheet of machinery & equipment

Description of equipment	:
Manufacturers' address	:
Supplier's address	:
Order No. and date	:
Date on which received	:
Date on which installed and placed	:
Date of commissioning	:
Size : Length x Width x Height	:
Weight	:
Cost	:
Motor particulars	: Watts/H.P./ R.P.M Phase: Volts:
Bearing/spares record	:
Belt specification	:
Lubrication details	:
Major repairs and overhauls carried out with dates	:

Maintenance records

Annexure III

Name of the machine/Equipment :

S.No.	Date	Nature of fault	Details of rectification done	Signature of in-charge

Table 1

Trouble shooting chart

Problem	Possible	Remedy
Compressor unit will not start	No power to motor.	Turn on power.
	Unloaders not operating	Repair unloaders.
		Repair or readjust controls.
	Obstruction to rotation.	Remove obstruction.
Motor overheating	Discharge pressure above rating.	Readjust control.
	Unloader setting incorrect.	Readjust unloader.
	Inlet filter clogged.	Clean or replace filter.
Overheating of compressor parts	Discharge pressure above rating.	Lower discharge pressure.
	Intake filter clogged.	Clean
	Worn or broken valves.	Replace
	Leaking gaskets.	Replace
	Unloader or control defective.	Replace
	Unloader setting wrong.	Correct
	Compressor components worn or broken.	Replace
	Cylinder head, intercooler dirty.	Clean
	Insufficient cooling water.	Increase quantity of cooling water.
	V-belt or coupling misalignment	Realign components.
	Bearing too tight.	Adjust bearings.
	Oil level too high.	Correct oil level.
	Lubrication inadequate.	Correct oil level. Correct oil pressure.
		Ensure correct oil. Viscosity is being used.
	Ambient temperature too high.	Lower ambient temperature. Increase ventilation.
	Valves dirty.	Clean valves.
	Belts too tight	Readjust belt tension.
	Packing too tight.	Readjust packings.
Delivery of air less than rated capacity	System leaks excessive.	Stop leaks.
	Intake filter clogged.	Clean or replace filter as applicable.
	Valves worn or broken.	Replace worn or broken valves.
	Belts slipping.	Tighten.
	Speed lower than rating.	Increase speed.
	Compressor components worn or broken.	Replace.
	Control device inoperative	Repair or adjust control device.
	Water quantity insufficient.	Increase water quantity.
	Inlet temperature too high.	Check water quantity and temperature at inter cooler.

Table 1-2 Trouble shooting chart (continued)

Problem	Possible	Remedy
Excessive vibration of compressor	Mounting bolts loose	Tighten mounting bolts.
	Misalignment of belt pulleys or drive couplings	Realign as necessary.
	Bearings out of adjustment or excessively worn.	Adjust or replace bearings.
Outlet water temperature above normal	Cylinder, head or intercooler dirty.	Clean compressor system parts.
	water quantity insufficient.	Increase cooling water supply.
	Compressor speed too high.	Slow down compressor.
Compressor noisy or knocks	Discharge pressure above rating.	Lower discharge pressure.
	Belts slipping.	Readjust belts.
	V-belts or coupling misaligned.	Realign.
	Pulley or flywheel loose.	Tighten pulley or flywheel mountings.
	Drive motor or compressor mounting bolts loose.	Tighten mounting bolts.
	Lubrication inadequate.	Increase oil level or pressure.
		Use correct oil viscosity.
	Intercooler vibrating.	Check for loose mounting hardware.
Operating cycle Lasts too long	Discharge pressure above rating.	Readjust control.
	Worn or broken internal compressor parts.	Replace worn or broken parts.
	Unloader or control device defective.	Replace defective device
Air receiver pressure above normal	Unloader or control defective.	Repair or replace defective parts.
	Unloader setting wrong.	Correct unloader setting.
	Leaks in control air piping.	Stop leaks.
	Control air line clogged.	Unclog control air lines.
Intercooler pressure above normal	Valves worn or broken.	Replace valves.
	valves not seated or incorrectly located.	Reseat or relocate valves.
	Unloader setting wrong.	Correct unloader setting.
	Intercooler passages clogged.	Clean intercooler.
	Insufficient water.	Increase water supply.

Table 1-2 Trouble shooting chart (continued)

Problem	Possible	Remedy
Intercooler pressure below normal.	System deman exceeds rating.	Upgrade compressor.
	System leakage excessive.	Stop leakage.
	Intake filter clogged.	Clean or replace air filter as applicable.
	Valves worn or broken.	Replace worn or broken valves.
	Unloader setting wrong.	Correct unloader setting.
Air in receiver too moist	Moisture separator not draining.	Unclog or repair separator drain.
	Air coolers ineffective.	Check temperature or cooler at discharge port.
	Inadequate cooling water flow rate.	Check cooling waterflow pressure.
Oil in air receiver	Clogged air fiter.	Clean or replace air filter element.
	Broken piston and/or rings.	Replace broken parts.
	Oil level too high.	Correct oil level.
	Oil viscosity incorect.	Change lubricant to proper viscosity.
	Oil wrong type.	Change lubricant to proper viscosity.
	Unloaded running time too long.	Use auto start/stop control.
Surging of distribution air	Operating at less than designed minium flow.	Increase flow of compressor
		Install surge control valve is discharge line.
Cavitation of water in cooling supply	Feed water level too low.	Increase feedwater level in reservoir.
	Air leaks into suction piping.	Stop leaks.

Loading and unloading of compressor and air dryer

Objectives: At the end of this lesson you shall be able to
- **describe loading and unloading of compressor**
- **state the concept of air dryer**
- **state the types of air dryer.**

Loading and unloading of compressors

Frequently require a constant pressure in the compressed air system, which makes demands on the ability to be control the compressed air flow from the compressor centre. There are number of methods for this depending on,e.g. the type of compressor, permitted pressure variations, consumption variations and acceptable losses. Energy consumption represents approx. 80% of the total cost for compressed air, which means that you should carefully consider the choice of regulation system.

There are two main groups of such regulation systems.

1 **Continuous capacity regulation** - This involves the continuous control of the drive motor valve according to variations in pressure. The result is normally pressure variations (0.1 to 0.5 bar), depending on the regulation system's amplification and its speed.

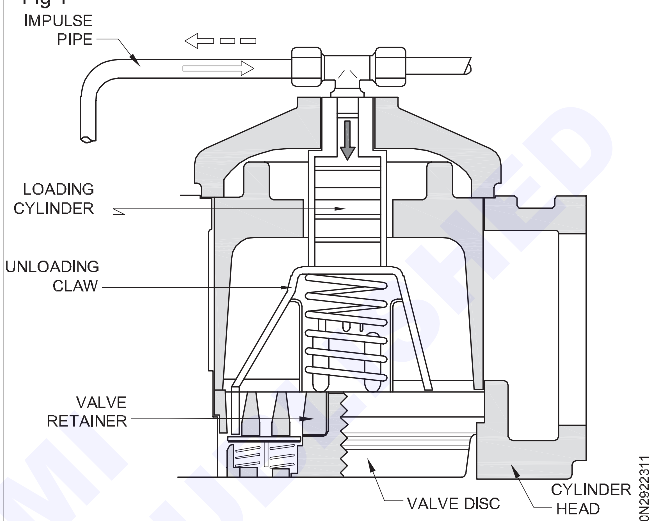
2 **Load/unload regulation** is the most common regulation system and involves the acceptance of variations in pressure between two values. This takes place by completely stopping the flow at the higher pressure (off-loading) and resume the flow rate (loading) when the pressure has dropped to the lowest value. Pressure variations depend on the permitted number of load/unload cycles per time unit, but normally lie within the range 0.3 to 1 bar.

The most common regulation principles for displacement compressors are "produce air"/"don't produce air" (loaded/unloaded) and are attained through the following ways.

1 Suction valve unloading

Piston compressors can be effectively relived by mechanically forcing the intake valves to the open position. Air is then pumped out and in under the position of the piston, with minimal energy losses as a result, often lower than 10% of the loaded shaft power. On double acting compressors there is generally multi-stage off -loading, where one cylinder at a time is balanced to better adapt the capacity to the demand. An odd method used on process compressors is to allow the valve to be open during a part of the piston stroke and thereby receive a continuous flow control. By varying the clearance volume on a piston compressor the degree of filling decreases and thereby the capacity. The clearance volume is varied by means of an externally connected volumes. This can be achieved by using off loading devices as shown in Fig 1.

Fig 1



UNLOADING DEVICE FOR A PISTON COMPRESSOR

2 Load-unload-stop

The most common regulation method used for compressors greater than 5 kW that combines a large regulation range with low losses. In practice a combination of the start/stop and different off-loading systems. The common regulation principles for displacement compressors are "produce air"/"don't produce air" (loaded /unloaded)

When air is required a signal is sent to a solenoid valve, which in turn guides the compressor's intake damper to the fully open position. The damper is either fully opened (loaded) or fully closed (unloaded), there is no intermediate position.

The traditional control, now common on smaller compressors, has a pressure switch placed in the compressed air system that has two set table values, one for the minium pressure(=loaded) and one for maximum pressure (unloaded). The compressor will then work within the limits of the set valves, for example, 0.5 bar. If the air requirement is small or nothing the compressor runs off -loaded (idling). The length of the idling period is limited by a timer (set e.g. to 20 minutes). When the time elapses, the compressor stops and does not start again until the pressure has dropped to minimum value. This is traditional tried and trusted control method. The disadvantage is that it gives slow regulation

A further development of this traditional system is to replace the pressure switch with and analogue pressure transducer and a fast electronic regulation system. If no air is used the pressure will remain constant and the compressor will run off loaded (idling).

Air dryer

A compressed air dryer is used for removing water vapor from compressed air.

Compressed air dryers commonly found in a wide range of industrial commercial facilities.

Usage

Drying air for use in commercial or industrial processes that demand dry air:

Telecom industry (pressurizes its underground cables to repel moisture and avoid shorts).

Painting.

Pneumatic tools.

Textile manufacturing.

Pneumatic control systems.

Feed air for zeolite type oxygen and nitrogen generators.

Dental office air.

Truck and train air brake systems.

The process of air compression concentrates atmospheric contaminates, including water vapor. This raises the dew point of the compressed air relative to free atmospheric air and leads to condensation within pipes as the compressed air cools downstream of the compressor.

Excessive water in compressed air, in either the liquid or vapour phase, can cause a variety of operational problems for users of compressed air. These include freezing of outdoor air lines, corrosion in piping and equipment , malfunctioning of pneumatic process control instrument, fouling of processes and products and more

There are various types of compressed air dryers. Their performance characteristics are typically defined by the dew point.

- Refrigeraed dryers
- Deliquescent dryers
- Desiccant dryer
- Membrane dryers

Refrigerated dryer

Refrigeration dryers employ two heat exchangers, one for air-to-air one for air-to-refrigeration. These dryers are used in refrigeration compressors.

Deliquescent dryer

A deliquescent dryer typically consists of a pressure vessel filled with a hygroscopic medium that absorbs water vapor. The medium gradually dissolves-or deliquesces-to form a solution at the base of the pressure vessel. The liquid must be regularly drained from the vessel and new medium must be added.

Deliquescent dryers are used for removing water vapour from compressed air, natural gas, and waste gases.

Desiccant dryer

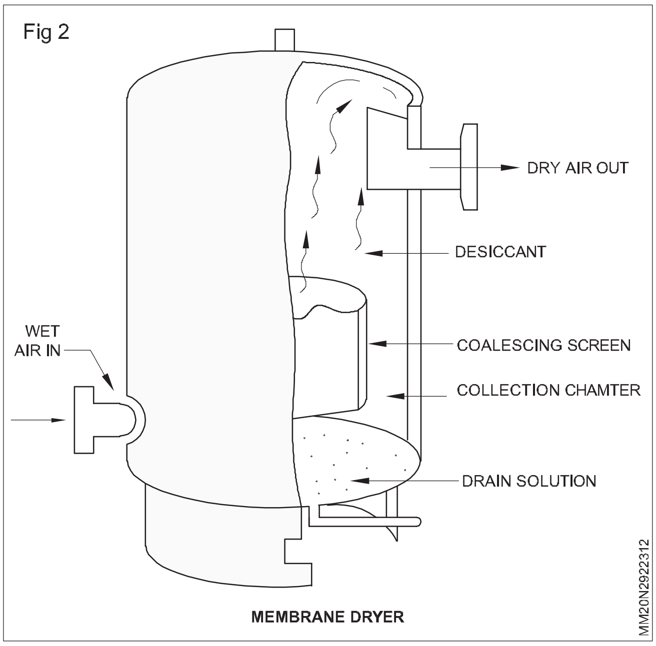
The term “desiccant dryer” refers to a abroad class of dryers. Other terms commonly used are regenerative dryer and twin tower dryer, and to a lesser extent absorption dryer.

The compressed air is passed through a pressure vessel with two “towers” filled with a media such as activated alumina, silica gel, molecular sieve or other desiccant material. This desiccant material attracts the water from the compressed air via adsorption.

Membrane dryer (Fig 2)

Membrane dryer refers to a dehumidification membrane that removes water vapor from compressed air. Typically, the compressed air is first filtered with a high-quality coalescing filter. This filter removes liquid water, oil and particulate from the compressed air. The water vapor-laden air then passes through the center bore of hollow fibers in the membrane bundle. At the same time, a small portion of the dry air product is redirected along the outside surface of the fibers to seep out the water vapor which has permeated the membrane. The moisture-laden sweep gas is then vented to the atmosphere, and clean, dry air is supplied to the application. The membrane air dryers are designed to operate continuously, 24 hours per day, 7 day per week. Membrane air dryers are quiet, reliable and require no electricity to operate.

Fig 2



Jacks

Objectives: At the end of this lesson you shall be able to
- **state the working principle of screw jack**
- **state the working principle of hydraulic jack**
- **mention safety points related to jacking of loads.**

Jacks

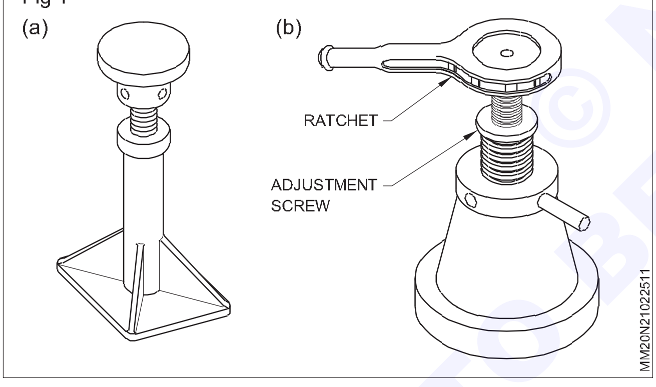
Jacks are portable hand operated devices for lifting and lowering heavy loads through a short distance. Some jacks are so designed as to extend or adjust the screw so that they can lift over a range of heights, but it should be noted that the extension should be kept minimum to get maximum stability of the jack.

Type of jack

Screw jack

A screw jack works on 'screw and nut' principle. For one complete rotation of the screw, it lifts the load to a distance equivalent to screw pitch. In a screw jack, the screw is rotated by an ordinary lever or by a ratchet lever,fitted to the screw head. Screw jacks are available in capacities up to 24 tones and lifting height up to 35 cm. (Fig 1a & 1b).

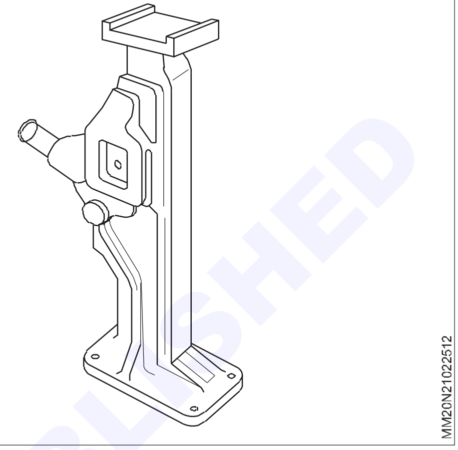
Fig 1



Rack and lever jack

A rack and lever jack may be used to lift the load either by the top or by the toe extending from the bottom of the housing of the jack. A lever pawl is used to raise or lower the bar. It is available in capacities up to 20 tones. (Fig 2)

Fig 2



Hydraulic jack

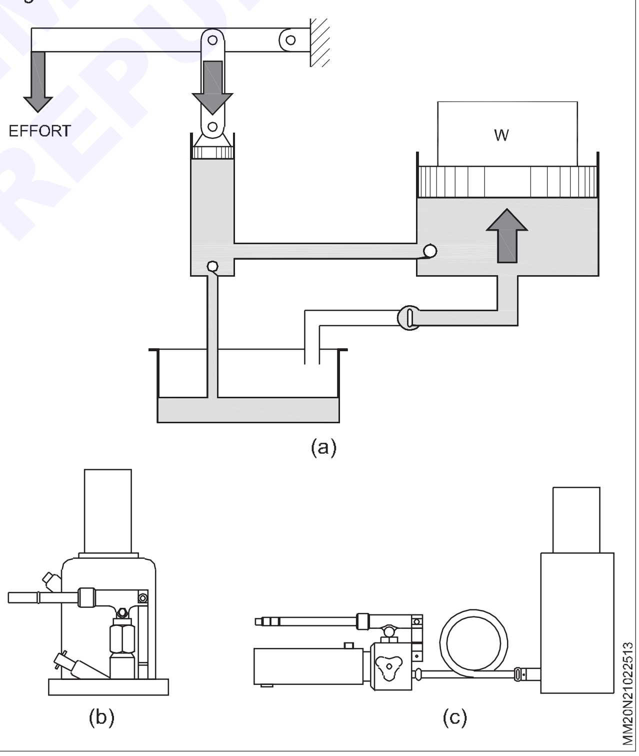
A hydraulic jack ideal for lifting and lowering heavy loads with precise control, In the principle of hydraulic jack, and available pressure can produce greater force by increasing the working piston area. (Fig 3a) Hydraulic jack is available in the capacities from 2 tonne to 1000 tonne and lifting ranges up to 50 cm.

Types of hydraulic jack

1 Integral pump type jack (Fig 3b)

2 Remote control pump type jack (Fig 3c).

Fig 3



The safe working load of a jack must be greater than the load to be lifted by the jack. Safe working load for mechanical screw jack-2 tones to 20 tones and that for hydraulic jack 5 tones to 1000 tones. In case of using more than one jack at a time for lifting a particular load, safe working load of the jacks should be considered.

Screw jack

Objectives: At the end of this lesson you shall be able to
- **state the two types of screw jack**
- **identify the parts of a screw jack**
- **state the function of a screw jack**
- **calculate the mechanical advantage, velocity ratio and efficiency of a screw jack.**

Types of screw jack

There are two types of screw jack, which are

1 Simple screw jack

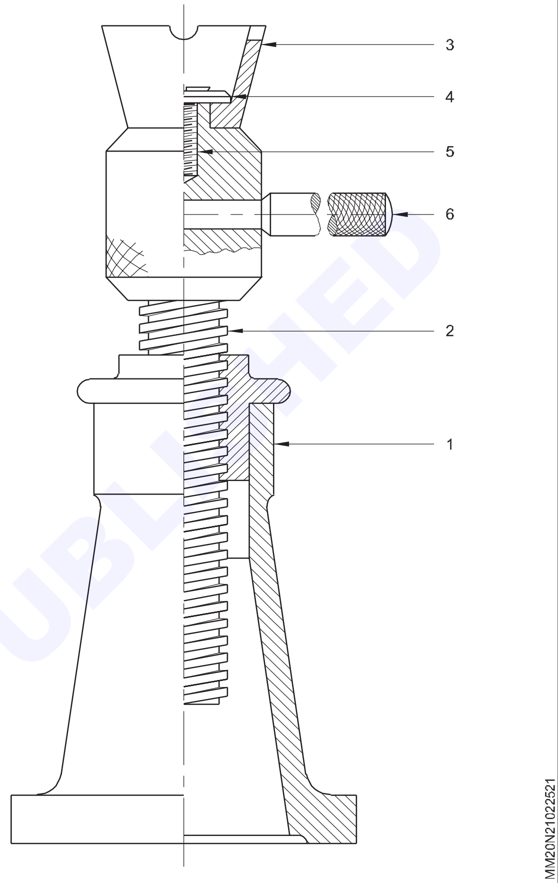
2 Different screw jack

Components of simple screw jack (Fig 1)

The following table shows the various components of a simple screw jack and the material by which they are made.

Sl.No.	Component	Material
1	Body	Cast-Iron
2	Spindle (Screw)	Mild steel
3	Cup	Cast steel
4	Washer	Mild steel
5	Set screw	Mild steel
6	Handle	Carbon steel

Fig 1



Function of screw jack

Simple screw jack (Fig 1)

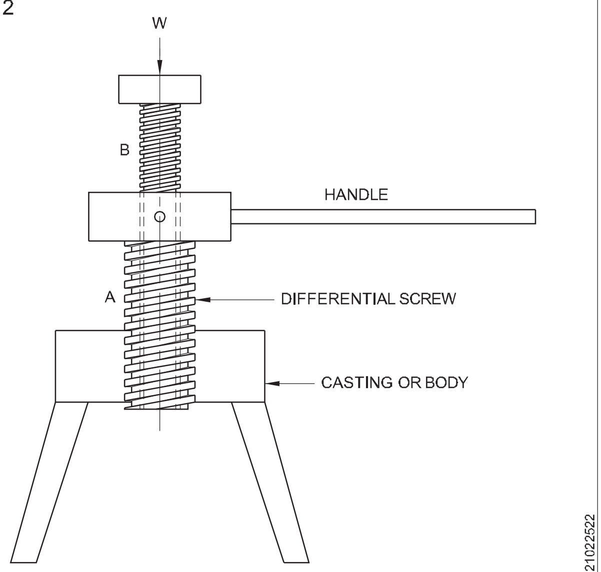
It consists of a spindle or screw has square threads on its outer surface which fit into the inner threads of the cast body as shown in Fig 1. The load to be lifted or lowered to be placed on the cup. The spindle or screw is rotated with the help of handle, in either clockwise or anticlockwise direction, by which the screw and cup is raised or lowered respectively, and thus the load is also raised or lowered.

Differential screw jack

Fig 2 shows the simple diagram of a differential screw jack. In this the spindle called differential screw is in two parts A and B, Part A is both on inside and outside whereas the part B is threaded on outside only, the external thread of Part A is fitted in the thread of the casting or body. The external thread of Part B is fitted in the internal thread of part A. Thus the part A of differential screw acts as screw for body thread and as a Nut for the Part B. the part B does not rotate but only will raise or lowers.

On rotating the handle in clockwise direction the part A of differential screw will raise and simultaneously the part B will lower down. Thus the net lift of the load is the algebraic sum of the motions of the part A and part B of differential screw.

Fig 2



DIFFERENTIAL SCREW JACK

Hydraulic jack

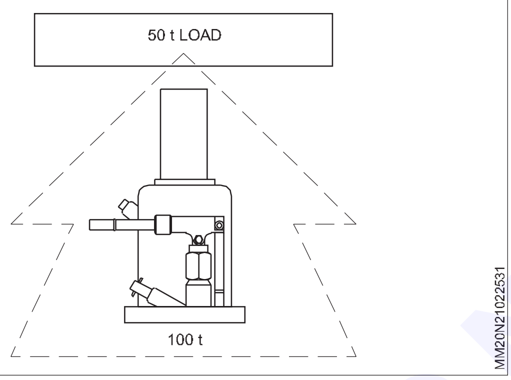
Objectives: At the end of this lesson you shall be able to
- **state the safety rules for the hydraulic jack**
- **select the hydraulic jack depending upon the nature of work to be lifted**
- **identify the parts of the hydraulic jack**
- **describe the function of the hydraulic jack**
- **locate the fault in hydraulic jack and rectify it.**

Safety rules for hydraulic jack

The following are some of the safety rules while working with hydraulic jack.

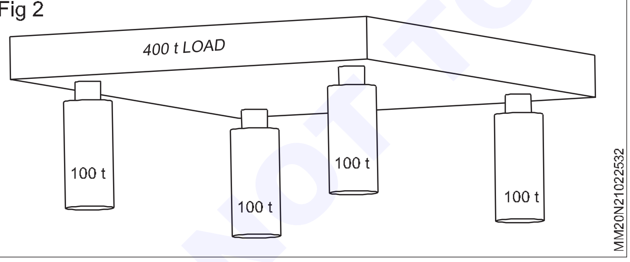
- Jack should be centrally loaded. Eccentric loaded causes dangerous accidents and damages. (Fig 1)
- The lifting capacity of the jack should be two times the weight of the load. This allows for reduction in oil pressure prevents strain and possible break down of jack (Fig 1)

Fig 1



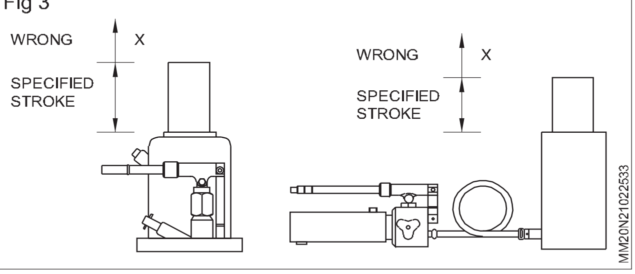
- To balance the load,heavy and uneven loads, the load should be divided evenly between the jacks. These jacks should be placed under the load at the points providing the best support balance and stability. For e.g. to lift a 200 tonne load, the necessary 400 tonne capacity could be handled by four 100 tonne jacks. (Fig.2)

Fig 2



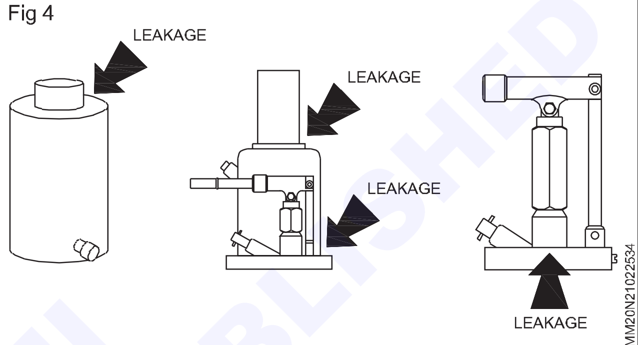
Never raise the hydraulic ram beyond the specified stroke (lift) (Fig 3).

Fig 3



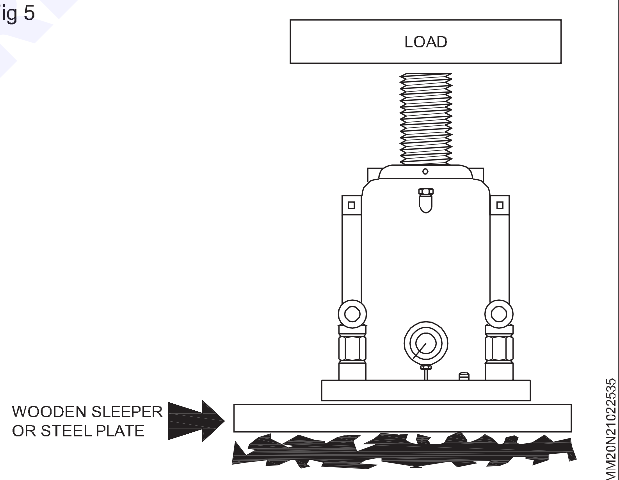
- Never drop (stack) load on the hydraulic ram.
- Never go under a load supported by hydraulic ram only.
- Never use hydraulic jack with observed leakages. (Fig 4)

Fig 4



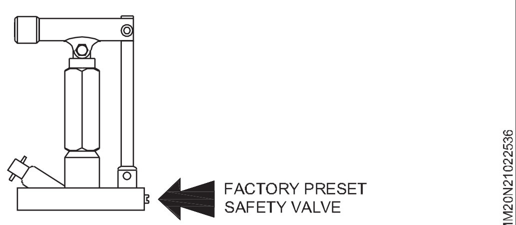
- Use safety lock nut type jacks for supporting load on jack for long periods.
- Use steel plates or heavy wooden sleepers where ground surface is soft an yielding (Fig 5)

Fig 5



Do not disturb factory preset internal safety valve provided for preventing overloading (Fig 6).

Fig 6



Selection of hydraulic jack

The following points to be considered, while selecting a hydraulic jack for particular job.

- Nature of application or operation.
- Lifting capacity
- How the load is to be lifted, i.e. whether from a single jacking point or more than one jacking point.
- How much height the load should be lifted, for example 10 Tonne load up to 150 mm can be safely lifted with a ram dia of 40 mm, but the same load when required to be lifted higher up would have to be supported by a large dia. ram depending upon the ultimate height of lift.

Components and function of hydraulic jack

Components of hydraulic Jack

The basic five fundamental components of hydraulic jack are

1 Reservoir

2 Pump

3 Valves

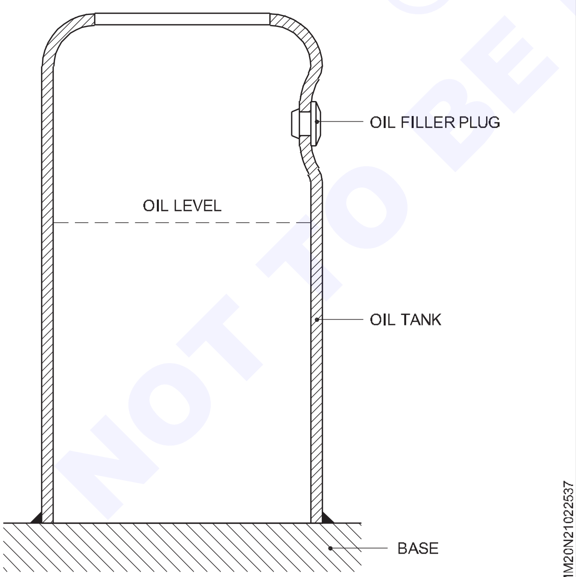
4 Hydraulic circuit

5 Cylinder and Ram

1 Reservoir

A Reservoir is the one, which stores the hydraulic oil Fig 7. This has one oil filler plug at the top as shown for oil filling.

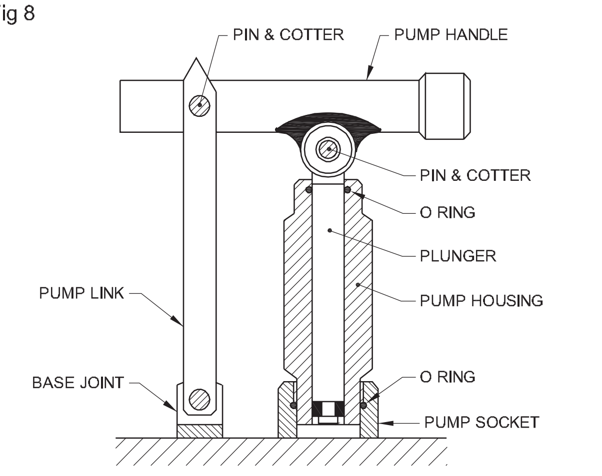
Fig 7



2 Pump

This consists of a highly precision pump plunger and cylinder, suction and delivery valves, safety valves with conical or steel balls. The pump functions at high efficiency by periodic cleaning and finishing of foreign particles which enters into the hydraulic system. (Fig 8)

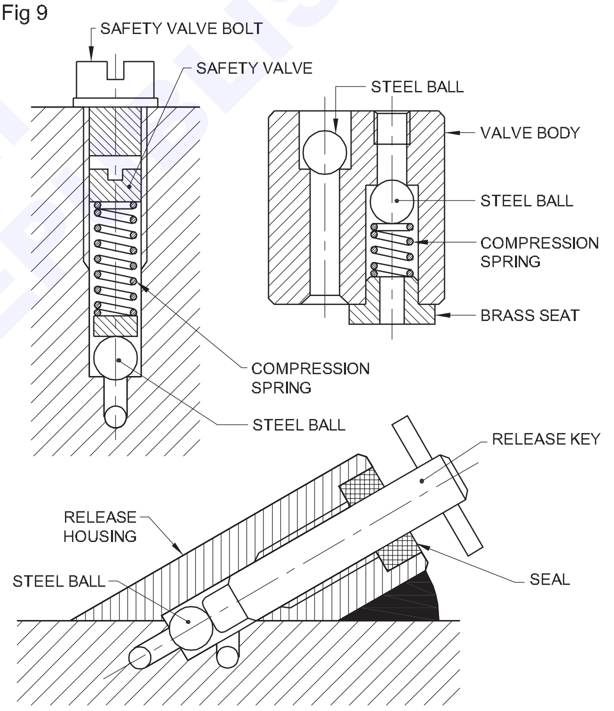
Fig 8



3 Valves

Valves are the components which control the flow of hydraulic oil to perform the desired function. (Fig 9) These are manufactured to close tolerance for the effective functioning.

Fig 9



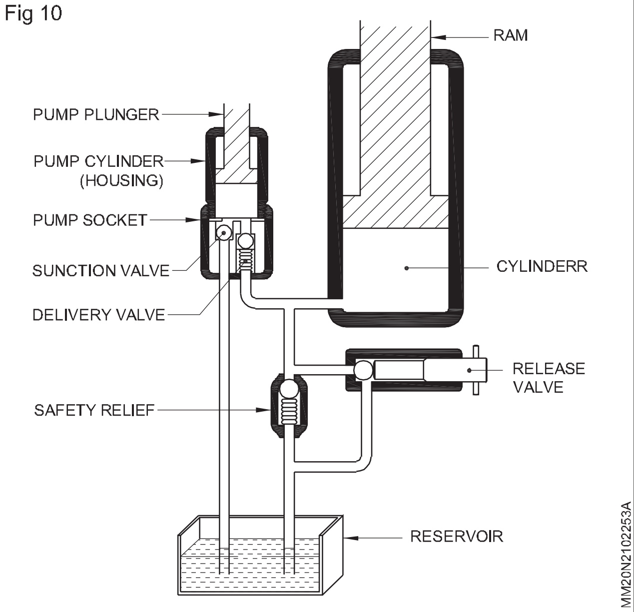
4 Hydraulic circuit

Hydraulic circuit is nothing but a network of passages in hydraulic system. The function of this hydraulic circuit is to transmit hydraulic oil from the reservoir by the pump through the valves to ram and cylinder which converts hydraulic pressure into mechanical force. It is important that the circuit is always leak proof as well as free from obstacles. (Fig 10)

5 Cylinder and ram

The outer housing or body is called cylinder and the inner sliding elements is called Ram which actually converts the hydraulic pressure into mechanical force.

Fig 10

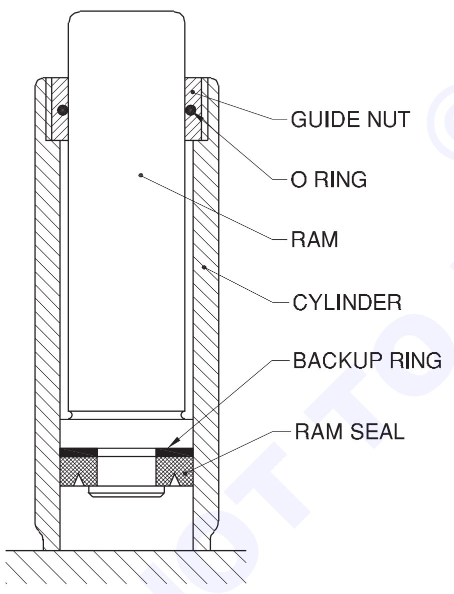


The Ram and cylinder are also manufactured to close tolerance and fitted with high quality seals which give it the necessary compression holding capacity and prevent leakages. (Fig 11)

Function of hydraulic jack

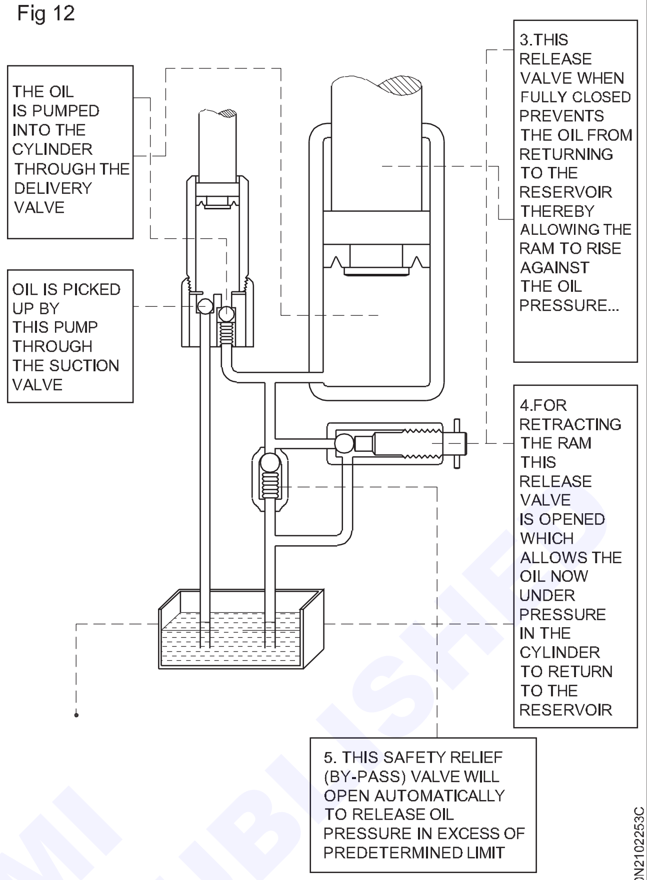
The following steps describes the function of hydraulic jack. (Fig 12)

Fig 11



- The release valve is closed tightly to ensure flow of oil from the pump to the cylinder only
- As soon as the pump is operated. Oil is sucked from the reservoir. As the pump plunger is raised up oil passes from the reservoir, into the pump cylinder with the suction valve opening up to allow oil from reservoir to enter into pump cylinder.

Fig 12



THE FUNCTION OF HYDRAULIC SYSTEM

- When the pump plunger is pressed down the delivery valve opens up to allow the passage of oil from the pump into the cylinder. At the same time the suction valve automatically closes to prevent oil returning to the reservoir.
- By repeating the above two operations successively more and more oil is pumped into the cylinder resulting in the generating of pressure by the action of the load being lifted.
- When the load is desired to be lowered the pressure within the cylinder is released by operating the release valve. The oil flows back into the reservoir as shown in the diagram.
- Due to neglect or other causes pressure within the system may continue to increase beyond the predetermined safe working limit. To prevent damage to the system a safety relief valve is located between the cylinder and the reservoir to release excessive pressure by opening up to the safety valve and discharge of oil into the reservoir.

Hoisting equipments and their application (chain hoists)

Objectives: At the end of this lesson you shall be able to
- **state the function of chain hoists**
- **name the different types of chain hoists**
- **state the advantages of different types of chain hoists.**

Lifting and moving of loads by hoisting equipments is a rigging operation. In rigging many types of hoisting equipments like hoists, derricks and cranes are employed. Both hand and electrically operated hoisting equipments are available and used widely.

Chain hoist

The chain hoist is a most widely used device for lifting loads. Chain hoists are dependable and usually portable.

Three basic types of chain hoists are the

- manual
- screw-geared
- spur-geared
- differential

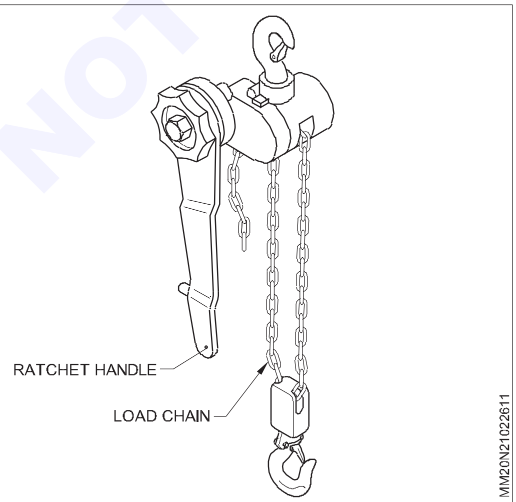
Chain pulley block

It is the most common portable device to lift the load. The common chain pulley blocks are as follows.

Manually lever operated chain hoists (Pull lift Fig 1)

It is a light weight portable hoist which may be used for pulling the load horizontally, vertically or at any angle. A reversible ratchet mechanism of the lever, permits short stroke operation for both tensioning or relaxing. An automatic friction type load brake is used , to control the load and permit accurate positioning. In some hoists, ratchet and pawl type break is also used, which involves ratcheting in both directions for controlling the load. Maximum loading capacity of this type is 6000 kg and maximum lift up to 1.5 metre. This is also known as come along hoist.

Fig 1

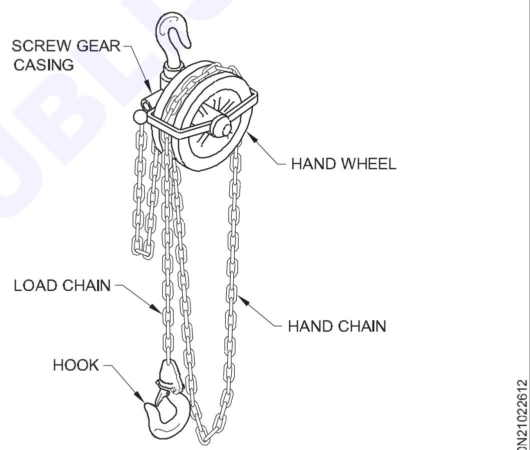


Screw-geared chain pulley block (Fig 2)

It is a common hoist where worm and worm-wheel is used to provide an inexpensive power train incorporating a high reduction ratio in a relatively small space. This types of chain-pulley block is less efficient, but it eliminates the need for a friction type holding brake because worm and worm wheel drive having one directional power transmission.

Maximum lifting capacity 5 tonne maximum lifting range 3 metre.

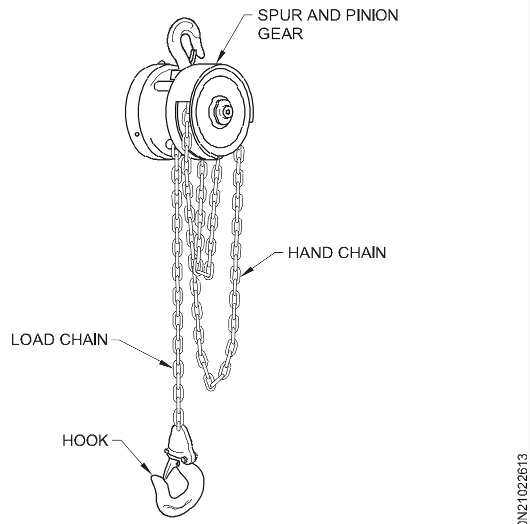
Fig 2



SCREW GEARED HOIST

Spur geared chain pulley block (Fig 3)

Fig 3



SPUR GEARED HOIST

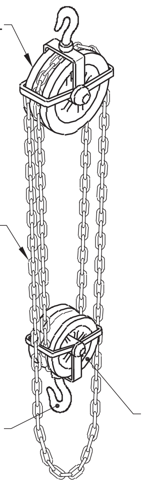
It has a more compact design and light weight. This type of chain pulley block is very efficient in moderate speed operation also. Generally friction type brake is used in this type of hoist but in some cases, automatic positive jaw brake is also employed.

Maximum loading capacity 15 tonne and maximum lift is 3 metre.

Differential chain pulley block (Fig 4)

This type of hoist is the simplest and least expensive but it has an efficiency rating approximately 30% of that of a spur geared unit. A dual-pocketed upper sheave (larger in diameter) and a single grooved lower sheave (smaller in diameter) are connected by an endless reeved chain. In this combination, the difference in diameter of the upper and lower sheaves results in such a small turning moment that normal friction holds the load in the suspended condition at any point.

Fig 4



Scaffolding

Objectives : At the end of this lesson you shall be able to
- **define scaffolding**
- **explain different types of scaffolding**.

Scaffolding

A temporary structure on the out side of the building by the side of the machine made of wooden planks and metal poles used by work men while building, repairing or cleaning building/machine is called as scaffolding.

Types of scaffolding and their uses

The general principle of a scaffolding construction, whether it is a static, rolling , or any other type of construction, remains the same-to provide a platform for workers and materials while work takes place.

Most often seen in construction projects, scaffolding structures and other constructs can be used for a variety of purposes. It is common to see scaffolding being used for repair work, to access high objects, for window cleaning tall buildings, and more. Choosing the most appropriate form of scaffold structure is an important stages in the project that you are undertaking.

Supported (Independent) scaffold (Fig 1)

Fig 1

This is the most commonly used form of scaffolding and is the type that you will see being used in construction work and on most other forms of work where elevation is required. Extra support may be required if the scaffolding will be long or required to take a lot of weight.

Supported scaffolding is built from the base upwards, and will normally be used wherever possible It is considered the easiest, most convenient, safest, and most cost effective form of scaffolding construct. Different forms of supported scaffolding are available, and each will serve a very specific purpose and used in specific purpose and used in specific circumstances.

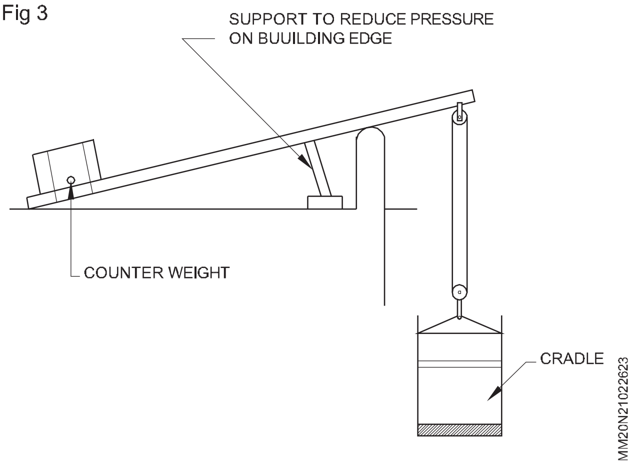
Suspended Scaffold

- Fixed or travelling Fig 2.

Fig 2

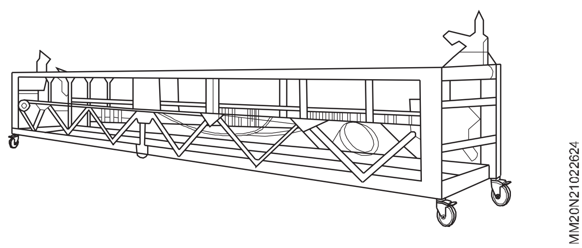
- Permanent or temporary Fig 3

Fig 3



- Manual or powered Fig 4

Fig 4



Suspended scaffolding is typically suspended from a roof or other tall construct. It is most commonly used when it is not possible to construct a base, or where access to upper levels may be required and the building of scaffolding from floor to the required level would be impractical.

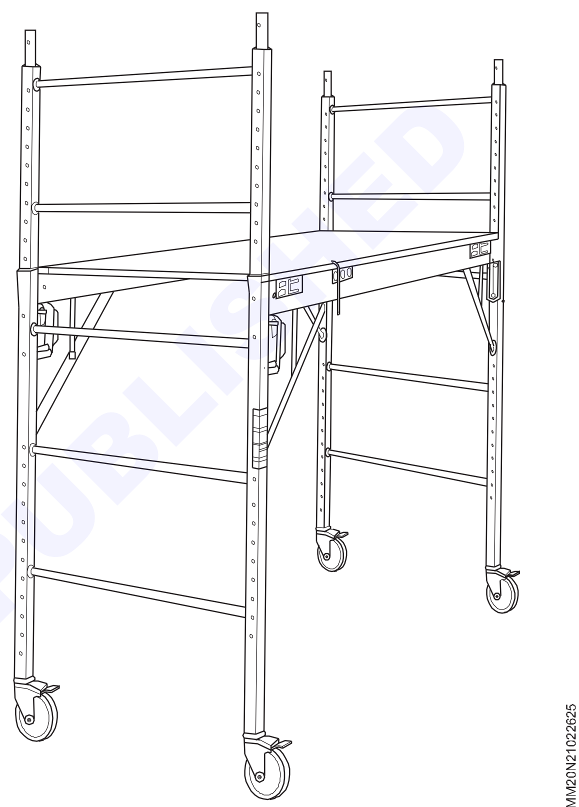
This types of scaffolding is commonly used by window cleaners on tall buildings, but may also be seen where repairs are need to the exterior of upper levels of similarly tall buildings. Supported scaffolding is usually preferred where possible.

Rolling scaffolding (Fig 5)

Rolling scaffolding is a similar type of construct to supported scaffolding, but rather than offering a stable base, it uses castor style wheels that enable the base to be moved. This is a useful form of scaffolding when you need to complete work over a longer distance than a single scaffolding construction would permit.

The wheels should be locked when workers or materials are on the scaffolding, in order to ensure the safety of those using it, and those around it.

Fig 5



Winches

Objectives: At the end of this lesson you shall be able to
- **classification of winches**
- **working principle and operation of winches**
- **advantages of winches**
- **application of winches.**

A winch is used to draw loads along the ground. It may also be used for hoisting purpose in some special cases.

Two major classification of winches are

1 Hand operated winches

2 Power operated winches

Hand operated winch

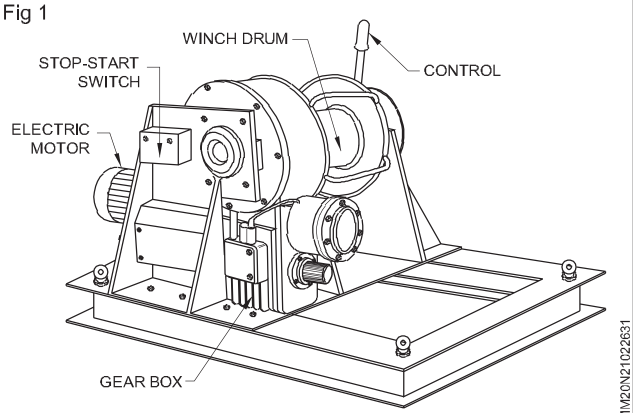
The types of under this are

1 Single reduction geared

2 Double reduction geared

Power winch (Fig 1)

Fig 1



The figure shows are electrically powered winch.

Alternate power sources could be diesel engine, compressed air, steam.

Single reduction geared winch

This has only one pair of gears having a large reduction ratio. It is relatively light in weight and easy to move above, but is limited in its high ratio.

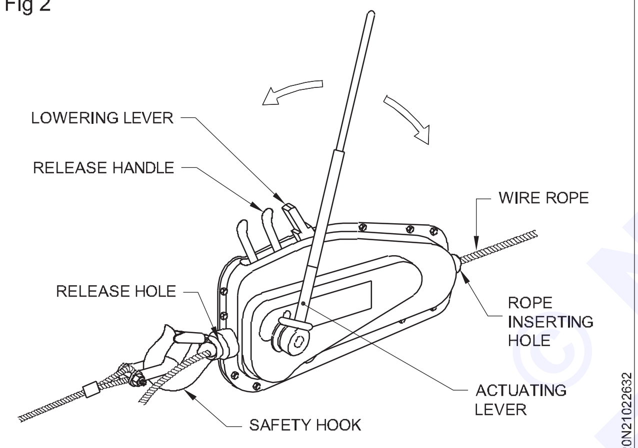
Double reduction geared winch

This has two pair of gears giving a double reduction. For light single reduction is used and for heavy loads double reduction is used.

Working principle of hand operated winch (Fig 2)

These are most correctly used and simple in design, construction and operation. The pulling and lifting operation is achieved by two pairs of steel jaws operated by a hand lever. The grip is actuated by the movement of cams through operation of hand lever and mechanism is such that heavier the load firmer is the grip.

Fig 2



HAND OPERATED WINCH

The wire rope is always held by one pair of jaws while the other pair having been opened by cam is moved by the lever for the next griping position. This smooth gear method draws a wire rope of unlimited length through the unit. This movement is reversible and is without jerk.

Capacity

The maximum capacity is single geared winch is about 1T and the double geared winch is about 5T.

Advantages

The advantages are,

- Light weight and compact
- Ready for work instantly
- Unlimited rope travel
- Any operating position
- Precision lifting or lowering
- Easily used with sleeve blocks to increase capacity
- Robust in construction
- Stands upto hard work
- High factor of safety with considerable overload margin

Application

- To draw load along the ground
- For rolling boilers in to position
- For any job requiring a long strong pull
- For hoisting jobs on gin pole

Connect wire ropes using bulldog grips

Objectives: At the end of this lesson you shall be able to
- **state components and material and properties of wire rope**
- **state construction and lay of wire rope**
- **state specification of wire rope**
- **state inspection of wire rope**
- **state joining of wire rope**
- **state maintenance of wire rope.**

Components of wire rope

The three basic components of a rope are (Fig 1)

1 steel wire

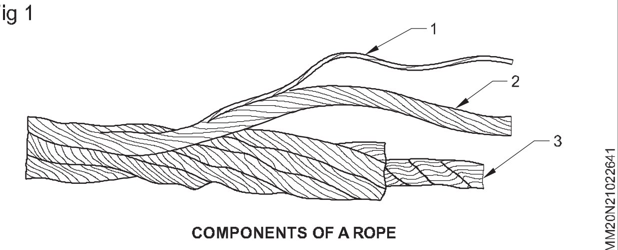
2 strand

3 core.

Wire rope material

Wire rope is made of iron, traction steel, galvanized steel, plow steel,bridge rope steel, stainless steel and phosphor bronze. For general application bright or high tensile steel wire having a tensile strength of 120 to 180 kgf/mm^2 are used.

Fig 1



COMPONENTS OF A ROPE

Properties of steel wire rope

i strength

ii flexibility

iii resistance to wear

iv resistance to crushing and distortion.

Rope construction

There are three types of wire rope constructions (Fig 2). They are:

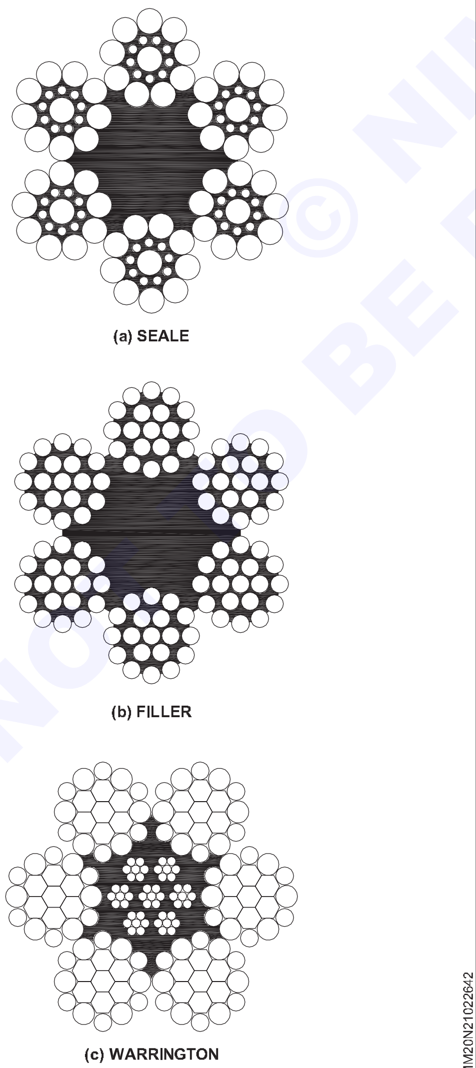
- Seale
- Filler
- Warrington

In seale types of construction, there are nine bigger diameter wires on the outer layer with nine smaller diameter wires in the next layer and with a bigger wire at the center to make a strand . Such six strands with a core makes a wire rope.(Fig 2a)

In filler type, twelve wires are on the outside with six in the next layer and one at the centre to make a strand. Six such strands with a core makes a rope. (Fig 2b)

In warrington type six wire ropes of big diameter with six smaller diameter ropes on the outside with six big dia. ropes in the next layer and one at the centre. Such six strands, with six smaller dia strands and a small dia wire at the centre forms core make a rope (Fig 2c)

Fig 2



Common lay of ropes

i Right hand ‘regular lay’

ii Left hand ‘regular lay’

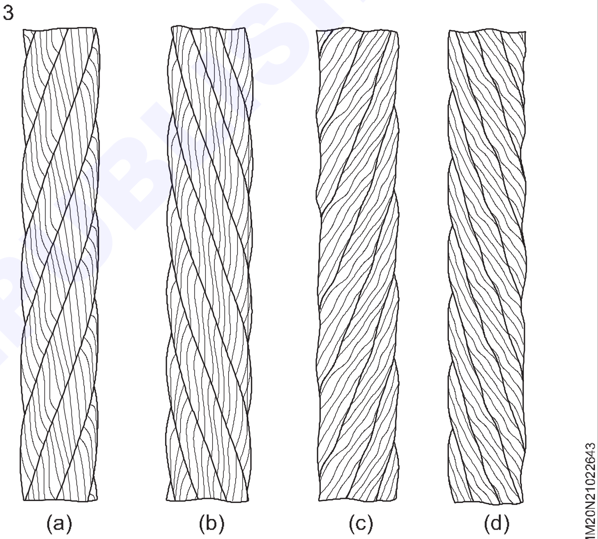
iii Right hand ‘lang’s lay’

iv Left hand ‘lang’s lay’

i) Regular lay ropes are so constructed that the direction of twist of the wires in the strand is opposite to that of twist in strands. There are two types as right hand and left and in one strands as shown in Fig 3a and b. These are commonly used in workshop applications.

ii) Long lay or parallel lay ropes Fig 3c and d are so constructed that the direction of twist of the wires in one strand is same to that of the strands in rope. There are also right hand and left hand types. (Fig 3c and d). These ropes are more wear resisting in their characteristics but they tend to spin. These are generally used in lifts and other hoists and also as haulage ropes.

Fig 3



iii) Reverse lay ropes: In this construction the wire in the too adjacent strands are twisted in the opposite direction. Theses are generally used for heavy applications.

Specification of wire rope

For specification of a wire rope, the following informations are to be furnished.

i Length

ii Diameter

iii Number of strands

iv Number of wire in each strand

v Type of rope construction

vi Type of core and type of lay.

Example (Ref. Fig No.2a,b and c)

6 x 19 seale (9/9/1) nine large outer wires, nine smaller inner wires and one core wire.

6 x 19 filler (12/6+6F/1) 12 outer wires, 6 inner pins 6 filler wire over a core wire.

6 x 10 warington (6 and 6/6/1) 12 wires alternatively small and large over 6 wires over a core or king wire.

Inspection of wire rope

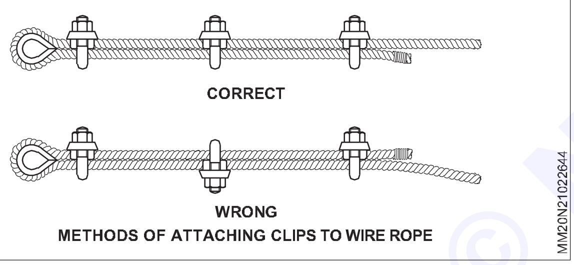
Every 3 cm of rope should be inspected for wear, wire breakage, corrosion, reduction in diameter (stretched due to load) etc. As a statutory regulation, ropes certified by the authority for the factor of safety. Normally, factor of safety is between 3 to 4 times the load tends to carry and 5 to 12 times for severe operating condition.

Joining of wire ropes

Wire ropes are joined by bulldog clamps. The method is very simple and capable of taking applied load on the rope (75 to 80% efficiency).

The process is to form a loop and eyelet is put on it. Now put one grip close to eyelet, the second one at the short end of the rope and the third one should be in between as a minimum of three clamps are to be put (as mentioned in the chart below). Distance between the grip should be 6 times the diameter of the rope. 'U' side of the grip must be on the short end side of the ropes as shown in Fig 4, clamps are evenly tightened to take load with 80% efficiency.

Fig 4



METHODS OF ATTACHING CLIPS TO WIRE ROPE

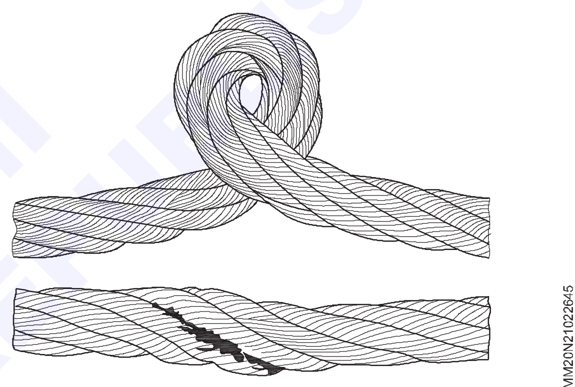
Number of grips for rope joining

Diameter of rope	Min.Nos.of grips
Upto and including 19 mm	3
Over 19 mm to 32 mm	4
Over 32 mm to 38 mm	5
Over 38 mm to 44 mm	6

Maintenance of wire rope

- Wire rope should be stored in cool dry place.
- Rope should not be allowed to form kink (Fig 5) which leads to damage and failure.
- Dust, dirt and mud should be brushed off and steam washed and dried whenever necessary.
- After drying oil lubrication should be done.
- Periodically, rope should be tensile tested to ensure its factor of safety.

Fig 5



Sling load for shifting

Objectives: At the end of this lesson you shall be able to
- **state different type of slinging arrangement**
- **state the common types of chain sling**
- **mention different types of fastening bolts,hooks, lifting clamps etc.**
- **illustrate various method of slinging practice**
- **define rigging and various rigs and fittings.**

Slinging is an important skill in lifting and shifting load in industrial practices.

Slings are made with fibre rope, (manila, sisal,nylon, terylene and polypropylene) chain, wire rope etc. Other appliances like hooks, eye bolts, shackles, lifting clamps etc are used to make or sling considering the type of the load.

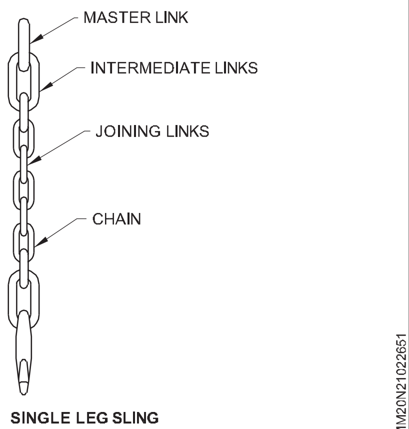
Chain sling

Chain links are fabricated by welding from carbon or alloyed steel. Links are formed to the shape and welded together to form a chain.

Chain slings are of different types, namely

- Single leg chain (Fig 1)

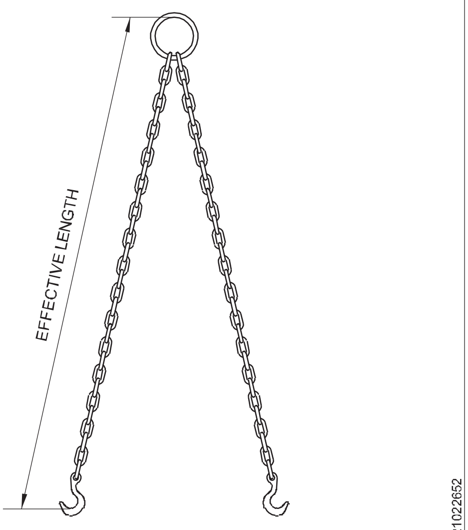
Fig 1



SINGLE LEG SLING

- Double leg chain (Fig 2)

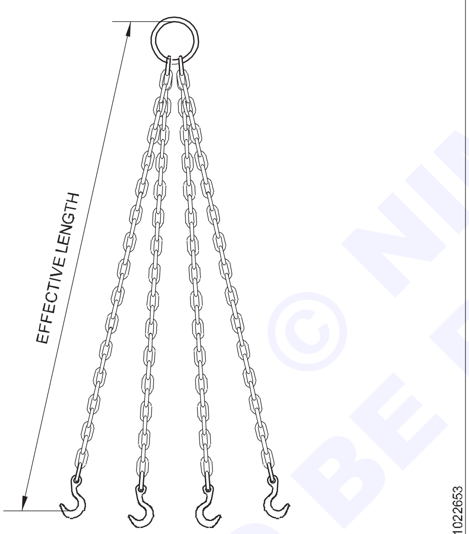
Fig 2



TWO-LEG CHAIN SLING, RING OR LINK AT ONE END, HOOKS AT OTHER ENDS

- Four leg chain (Fig 3)

Fig 3



FOUR-LEG CHAIN SLING, RING OR LINK AT ONE END, HOOKS AT OTHER ENDS

- Endless chain (Fig 4)

A chain will have the following components (Fig 1)

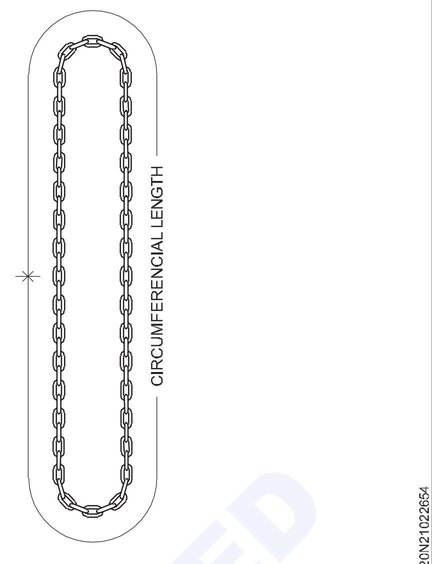
- Master link.
- Intermediate link.
- Joining link.
- Chain hook.

Wire rope sling

Wire rope slings are made of steel wire rope to form eye thimble mechanically spliced which accommodates a master ring on one side and or plain eye look is known as single legged sling (Fig 5a). Similarly, two legged, three legged and four legged slings are shown in (Fig 5b, c and d) respectively.

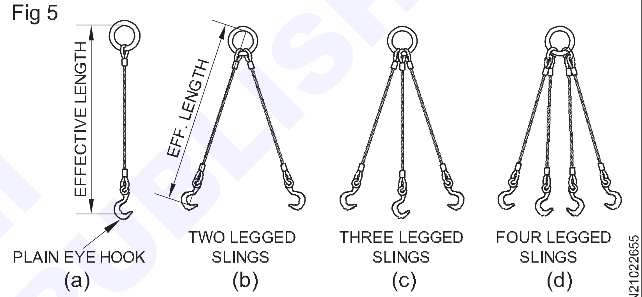
A few other slings like sling with safety swivel hook, Dee shackle and plate lifting clamp with effective length are shown in Fig (6a, b and c) respectively.

Fig 4



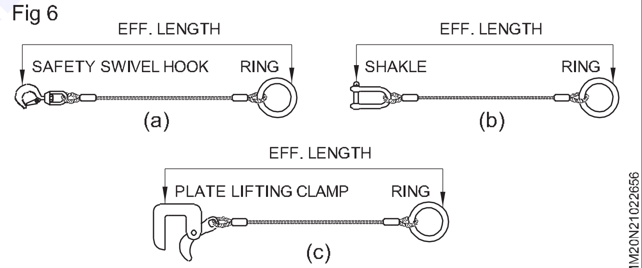
ENDLESS CHAIN SLING

Fig 5



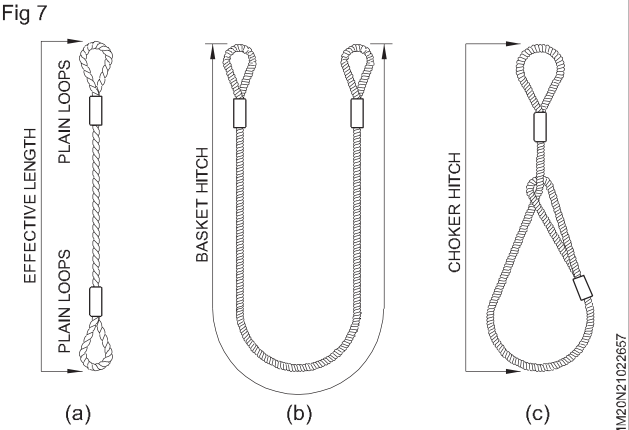
SINGLE LEG SLING MULTIPLE LEG SLINGS

Fig 6



Some other types of single part rope slings include plain loop on both ends (Fig 7a), basket hitch (Fig 7b) and choker hitch (Fig 7c) are shown.

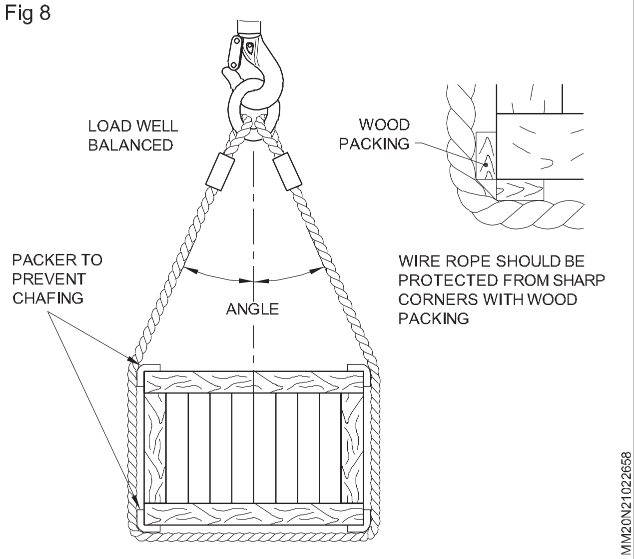
Fig 7



The following points are to be noticed and followed strictly.

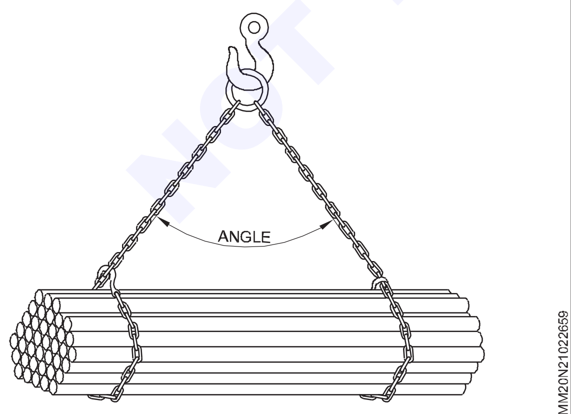
- Fibre rope sling should be used only for lifting and shifting lighter loads.
- In case of sharp edges use soft pads (packer,wooden blocks) Fig.8 to protect the sling and the edges of the load as well.

Fig 8



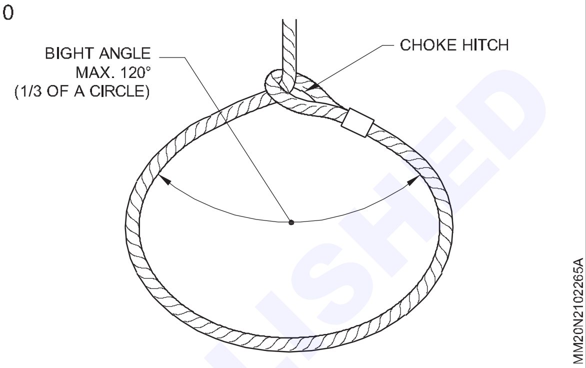
- Check the condition of the sling and consider the load carrying capacity of the sling.
- Fibre rope get spoiled due to heat and in presence of toxic liquid and fumes. However, polypropylene ropes offer goods resistance to water chemicals and alkalis. They are stronger, reliable and durable comparing to other fibre ropes.
- Always prepare the sling to keep the load in well balanced condition.
- Prepare a sling for the load within permissible angle as in Fig.9 (30^{0,}90^{0},120$^{0)}$.). Lesser the angle load carrying capacity of the slings is more. When the angle exceeds 120^0 ,the load carrying capacity of the sling is reduced to half.

Fig 9



- Ensure about the safe working load (SWL) of the chain and wire rope slings.
- Chains should not be twisted for slinging.
- Avoid formation of loop in wire rope slings which will lead to damage.
- Avoid riding on the load.
- Use guide rope for lengthy article being handled by a single crane.
- Avoid putting a sling round a radius of less than three times the rope diameter.
- Sling cylindrical object with wire rope wherein bight angle should not exceed 120^0. (Fig 10)

Fig 10

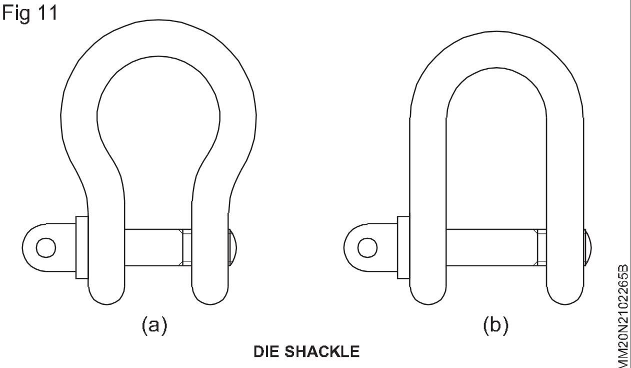


- Always keep yourself away from the suspended load.
- After completing of the work always return the hook fasten to the master ring.

Shackless

These are used for holding rings, eyes and hook which allow slings to adjust themselves easily to prevent bends, kinks etc in wire ropes. They are often used to join together the ends of slings. Bow shackle and Dee shackle are shown in (Fig 11a and b). Dynamo eye bolt (Fig 12a), Eye bolt with link (Fig 12b). These are used commonly to lift vertical load such as dynamo and other loads, provided with screwed holes to fit eye bolt.

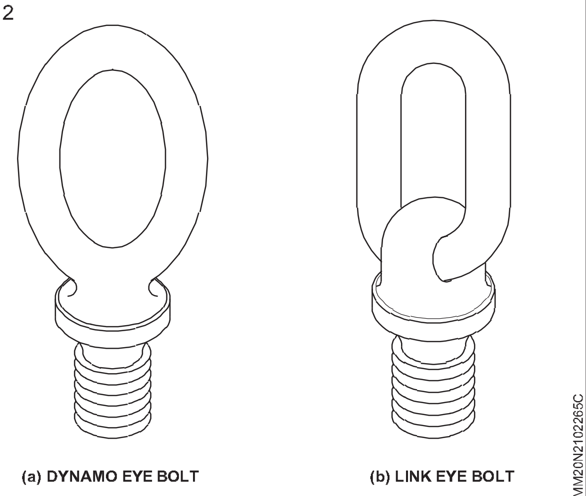
Fig 11



Slinging hook

Hooks are used in chain and wire rope for anchoring load. A few common types are shown in (Fig 13a,b,c,d,e). These hooks are made of high Tensile steel and drop forged to the shape. Eye hook (Fig 13a) is commonly used for handling load by the crane. Bureau of Indian Standard has recommend in eye hook with safety catch (Fig 13b) for general handling purposes. Swivel spring safety hook

Fig 12

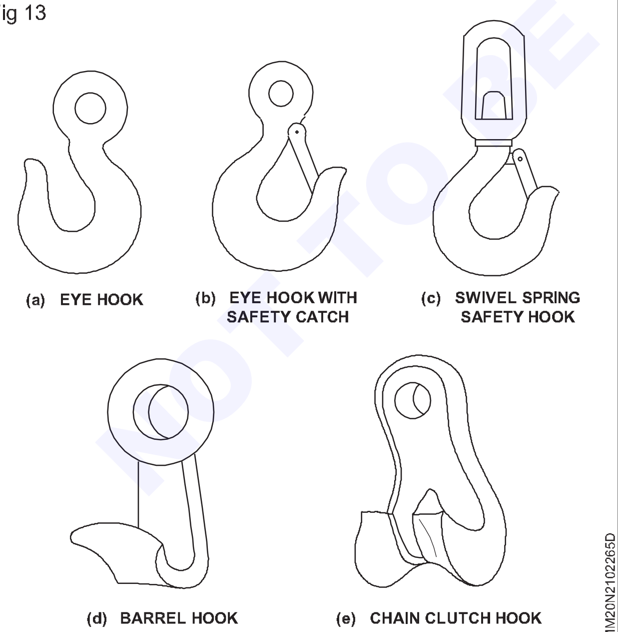


(Fig 13c) is capable of turning around and adjust itself to prevent twisting. Barrel hook (Fig 13d) is used for handling barrel. Chain clutch hook (Fig 13e) can be used for fastening to any portion of the chain after wrapping around the load. Cargo hook (Fig 14a) is used for handling general cargo in port. Ramshorn hook (Fig 14b) is used in heavy duty crane to fasten the sling from both sides of the hook. Joist or girder hook (Fig 14c) is used for handling joists or girders.

Lifting clamps

Lifting clamps are of various designs to suit the application. Vertical and horizontal plate lifting clamps as shown in (Fig 15a and b) respectively are used for lifting plates vertically and horizontally. As the tension is applied to the rope or chain, the jaws grip the plate tightly for effective lifting.

Fig 13



Tensioning screws

These screws or bolts are used in a situation where adjustment in tension is essential.

Fig 14

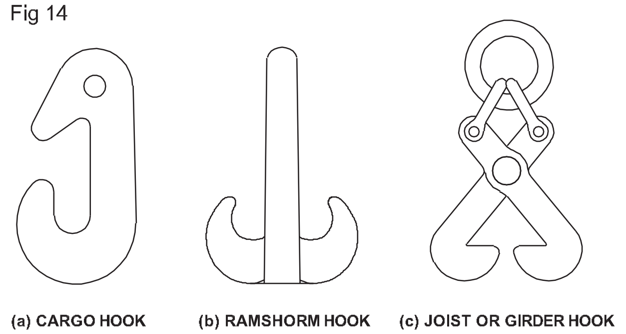
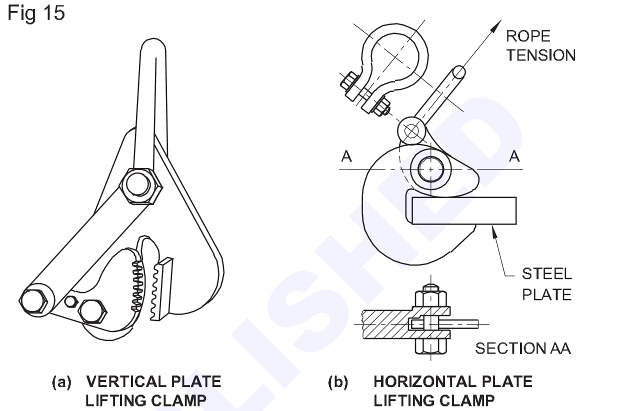


Fig 15



Common types

1 Union bolt (Fig 16a)

2 Straining screw (Fig 16b)

3 Rigging screw (Fig 16c)

4 Turn buckle (Fig 16d)

Union bolt is commonly on electrical post to keep it in erect condition. The centre part of the link is turned by tommy bar to keep the rope under tension.

Straining screw, rigging screw and turn buckle are also used in similar applications often in slinging ropes for adjusting the tension of the sling to keep the load in balanced condition.

Method of slinging

A few common methods of putting slings on the hooks have been shown in Figs 17a and 17b.

A cylindrical object slinging is shown by steel wire rope sling (basket hitch) Fig 18 which becomes automatically balanced when the slings are of equal size.

Fig 19 shows barrel slinging by chain using barrel hook.

Fig 20 shows chain slinging with four legged chain sling using two endless chain wherein the object has the marking of slinging location.

Fig 16

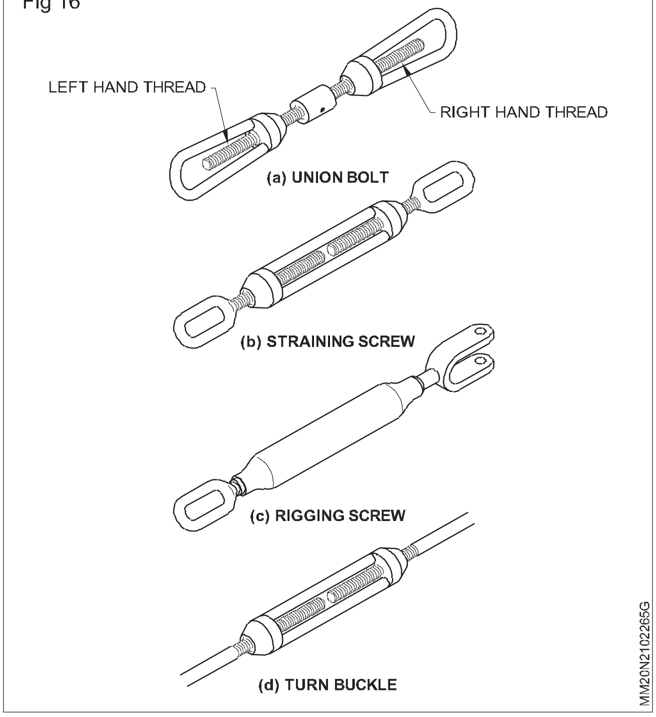


Fig 17

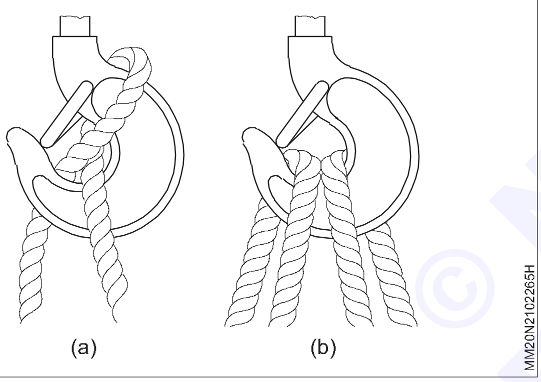
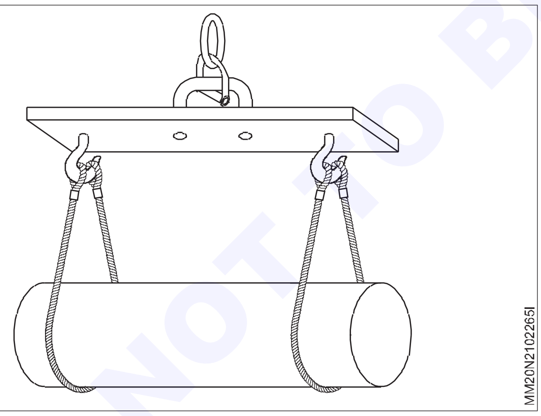


Fig 18



Slinging methods

Wooden casing arrives at the purchaser's premises with sling marks as shown in Fig 21.The casing should be unpacked and suitable slings are made to shift to the place of installation.

Fig 19

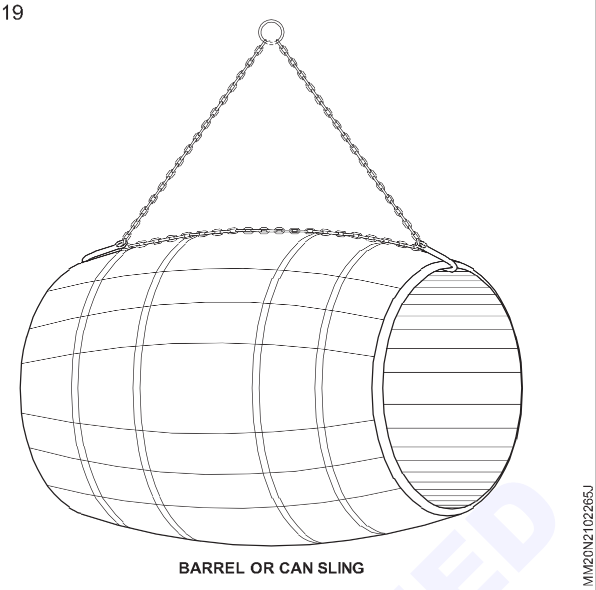
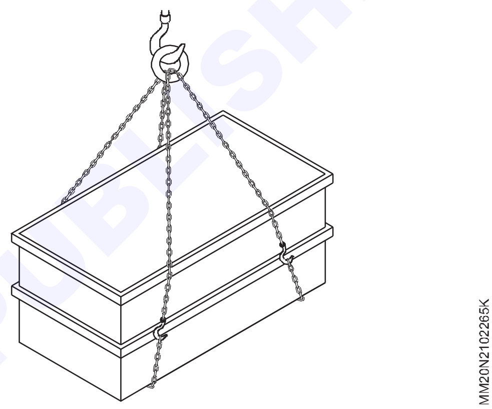


Fig 20



Such shifting is done commonly by fibre rope slings for lighter machines and comparatively heavier machines are shifted using suitable wire rope and chain slings. Suitable packings are to be used for protecting finished surfaces of the machineries.

A few method of slinging shaper, lathe, radial drilling machine, vertical milling and universal cylindrical grinder are shown in Fig 21 respectively.

Rigging Theory

Rigging is the action of designing and installing the equipment, in the preparation to move objects. A team of riggers design and install the lifting or rolling equipment needed to raise, roll, slide or lift objects such as with a crane or block and tackle.

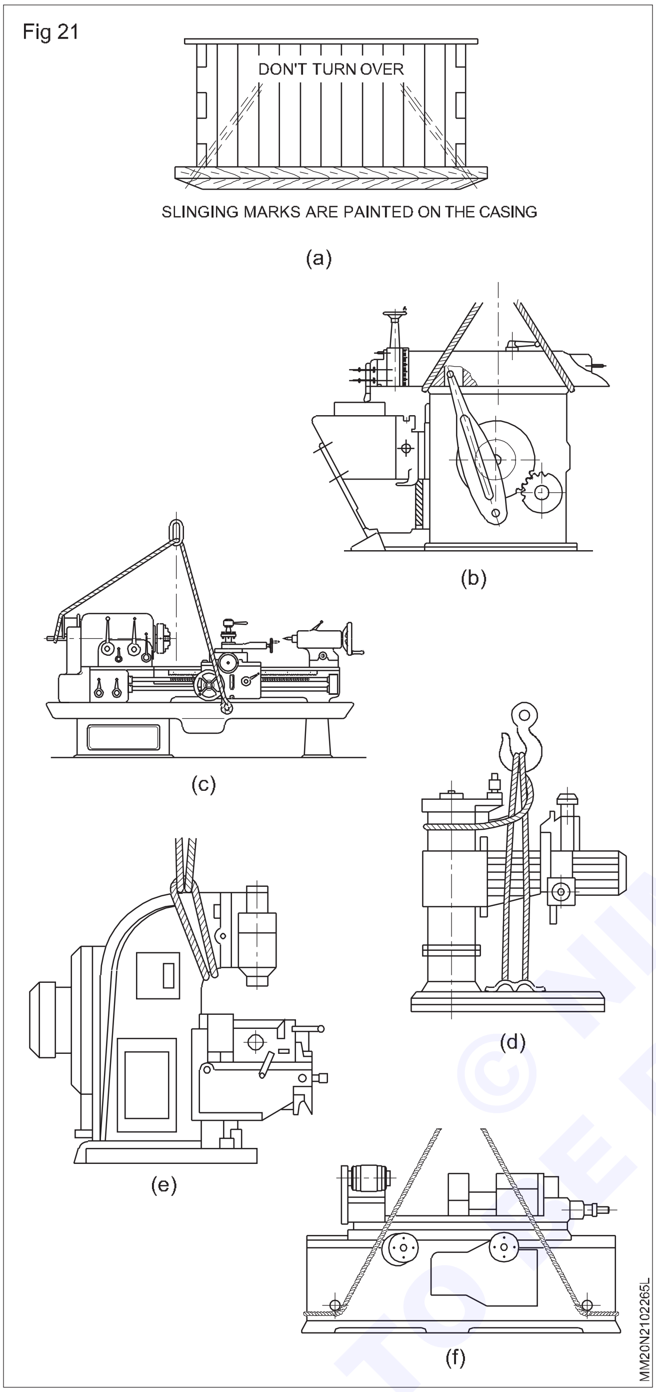
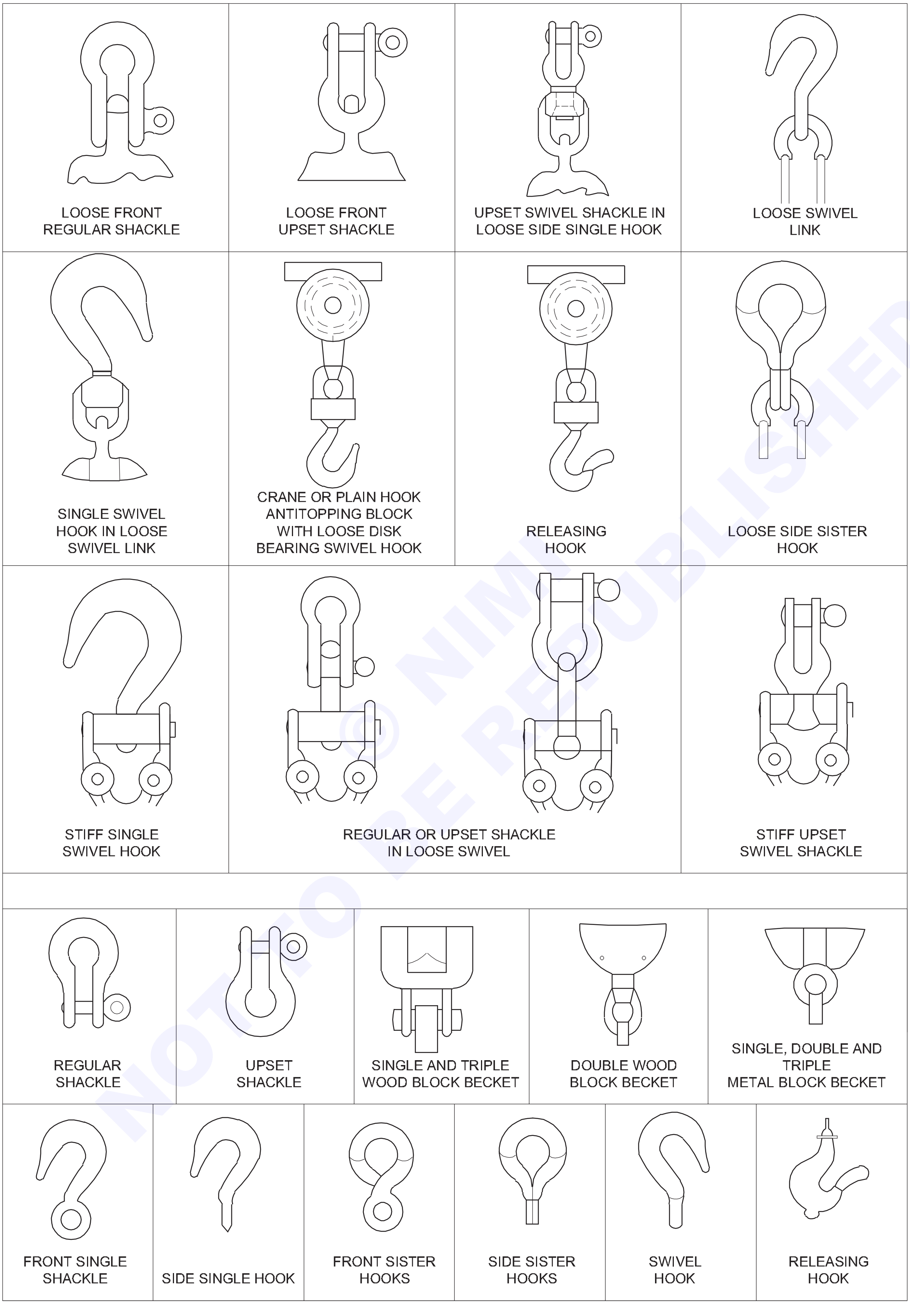


Fig 21

Rigging is the equipment such as wire rope. turnbuckles, clevis, jacks used with cranes and other lifting equipment (Fig 22) in material handling and structure relocation. Rigging systems commonly include shackles, master links and slings. Also, lifting bags in under water lifting.

Fig 22



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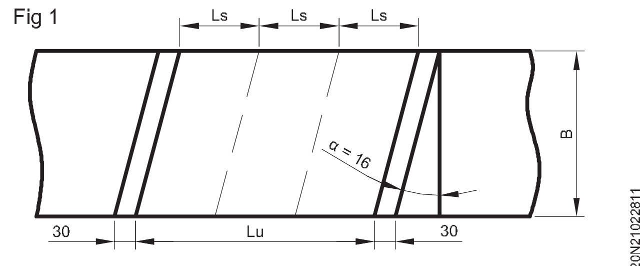
Method of belt joining (splicing)

Objectives : At the end of this lesson you shall be able to
- **explain the splicing the conveyor belt**
- **describe types of splicing.**

Splicing the conveyor belt

Rubber conveyer belts are often the basic elements of transportation systems. One of the most important conditions for satisfactory transportation through the use of conveyer is by correctly splicing conveyer belts. The correct procedure for the splicing of conveyer belts is depicted in Fig 1.

Fig 1



SPLICING THE CONVEYORT BELT

Conveyer belts are exposed to complex tensions (shearing, extension, bending) during use. Correct preparation and splicing are the most important conditions for conveyer belt durability.

Cold splicing the conveyor belt

It is possible to splice conveyer belts by using either cold or hot bonding. The advantages of cold over hot bonding are as follows:

- Shorter preparation time needed
- Less powerful electric power source required
- Smaller weight of equipment and tools

It is necessary to ensure the following in order to correctly and successfully splice the conveyer belt

- Ensure that the conveyer belt marking is correctly done
- Ensure that the textile inserts in the conveyer belt aren't damaged during the preparation
- Ensure that the upper and the lower part of the conveyer belt are dry and clean
- Ensure that the preparation, application and drying of the adhesive are followed as under the manufacturer's recommendations

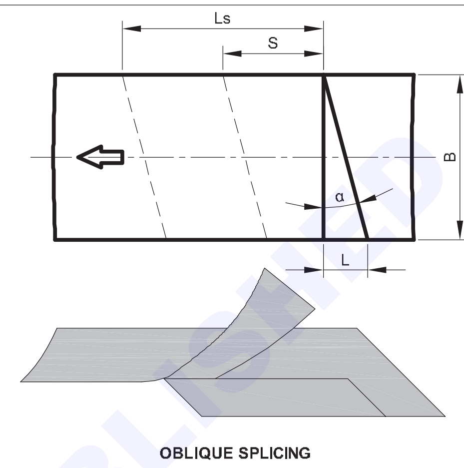
Splicing types

There are the three types of splicing:

- oblique splicing
- saggital splicing
- double saggital splicing

Oblique splicing (Fig 2)

Fig 2



OBLIQUE SPLICING

B - width of the conveyer belt

L - additional length for slope

S - length of stair

Ls - length of splicing

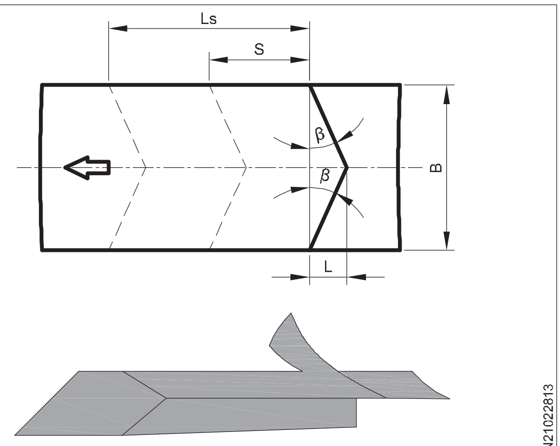
L = 0.3 B

tan α = L/B, angle = 16^0 42'

Oblique splicing is used for conveyer belts which have the length of several hundred meters. Damage caused by rubber wipers can be avoided by splicing under an angle of 16^0 42' . Rubber wipers are used for cleaning the internal parts of the conveyer belt and determine the direction of slope.

Sagittal splicing (Fig 3)

Fig 3



OBLIQUE SPLICING

Sagittal splicing is used for conveyer belts which have a stronger length, usually of several meters

B - width of the conveyer belt

L - additional length for slope

S - length of stair

Ls - length of splicing

L = 0.3 B

tan β = 2L/B, angle = $30^0 57'$

Double sagittal splicing (Fig 4)

Double saggital splicing is used for reversible conveyer belts which have a length of several meters (Fig 4)

B - width of the conveyer belt

L - additional length for slope

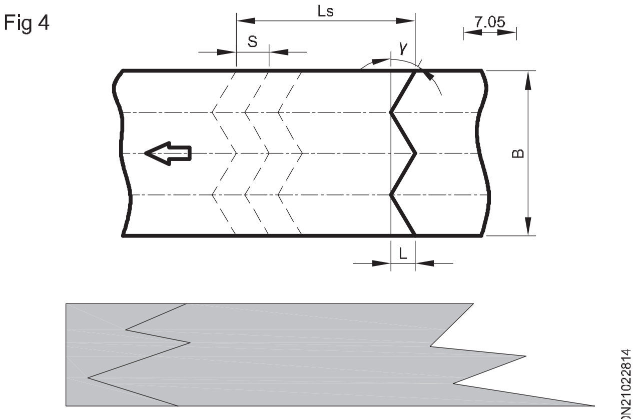
S - length of stair

Ls - length of splicing

L = 0.3 B

tan γ = 4L/B, angle =$50^0 62'$

Fig 4



OBLIQUE SPLICING

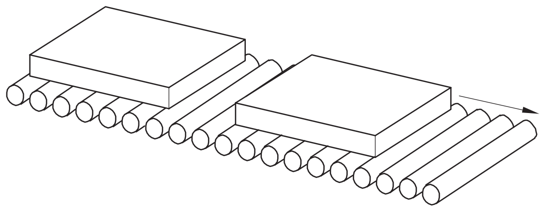
Conveyor

Objectives: At the end of this lesson you shall be able to
- **state the purpose of conveyor**
- **state the constructional features of the conveyor**
- **describe different safety devices in conveyor system.**

Conveyor (Fig 1)

A conveyor is a device which moves material, cardboard boxes, metal boxes, plastic boxes and other bulk quantity of materials like coal, coke, etc. A conveyor can also move material from one place to another.

Fig 1



CONVEYOR

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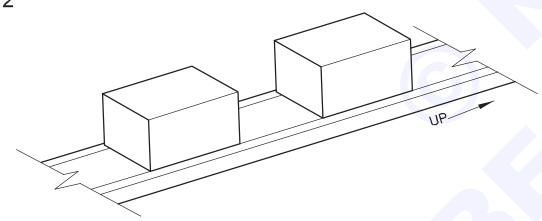
Belt conveyor (Fig 2)

It is a machine with a moving belt. The machine is made with the following parts.

Fig 2



BELT CONVEYOR

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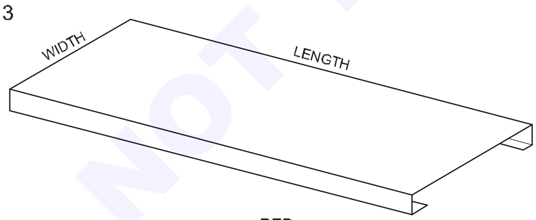
Components of conveyor

Conveyor bed (Fig 3)

Fig 3



BED

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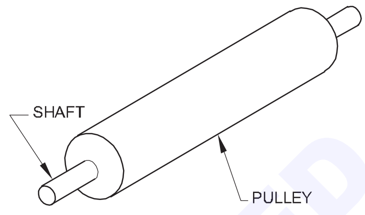
Pulley (Fig 4)

A pulley is like an IRON pipe and are put on each end of the bed. The pulleys are as wide as the "bed " and having a steel shaft through it. The shaft turns on a bearing and thus the pulley turns with the shaft.

Bearing (Fig 5)

When two pieces of steel touch each other; they cannot turn easily without bearings. Bearings use steel balls

Fig 4



PULLEY

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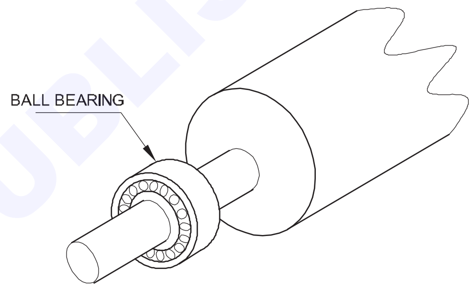
to prevent the pulley shaft and the conveyor bed from rubbing together in order to run the shaft easily.

Fig 5



BALL BEARING

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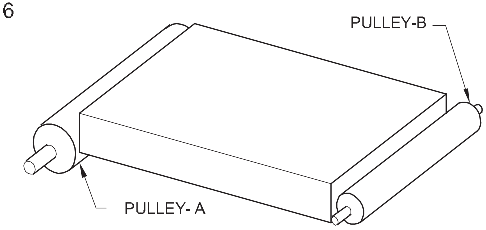
Drive and driven pulleys (Fig 6)

Pulley "A" is the drive pulley.

Pulley "B" is the driven pulley.

The drive pulley is usually larger because it does the work. The drive pulley is turned (driven) by a motor. A sprocket is put on the drive pulley shaft.

Fig 6



DRIVE AND DRIVEN PULLEYS

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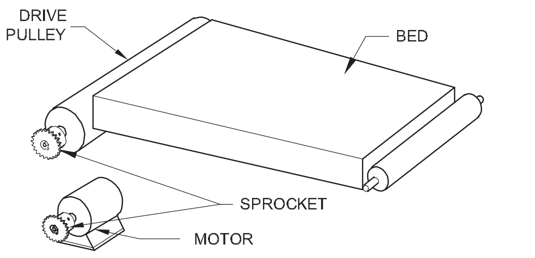
Sprocket arrangement (Fig 7)

A sprocket is a metal "wheel" with "teeth" on the outside. (Fig 8)

Chain (Fig 9)

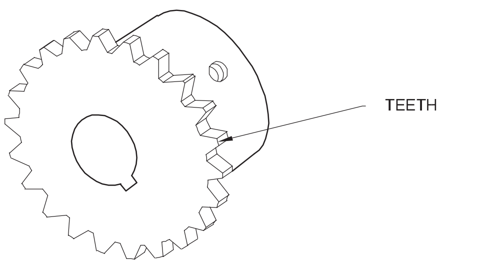
A chain is put around the Drive Pulley Sprocket and the motor sprocket. The chain moves when the motor is started and turns the drive pulley.

Fig 7



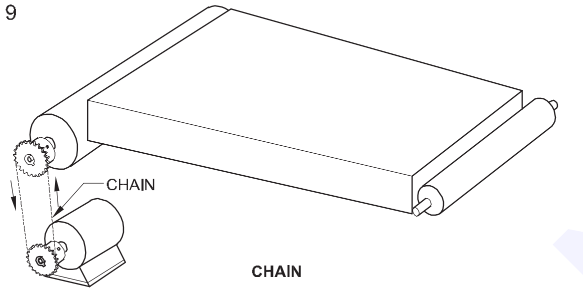
SPROCKET ARRANGEMENT

Fig 8



SPROCKET

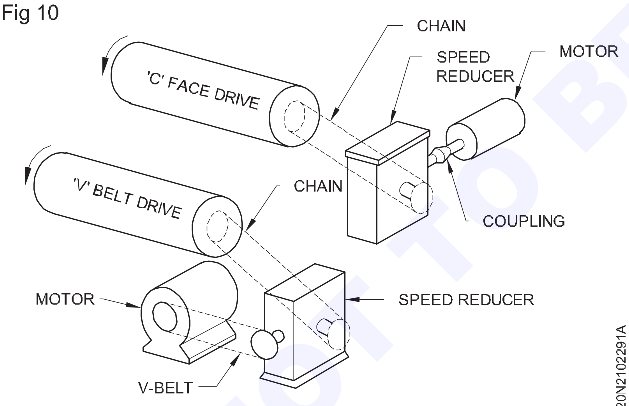
Fig 9



CHAIN

Speed reducer (Fig 10 & Fig 11)

Fig 10



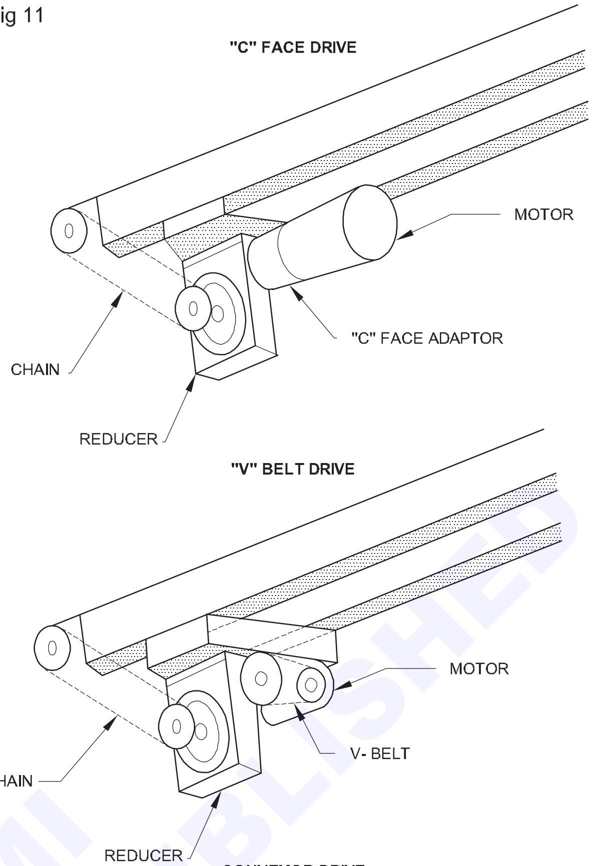
SPEED REDUCER

The motor is connected to the reducer with a V-Belt or a “C” face coupling. The reducer is connected to the drive pulley with a chain. So the Drive Pulley turns slower. All those parts (the motor, the speed reducer, and the drive pulley) are called conveyor drive. The motor and reducer are put under and within the conveyor bed to reduce the space.

Tail pulley (Fig 12)

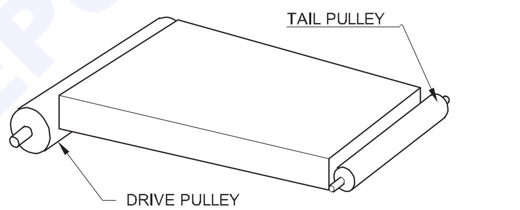
The tail or driven pulley is located at the tail end of the conveyor and it turns freely. Now a “belt” can be put around the pulleys.

Fig 11



CONVEYOR DRIVE

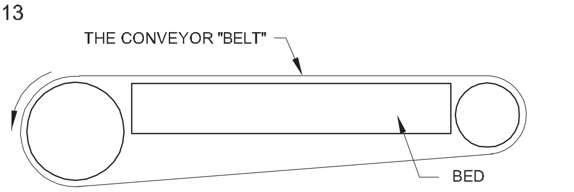
Fig 12



TAIL PULLEY

Belt (Fig 13)

Fig 13



BELT

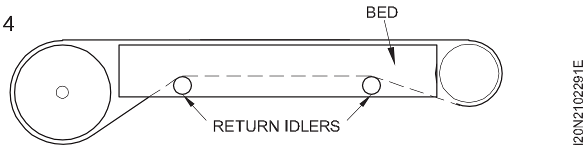
Idler (Fig 14)

The drive pulley turns and moves the belt around it continuously till the motor stops. It is dangerous to have the belt hang down under the conveyor bed. In order to avoid these circumstances small rollers are put into the conveyor Bed to hold up the belt. These rollers are called idlers.

The snub idler (Fig 15)

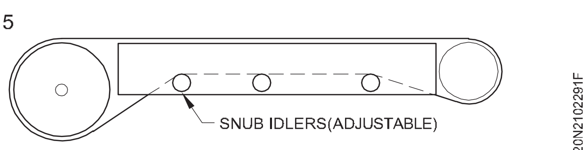
The Snub Idler is closer to the drive pulley. It makes the belt hug more of the drive pulley surface The Snub Idler is adjustable on both sides of the conveyor. The Snub Idler is used to steer the belt.

Fig 14



IDLERS

Fig 15



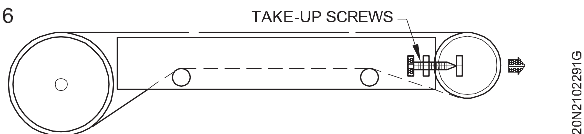
SNUB IDLERS

Take up unit system (Fig 16)

Some belts are more stretched than the others. In this circumstances take up units are used to adjust the tail pulley to take up stretch.

There are “take up” screw on both sides of the conveyor. Move these screws out slowly to make the belt tight.

Fig 16

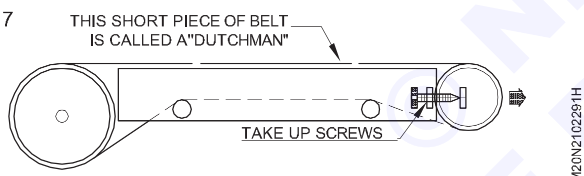


TAKE UP UNITS

Take up unit for longer belts (Fig 17)

Longer conveyors are provided with one or more short pieces of belt added to take up more.

Fig 17

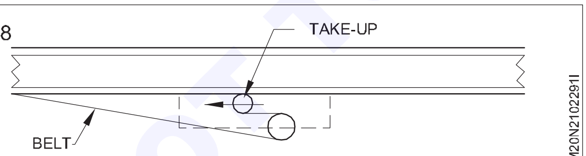


TAKE UP UNITS FOR LONGER BELTS

If a “Dutchman” was not provided , it is need to add an underside take-up to perform take up of the conveyor.

Underside take up (Fig 18)

Fig 18

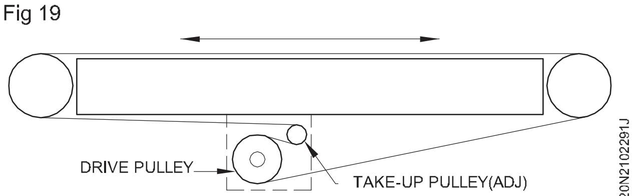


UNDERSIDE TAKE UP

Center drive (Used with horizontal belt conveyors) (Fig 19)

When belt movement is reversible and overall length of conveyor cannot change.

Fig 19



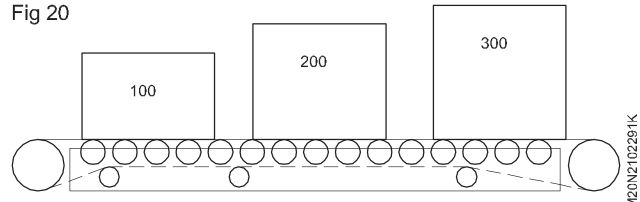
CENTRE DRIVE

The centre drive should be used because

- Drive pulley “pulls” belt in either direction
- Take-up pulley can now be used to take-up belt.

Roller bed conveyor (Fig 20)

Fig 20



ROLLER BED CONVEYOR

When heavy loads must be moved, it is best to use a conveyor bed with rollers. It can also be used when heavy loads are required to move without using large motors.

Safety devices in conveyor systems

A number of accidents involving conveyor belts can be developed to a serious injuries while maintenance and operation. The following are the different types of safety elements which are incorporated with belt conveyors to eliminate accidents.

1 Guard

It is a machine element that isolate the accident caused parts separately .

There are three types of guards

i Fixed guard

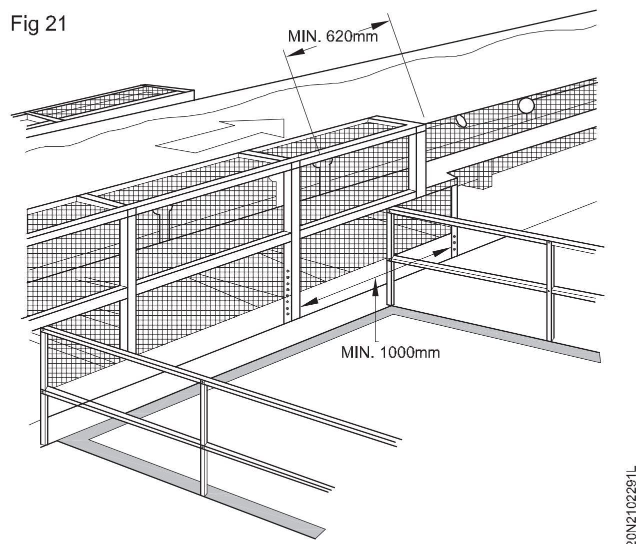
ii Interlocking guard

iii Interlocked guards with locking

iv Barrier guard

Surrounding barrier guard (Fig 21)

Fig 21



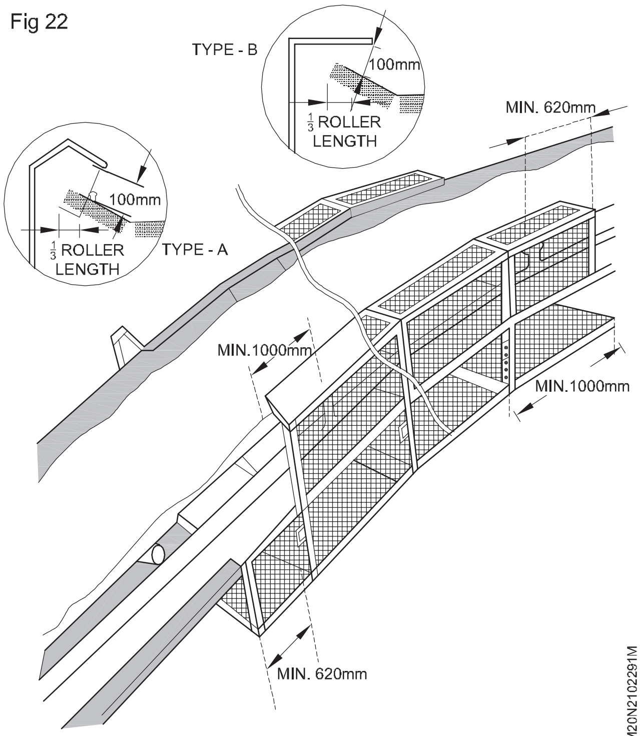
SURROUNDING BARRIER GUARD

Curved zone surrounding guard (Fig 22)

Barrier guard (Fig 23)

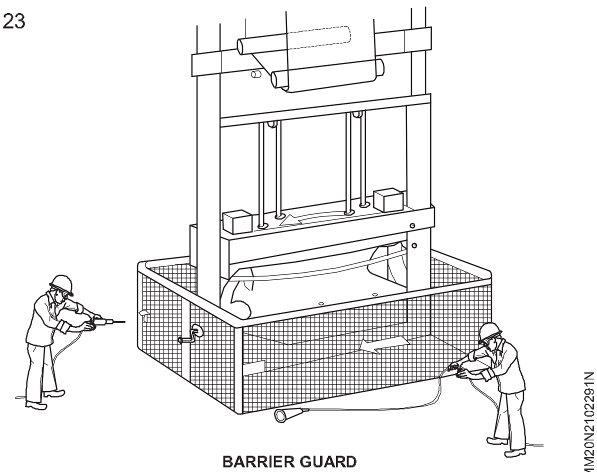
Barrier guards do not completely surround danger zone but rather restrict or prevent access by their size and separation from the danger zone.

Fig 22



CURVED ZONE SURROUNDING GUARD

Fig 23



BARRIER GUARD

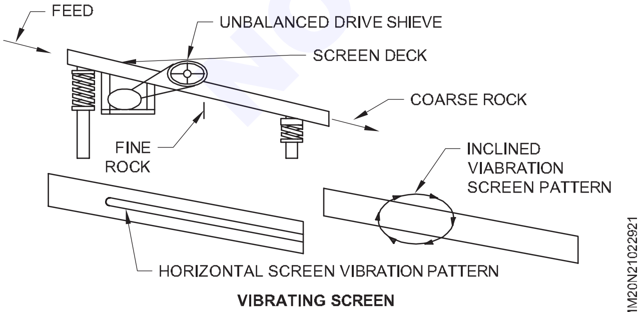
Vibratory screen

Objectives: At the end of this lesson you shall be able to
- **explain the working of vibratory screen**
- **state different parts of vibratory screen**
- **describe pulley lagging and types**
- **define belt sway.**

Vibrating screen

The simplest Vibrating Screen Working Principle can be explained using the single deck screen and put it onto an inclined frame. The frame is mounted on springs. The vibration is generated from an unbalanced fly wheel. A very erratic motion is developed when this wheel is rotated. You will find these simple screens in smaller operations and rock quarries where sizing isn't as critical. As the performance of this type of screen isn't good enough to meet the requirements of most mining operations two variations of this screen has been developed. (Fig.1)

Fig 1

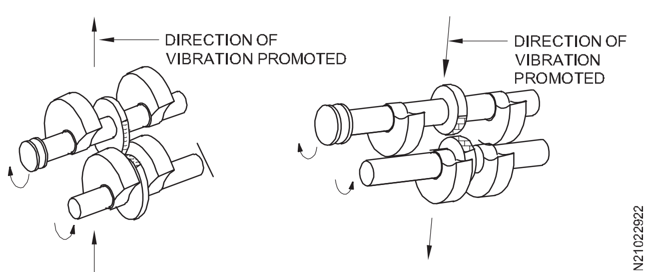


VIBRATING SCREEN

The pattern of vibration for the horizontal screen deck is back and forth while the inclined vibrating screen is circular.

There are different ways to generate the vibration itself. A double counterbalance system is used in the horizontal screen. (Fig 2)

Fig 2

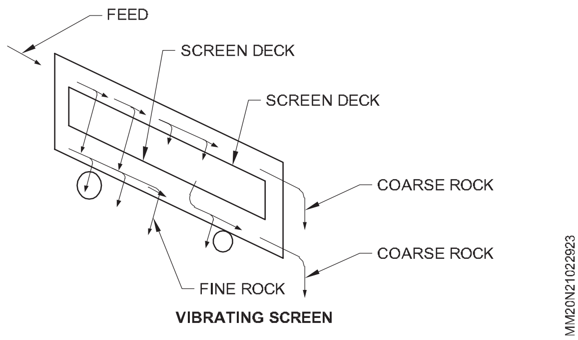


VIBRATING SCREEN

Why these screens are vibrated is to ensure that the ore comes into contact with the screen. By vibrating the screen the rock will be bounced around on top of it. This means, that by the time that the rock has travelled the length of the screen, it will have had the opportunity of hitting the screen mesh at just the right angle to be able to penetrate through it .If the rock is small enough it will be removed from the circuit. The large rock will of course, be taken to the next stage in the process. Depending upon the tonnage and the size of the feed, there may be two sets of screens for each machine.

Each set of screens will be called a deck (Fig 3)

Fig 3



VIBRATING SCREEN

Pulley lagging

Lagging serves as a protective layer which will guard the pulley from premature failure due to abrasion. Simultaneously lagging can also protect the conveyor belting from wear failure caused by abrasion. Lagging can also increase the friction between the pulley and the belt which is usually needed to transfer torque from pulley to the belt

Rubber or ceramics are the most common materials to make lagging over the pulleys. The primary purpose of pulley lagging is to enhance the traction between the drive pulley and the underside of the conveyor belt by increasing the coefficient of friction between these two surfaces. Pulley lagging is specified by the lagging material, hardness of material, desired thickness and the pulley diameter after lagging.

The lagging material should depends upon

i chemical & environment compatibility

ii wear characteristics.

iii maintenance

iv belt material

v release properties in connection with the removal of sticky particles.

Types of lagging

Grooved lagging

The contact surface of most lagged pulleys can be modified from a rough ground finish to include several types of groove patterns. These groove patterns assist conveyor pulley in dispersing or eliminating water and debris away from the center of the pulley, resulting in increased traction and enhanced belt tracking characteristics

Knurling

Knurling is a manufacturing process in which the surface of steel is altered by forming a pattern into the surface of the metal. The result of this process is a coarse pattern, typically diamond shaped, which gives the surface of the conveyor pulley excellent traction capabilities in most environments. However, because the surface is purposefully coarse, knurled pulleys can accelerate belt wear. Knurling is typically specified by communicating a pattern type (diamond, straight or diagonal) and level of coarseness using TPI, or Teeth per inch as an indicator. Generally speaking, the lower the number of teeth provided per inch of surface area, the deeper the depth of groove provided, resulting in a rougher, coarser surface finish.

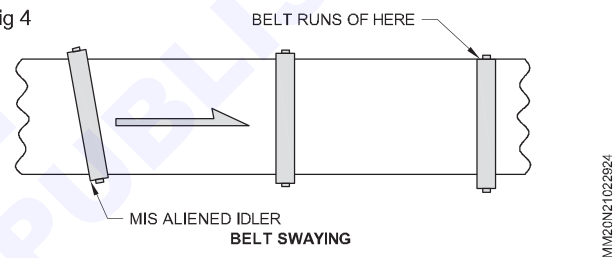
Special surface finishes

The construction of most conveyor pulleys allows the contact surface to be machined, ground, media treated or polished if a more consistent finish is required. A special surface finish may be desirable for

- Ease of cleaning/ sanitary needs
- Grooves
- Scratches or pits
- Need for a more consistent surface finish
- Specific tolerances.
- Other performance enhancing features

Belt swaying (Fig 4)

Fig 4



BELT SWAYING

The belt will move toward the side that has more friction or the side that reaches the friction first. When a side of the belt confront with friction, that side moves slower and the other side move faster due to imbalance. This is known as belt swaying. Idlers installed at an angle are used for avoiding bell swaying.

The most common causes of sway are

- faults with belt or its splices.
- faults with the conveyor, structure components
- faults with material loading.

Sway on reversing belts

Due to reversing the tension areas in the belting. Change its location. The carrying side changes from being pulled to being pushed.

The belt may run fine in one direction and sway in reverse direction. Different sets of belt steering control rollers and corrective rotating components are used to avoid these types of swaying.

Swaying due to other problems

Other problems like off centre loading, multiple load points etc are also caused belt swaying. It can be avoided by using proper loading chutes and usage of adjustable deflectors.

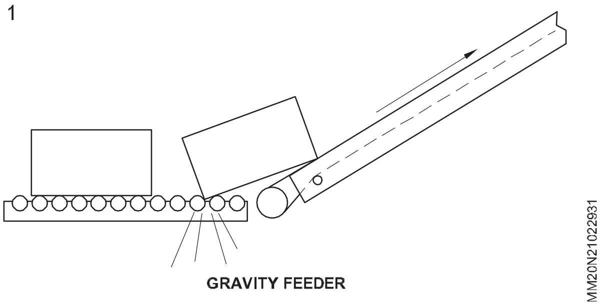
Feeders and its types

Objectives: At the end of this lesson you shall be able to
- **describe feeder and its working**
- **state types of feeders**

Feeders

When boxes move from gravity conveyor to inclined belt conveyor, the box usually stops or “hangs up” and will not transfer (Fig 1)

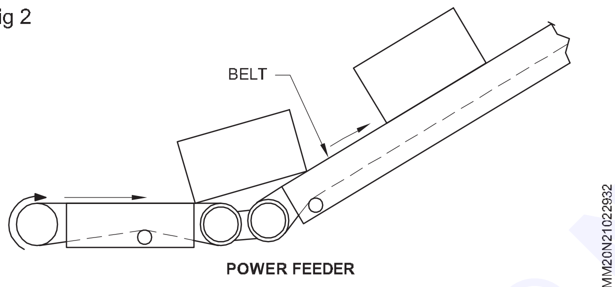
Fig 1



GRAVITY FEEDER

This can be avoided by using a power feeder as shown in Fig 2 and the transfer of box becomes positive.

Fig 2



POWER FEEDER

Feeders and their types

Feeders are devices mounted at the outlet of storage units such as bins, bunkers, silos-or hoppers which are used to control and meter the flow of bulk materials from the storage unit to meet the specified discharge flow rate. When the feeder stops, material flow ceases and when the feeder is turned on, there is a close correlation between its speed of operation and the rate of discharge of the bulk material. The importance of the feeder to be designed as an integral unit with the storage unit cannot be too greatly emphasized. A well designed storage unit may be prevented from functioning correctly if the feeder is poorly designed, and vice versa. It is particularly important that both the feeder and the storage unit are designed as an integral unit so as to ensure that the flow from the storage unit is fully developed with uniform draw of bulk material from the entire outlet of the storage unit. While there are several types of feeders which are used commonly, it is essential that they are to be selected to suit the particular bulk material and the range of feed rates required. The properly designed bulk material handling system always commences from the feeder. The feeder decides the magnitude of load on the handling system. Therefore the handling system load condition and there by its performance is governed/controlled by feeder. Feeder for controlling the flow of bulk materials onto conveyor belts require the following criteria to be met.

- They are to deliver the range of flow raters required.
- They are to handle the range of particle or lump sizes and flow properties expense.
- They are to deliver a stable flow rate for the given equipment setting. They have to permit the flow rate to be varied easily over the required range without affecting the performance of the storage units from which they are feeding.
- They are to feed material onto the conveyor belt in the correct direction at the correct speed with the correct loading characteristic and under condition which produces minimum impact, wear and product degradation. Often a feed chute is used in conjunction with the feeder to achieve these objectives.
- They have to fit into the space available.

Various types of feeders which are available given below

Belt feeders

Belt feeders are one of the most widely used feeders. They are used to provide a controlled volumetric flow of bulk materials from the storage units. They generally consist of a flat belt supported by closely spaced idlers and driven by end pulleys. Belt feeders are suited for handling of granular materials of comparatively lesser lump size.

Belt feeders are not recommended for very hard and tough bulk materials which have sharp cutting edges and comparatively, large lumps.

Apron feeders

Apron feeders are a version of belt feeders and are useful for feeding large tonnages of bulk materials and for those bulk materials which requires feeding at elevated temperatures. They are also able to sustain extreme impact loading.

Apron feeders are used for dealing with bulk materials which are very hard, abrasive and tough and for lumps of large dimensions and which are beyond the scope of belt feeders.

Vibratory feeders

Vibratory feeders are used extensively in controlling the discharge of bulk materials from storing units and stock piles and directing these materials onto the conveyor belts. They are especially suitable for a broad range of bulk materials, are being able to accommodate a range of particle size and are being particularly suitable for abrasive materials. However they are generally not suited to fine powders under 150 to 200 mesh where flooding can be a problem

Electromagnetic vibrating feeders - These feeders are economical compared to other feeders since the number of Items in equipment is very less. These are suited for granular materials or materials of limited lump size.

Mechanical vibrating feeders - These feeders function like electromagnetic vibrating feeders. However, vibrations are created by unbalanced rotating mass.

Reciprocating feeders

The reciprocating feeders are in use since a very long time. The feeder has reciprocating tray. The reciprocating motion is imparted by crank or eccentric and connecting rod. The feeder discharge is volumetric in nature and is less susceptible to flow ability of material, as compared to Vibrating feeder. However, material movement on tray is of simple dragging nature, instead of jumping type as in case of vibrating feeder.

Screw feeders

The screw feeders are suitable for material which are granular/ powdery or which have small size lumps (in tens of mm). Screw feeders are widely used for bulk materials of low or zero Cohesion such as fine and granular materials which have to be dispensed under controlled Conditions at low flow rates.

Drag chain/drag flight feeders

Drag Chain/drag flight feeders extract the material from the storage unit. They are suitable for materials of moderate size lumps and of average abrasiveness.

Rotary table feeders

Rotary table feeders are generally used for the volumetric feeding of fine bulk materials solids which have reasonably good flow ability they are suitable to install under storage unit outlet of larger diameter to prevent clogging by the sluggish material.

Rotary vane feeders

The rotary vane feeders are can be considered as an extremely short apron feeder. They are particularly used to discharge fine freely flowing bulk materials from the storage units.

Rotary drum feeders

This simple and sturdy feeder is suitable for free flowing and small lump bulk materials.

Rotary plough feeders

Normally rotary plough feeder is travelling type and extracts material from storing unit shelf. The feeder travel and thereby storage unit outlet length can be up to 200 m or so. This feeder is suitable to operate in tunnel under stockpile.

Types of maintenance

Objectives: At the end of this lesson you shall be able to
- **state maintenance and its types**
- **state the function of each maintenance**
- **distinguish between breakdown maintenance and preventive maintenance**
- **state the importance of breakdown and preventive maintenance in productivity.**

Maintenance is a process adapted to extent the life as well as the performance of machines, equipments, tools, etc.

Types of maintenance

- Scheduled maintenance
- Preventive maintenance
- Breakdown maintenance
- Predictive maintenance

Scheduled maintenance

- This is called as routine maintenance.
- In order to get trouble free service from productive equipments.
- Following activities is necessary to carry out.
  - i Lubrication
  - ii Periodic inspection
  - iii Adjustments of various parts
  - iv Cleaning
  - v Periodic overhaul
  - vi Repair and replacement, etc.

All the above maintenance operations are carried out while the machine is running or during pre-planned shutdowns.

This type of maintenance may prevent breakdown of equipments.

Routine maintenance should not interfere with production schedules.

Preventive maintenance

- Preventive maintenance is the maintenance undertaken to prevent breakdown.
- Weak spots as bearings, parts under excessive vibration and heat etc., are located by regular inspection.
- The parts of equipments are changed before the end of its lifetime to reduce danger of breakdown.
- The underlying principle of preventive maintenance is that “Prevention is better than cure”.
- Preventive maintenance is a definite programme of periodic cleaning, servicing, inspection and replacement of worn out and damage parts for vital plant facilities.

Importance of Preventive maintenance

Preventive maintenance is important because of the following advantages.

- Prevention of accidents.
- Prevention of damage to material and equipment.
- Reduce downtime and lower unit cost.
- Prevention of economic losses resulting from machinery breakdown.
- Decrease maintenance and repair cost.
- Increased efficiency in machinery performance.
- Improve quantity and quality of product.
- Reduced major and repetitive repairs of machines.
- Finds small problems before they become big ones.

Breakdown maintenance

This is called corrective maintenance or emergency maintenance. A machine is permitted to run without much attention till it breaks down. When it actually breaks down, it will be attended, since no attempt is made to prevent the occurrence of breakdown.

Breakdown maintenance is harmful. It is unpredictable and results in production loss. Hence any breakdown has to be given more priority and the equipment shall be got back into service as quickly as possible. In addition to repairing, causes of breakdown shall be investigated in order to avoid breakdowns in future.

Cause of equipment breakdown

- Failure to replace wornout parts.
- Lack of proper lubrication and cooling system.
- External factors such as voltage fluctuations, poor quality oils, etc.
- Not caring for equipments vibrations, unusual sounds, excessive heat on equipments and other minor faults.

Disadvantages of breakdown maintenance

- Production delays and stoppage.
- Inefficient use of maintenance manpower.
- Production and maintenance overtime.
- Not suitable for items regulated by statutory provisions. Eg., Cranes, Lifts, Pressure vessels, etc.

Difference between breakdown maintenance and preventive maintenance

Sl. No.	Breakdown maintenance	Preventive maintenance
1	Maintenance is undertaken only after breakdown	Maintenance is undertaken only before breakdown
2	No attempt is made to prevent breakdown	Maintenance is made to prevent breakdown
3	This is unpredictable activity.	Predictable activity.
4	Maintenance cost less.	Cost of maintenance is high.
5	Not suitable for equipments like cranes, hoists, pressure vessels.	Can be applied to all types of equipments.
6	Results in production loss and more "Down time"	Such disadvantages are eliminated.

Predictive maintenance

Scheduled programme of maintenance and preventive maintenance need careful planning. Hence it is necessary to know what is happening to different parts of machine tool equipment under actual working conditions. This will useful to estimate the lifetime of different parts of machine-tool equipments and to access the frequency of periodically maintenance.

In predictive maintenance, condition of equipment are checked periodically making use of human senses such as hearing, smell, sight, etc.

There are sensitive instruments to predict troubles in machines.

- Audio gauges
- Vibration analyzers
- Amplitude meters
- Pyrometers
- Strain gauges etc.

The above sensitive instrument are useful for the maintenance men to take timely action such as equipment adjustment, recondition or overhauling.

Upnormal sound coming out of a running machine predicts a trouble. Overheat a bearing predicts a trouble. Simple hand touch can point out many upnormal conditions and thus predict trouble.

Predictive maintenance increases the service life of machine tool and equipment without fear of failure.

Effect of maintenance on machine tool equipments life output and quality

- Life of machine tool equipment increases with increase in the performance of machine tool equipment.
- The products will be of good quality. The quality of goods produced may be consistent.
- Output of goods from the machine increases. This also results in lower unit cost.

Proactive maintenance

Proactive maintenance is a preventive maintenance strategy for maintaining the reliability of machines or equipment. The purpose of proactive maintenance is to view machine failure and similar problems as something that can be anticipated and dealt with before they occur.

Proactive maintenance focuses primarily on determining the root causes of machine failure, and dealing with those issues before problems occur. It is often seen as a cost-effective practice since it allows a company to avoid machine failure and solves issues before they become problems.

Reactive maintenance

The oldest maintenance approach is reactive. Equipment is not repaired or replaced until it breaks. In this maintenance equipment fails with little or no warning so this could be down until replacement parts arrive, resulting in income loss. In this maintenance cost and down time increased and also create safety issues. Reactive maintenance can be suitable in some situation such as for non critical and low cost equipment with little or no risk of capital loss or production loss.

Importance of breakdown maintenance and preventive maintenance in productivity

The importance of an effective maintenance program cannot be overlooked because it plays such an important role in the effectiveness of lean manufacturing. As in personal health care insurance, maintenance may be considered the health care of our manufacturing machines and equipment. It is required to effectively decrease waste and run an efficient, continuous manufacturing operation, business, or service operation. The cost of routine maintenance is very small when it is compared to the cost of a major breakdown at which time there is no production.

Purpose of maintenance

The importance use of routine maintenance is to ensure that all equipment required for production is operating at 100% efficiency at all times. Through short daily inspections, cleaning, lubricating and making small adjustment, small problems can be detected and corrected before they become a major problem that can shut down a production line. A good maintenance program requires company wide participation and support by everyone ranging from the top executive to the shop floor personnel.

Reliability Centered maintenance RCM is a maintenance program to optimise its maintenance of plant based on theirs reliability performance and criticality ,RCM can help to reduce cost, improve safety and enhance customer satisfaction by preuenting failures extending plant life RCM Program contain there steps

- undestant plant
- sefety right maintenance strategy
- implement and monitor the maintenance plan

Concept of TPM & OEE

Objectives : At the end of this lesson you shall be able to
- **explain the concept of TPM**
- **state advantage of TPM**
- **explain the concept of OEE**
- **describe the components of OEE and their effects.**

Total Productive Maintenance(TPM) concepts

TPM aims to maximize overall equipment effectiveness. Establishes a complete system of productive maintenance for the machines/equipments entire life span is implemented by various departments. [Engineering, Operations, Maintenance, Quality and Administration]

TPM can be considered as the medical science of machines.

TPM involves every single employee, from top management to all the operators on the shop floor. TPM raises and implements productive maintenance based on autonomous small group activities.

TPM is a maintenance program which involves a newly defined concept for maintaining plants and equipment.

The goal of TPM is to an extent increase production while, at the same time, increasing employee morale and job satisfaction.

TPM brings maintenance into focus as a necessary and vitally important part of the business. It is no longer regarded as a non-profit activity.

Downtime for maintenance is scheduled as a part of the manufacturing day. In some cases as an integral part of the production process.

The goal of TPM is to stop the emergency and unscheduled maintenance.

Form different teams to reduce defects and self maintenance.

Advantages of TPM

- Avoids wastage in quickly changing economic environment.
- Produces goods without reducing product quality.
- Reduces maintenance cost.
- Produces a low batch quantity at the earliest possible time.
- Ensures the non defective goods to the customers.
- Reduce customers complaints.
- Reduce accidents.
- Follow pollution control measures.
- Favourable change in the attitude of the operator.

Overall equipment effectiveness (OEE)

Overall equipment effectiveness (OEE) is a concept utilized in a lean manufacturing implementation. OEE is described as one such performance measurement tool that measures different types of production loses and indicate areas of process development. The OEE concept normally measures the effectiveness of a machine center or process line, but can be utilized in non-manufacturing operation also.

The high level formula for the lean manufacturing OEE is

OEE = Availability x Productivity x Quality

Availability

The availability is part of the above equation measures the percentage of time the machine/equipment of operation was running compared to the available time. For example if the machine was available to run 20 hours but was only run for 15, then the availability is 75 percent 15/20. The five hours when the machine didn't run would be set up time, breakdown or other downtime. The 4 hours the company did not plan to run the machine is rarely used in the calculation.

Performance

The performance part of the equation measures the running speed of the operation compared to its maximum capability often called the rated speed. For example, if a machine produced 80 pieces per hour while running, but the capability of the machine is 100, then the performance is 80% (80/100). The concept can be used multiple ways depending on the capability number. For example, the machine might be capable of producing 100 pieces per hour with the perfect part, but only 85 on that particular order. When the capability of 100 is used for the calculation, the result is more a measure of facility OEE.

Quality

The third portion of the equation measures the number of good parts produced compared to the total number of parts made. For example if 100 parts are made and 95 of them are good, the quality is 95% (95/100).

Combining the above example into the OEE equation the OEE is

OEE = 75% x 80% x 95% = 57%

Components of OEE and their effects

Variable	Prevents	Methods to improve
Availability	Idle time of machines. Adjustment time. Breakdowns.	Decrease the reactive maintenance improve PM scheduling. Restrain personnel information transfer.
Performance	Material variation inefficient work process poorly operating equipments outdated system poor lubrication	Replacements Equipment service Regular equipments PMs
Quality	Improper alignment of system Improper maintenance of records. Inconsistent raw materials doubtful work.	Improve the quality of product.

Maintenance procedure

Objective : At the end of this lesson you shall be able to
- **describe the normal procedure followed in machine tool maintenance in shop floor.**

Any kind of action or activity there should be some procedure and sequence likewise maintenance also has some normal procedure to execute the maintenance activity without any confusion. If maintenance is not followed any procedure there will be time loss and the machine and equipment could not be ready in time. The procedure guides the maintenance people how to start, execute, where to inspect and how to complete the maintenance in time. The maintenance is carried out with the following procedure.

- Initial cleanup
- Identification of fault
- Dismantling
- Inspection
- Identification of cause for defect
- Inspection and replacement/ Repair of spares
- Reassembling
- Trial run
- Inspection with standards
- Maintaining records

Initial cleanup

Main machine, connected accessories, lubrication system, panels and adjacent parts are to be cleaned first.

Identification of fault

The fault of the machine is to be identified by visual inspection and getting information from the complaint and justified the same.

Dismantling

The fault area is dismantled with the referring to the manual and all the spares are kept separate in a tray and preserved safely.

Inspection

All the dismantled parts such as gear, bearing, shaft, key, etc. are cleaned and inspected for any damages. Any damages/breakage is recorded in the maintenance checklist.

Identification of cause for defect

The defect in spare parts thoroughly examined and analysed the causes for damage and the same has to be rectified.

Inspection and replacement/ repair of spares

The damaged or broken spares are procured from stores/ repaired and the same is inspected to the standards.

Reassembling

The next course of action is assembling the parts in reverse manner of dismantling order.

Trail run

After completion of assembling the machine is first run manually and all the lubrication, electrical connection to be given. Finally the machine is trial run for some time and observed for any unusual sound from the machine.

Inspection with standards

The machine is finally checked/inspected for geometry accuracy safety hazards etc., According to the manufacturer standard any other recommended standard as required by the nature of maintenance work carried.

Maintaining records

All the activities related to fault attended, spares changed, etc. to be recorded in the inspection report/maintenance record, machine history cards suitably for future reference.

Meantime between failure and meantime to repair (MTBF & MTTR)

Objectives : At the end of this lesson you shall be able to
- **define MTBF**
- **define MTTR.**

Meantime between failures MTBF

It is the predicted elapsed time between inherent failures of a system during operation. MTBF can be calculated as the arithmetic mean (Average) time between failures of a system. The term is used in both plant and equipment maintenance contexts.

The definition of MTBF depends on the definition of what is consider a system failure. For complex, repairable system, failures are considered to be those out of design condition which place the system out of service and into a state for repair. Failures which occur that can be left are maintained in an unrepaired conditions and do not place the system out service, are not considered failures under this definition. In addition units that are taken down for routine. Scheduled maintenance or inventory control are not considered with in the definition of failure.

$$\text{MTBF} = \frac{\text{Total running time}}{\text{Number of failures}}$$

Meantime to repair (MTTR)

MTTR is the average time required to trouble shoot and repair failed equipment and return it to normal operating conditions. It is a basic technical measure of the maintainability of equipment and repairable parts. It is the total corrective maintenance for failure divided by the total number of corrective maintenance actions for failures during a given period of time.

In OEE calculation

OEE = A x P x Q

The ‘A’ (Availability of machine in hours) is calculated by

$$A = \frac{\text{MTBF} - \text{MTTR}}{\text{MTBF}2a}$$

Where,

P = Performance (Productivity)

Q = Quality

Inspection, Types of inspection and gadgets for inspection

Objectives : At the end of this lesson you shall be able to
- **state the need of inspection**
- **state the function of inspection**
- **list out the type of inspection**
- **discuss the each type of inspection**
- **list out the gadgets used for inspection.**

Inspection

Inspection is necessary for any machine/equipment where remarkable risk to health and safety may arise from wrong installation, re-installation or any other circumstances. The purpose of inspection is to find whether machine can be operated, adjusted and maintained safely. The need for inspection and inspection intervals to be determined through risk assessment.

The summary of inspection should be recorded and same should be kept atleast until the next inspection of that machine. Machine/equipment that required inspection should not be used unless the machine has been inspected.

If the machine/equipment obtained from any other source (eg. Hired). One should be ensure that physical evidence of last inspection is accompanied with the machine, such as inspection report, some form of tagging, labelling system or colour coding.

Function of inspection in maintenance

1 Periodic inspection of machines and equipments as per checklist (Annexure 1)

2 Keeping basic records of each machine & equipments.

3 Preparation of list which need for repairs (or) spare for replacements.

4 Analysis of inspection report and systematic review of reports of machines/equipments.

5 Assigning of frequency of inspection.

The following Annexure 1,2 and 3 are the formats used in maintenance inspection.

Annexure I

INSPECTION CHECK-LIST

Name of the machine : Location of the machine :

Machine No :

Model No :

Inspect the following items and tick in the appropriate column and list the measures for the defective items.

Item to be checked	Good working/Satisfactory/Status	Defective	Remedial measures
Availability of machine manual			
Safety guards			
Installation			
Level of the machine			
Belt and its tension			
Bearing sound			
Driving clutch and brake			
Exposed gears			
Working in all the speeds			
Working in all the feeds			
Lubrication system			
Coolant system			
Sliding part and its travel			
Safety and limit switches			
Electrical controls			
Proper lighting			
Emergency stop			
Alarm speciality			
Condition of work holding devices			
Condition of tool holding devices			
Condition of accessories and attachments			
Chip collection and disposal			

Conclusion of inspection

Recommendations

Inspected by

Signature

Name :

Date :

Signature of in-charge

Annexure II

EQUIPMENT RECORD

History sheet of machinery & equipment

Description of equipment :

Manufacturer's address :

Supplier's address :

Order no. and date :

Date on which received :

Date on which installed and placed :

Date of commissioning :

Size : Length x Width x Height

Weight :

Cost :

Motor particulars : Watts : R.P.M Phase : Volts

Bearings/Spares record :

Belt specification :

Lubrication details :

Major repairs and overhauls carried out with dates

Annexure III

Inspection records

Sl. No.	Name of the machine/ Equipment	Nature of fault identified	Date	Nature of action taken

Types of inspection

To ensure optimum functioning of equipments/machineries and accident free functioning inspection is to be carried out at various methods. The general inspection methods are

- Equipment inspection
- Shutdown inspection
- Running equipment inspection
- Spare parts inspection

Equipment inspection

The inspection carried out after installation, re-installation, re-conditioning, maintenance is known as equipment inspection. It may eliminate risk to health and safety hazards may arise from wrong installation or wrong assembling. The equipment inspection is carried out at the intervals as prescribed earlier with respect to the nature and working condition of the machine.

Shutdown inspection

Any inspection in part of a plant like heat exchangers, piping units, hydraulic units can be done by shut downing the whole plant/unit. In this inspection all activities should be well planned with time frame. The inspection activities performed during these must be perfect to allow the operation to restart quickly and safely. This type of inspection is done to avoid major shutdown of entire plant due to breakdown of small equipments. For example any failure in pneumatic/hydraulic unit will create major unnecessary plant shut down.

Running equipment inspection

Some condition of the equipment parts can be inspected while running only like bearing heat and sound and lubrication system, safety tripping systems, etc. Since this inspection is carried out while the equipment/machines are in running condition, care to be taken to avoid any damage to gadgets used for inspection and to injury to the personnel.

Spare parts inspection

Parts procurred or repaired for re-assembling has to be inspected visually, dimensionally, functionally and material quality to avoid unnecessary breakdown at unexpected time. The advantages of spare parts inspection are

- avoid unexpected breakdown
- reduce production loss and cost
- increase uptime
- increase overall equipment effectiveness
- ensures the originality of the machine
- ensures the proper functioning of machine.

Gadgets used for inspection

Special devices are need to inspect the machines. The following gadgets are generally used for inspection purpose.

- Spirit level/optical/electronic or laser technological leveller
- Belt aligner/pulley aligner
- Bearing tester
- Viscometer
- Laser shaft alignment equipment
- Straight edges

Condition monitoring

Objectives : At the end of this lesson you shall be able to
- **explain the activity of condition monitoring**
- **describe the common devices used in condition monitoring**
- **state the importance of condition monitoring.**

Condition monitoring

Condition monitoring is the process of monitoring a parameter of condition in machines. (Vibration, temperature, sound, lubrication, etc.). In order to identify a significant change which is indicative of a developing fault.

Condition Monitor (CM) is not a life-extending activity. Life-extending activities are things such as lubrication, alignment, balancing and operating procedures. It's very important to keep this very basic fact clear in all communications within your plant; Otherwise, too little importance may be placed on the planning and scheduling of corrective work orders originated in CM.

CM only provides information on failures before there is a breakdown. You can do it with inspection tools vibration monitors, infrared temperature guns, pressure gauges, voltmeters and others. You can also execute CM subjectively by looking, listening, feeling and smelling.

Common devices used for condition monitoring

- Vibrometer
- Temperature gun/thermometer
- Engineer's stethoscope
- Viscometer

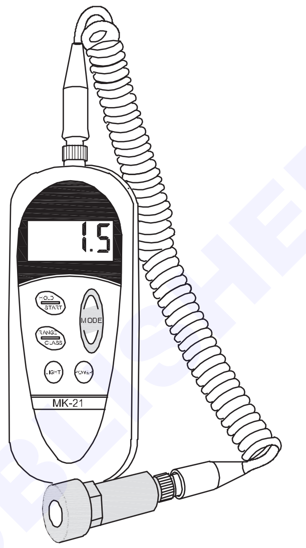
Vibrometer

Vibrometer (Fig 1) is a portable device which is used to measure vibration and oscillation in many machines and equipments. Measurement of vibration meter cover the following parameters.

- Vibration acceleration
- Vibration velocity
- Vibration displacement

Vibrometer is available in contact and non contact types. The reading taken in vibrometer can be stored and retrieved for later use. The same will be compared with allowable standards. If this reading is more than the level, attention to be given to rectify the defect.

Fig 1



Thermometer (Fig 2)/**Temperature gun** (Fig 3)

The heat produced due to excessive friction and malfunctioning in machineries and equipment can be measured with temperature measuring devices. There are so may types available. The major types are contact and non-contact types. In contact type the temperature is measured by touching the probe in the target. Where as in non contact type, the device is placed away from the target and temperature is measured by sensing the radiation emitted from the target.

The measured temperature is more than the permissible. It indicates failure starts due to any one of the reason like lubrication failure, excessive friction, etc.

Fig 2

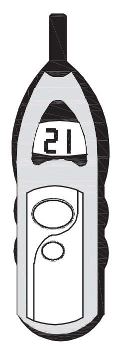
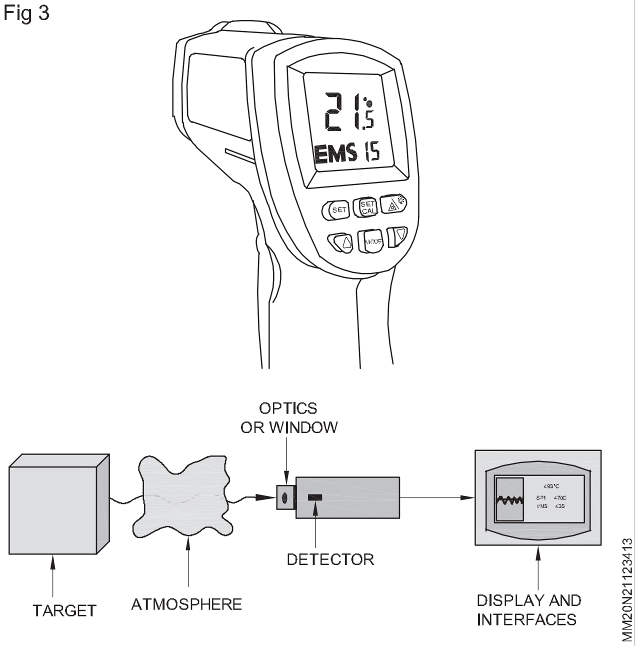


Fig 3



Engineer's stethoscope (Fig 4)

Engineer's stethescope is a sensitive instrument used to detect the noise or vibration produced in the trouble some machine parts like bearings.

Fig 4

Viscometer (Fig 5 & 6)

Viscometer is an instrument used to measure the viscosity of the fluid.

Lubricant in the machineries losses its viscosity due long use, raise in temperature, contaminated and this is measured with viscometer. Based on the viscosity corrective action to be taken.

Fig 5

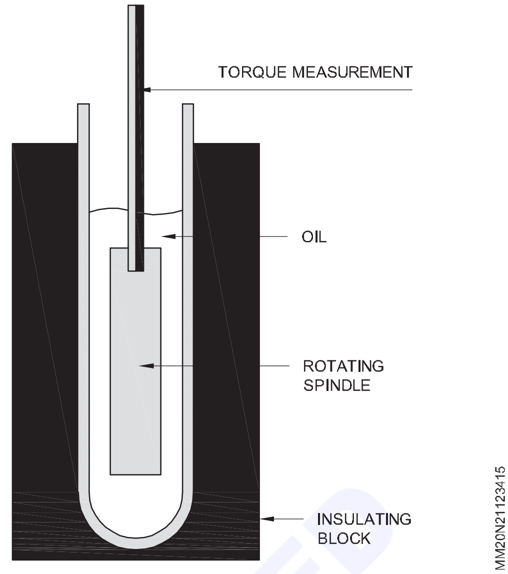
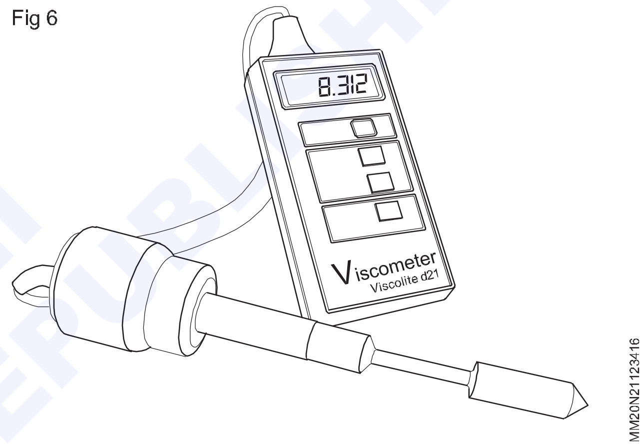


Fig 6



Importance of condition monitoring

Condition monitoring involves continuous detection of machinery components or equipments while its running. CM allows maintenance to be scheduled or other actions to be taken to avoid frequent failures. Thus CM reduce the breakdowns and thus improve the productivity.

Testing machine tools

Objectives : At the end of this lesson you shall be able to
- **state the necessity of testing machine tools**
- **state the importance of acceptance test charts**
- **distinguish between performance test and geometrical tests**
- **enumerate the uses of test charts**
- **state the purpose of periodic geometrical tests.**

Testing machine tools

Unless a machine tool is accurate, it will not produce accurate work. It is necessary for the manufacturer to state the degree of accuracy of the various movements controlling the accuracy of the components produced by the machine.

Acceptance test charts

Most makers of machine tools do this by means of test charts which indicate the maximum permissible error, together with the actual error of the part when it was tested at the maker's works.

Such information and tests are available in BIS machine tool standards. For checking machines after installation/ repairing so as to ensure that.

- It has not been distorted in transit
- It has been properly fixed in position
- It will yield an accurate product

The test charts are in three sections

- Levelling
- Geometrical test
- Performance test

Levelling

The machine must first be carefully levelled on a rigid floor by means of steel wedges, packings, etc. and checked with precision level as specified in the charts. Each test is based on the correct erection and levelling of the machine.

Geometrical test

This test is carried out to know the grade of accuracy of the assembled machine while idle and in an unloaded condition and after running the main spindle for atleast an hour at its mean speed. The machine should be tested in its fully assembled state.

> **Ensure that the machine is levelled before the test is done.**

Performance test

This test is to ascertain the precision of a machine tool for the finishing operation for which the machine has been designed.

The practical tests should be carried out on pieces, the production of which does not require operations other than those for which the machine has been built.

The degree of working accuracy of the machine, besides depending on the machine itself, is also influenced by the following factors.

- The type of cutting tools
- The material of the cutting tool and workpiece
- The cutting speed feed and depth of cut
- Tool and work-holding units
- The skill of the operator

Importance of condition monitoring and various techniques used for condition monitoring regarding vibration temperature , sound and lubrication condition

Condition monitoring is a crucial in various industries top assess the health and performance of machinery and equipment. It involves the regular inspection and analysis of specific parameters to detect anomalies, predict potential failures, and optimise maintenance activities. The importance of condition monitoring cannot be overstated ,as it several benefits, including cost savings, improved reliability, and increased safety. Here's an overview of the importance of condition monitoring and various techniques used for monitoring parameters such as virbration, temperatures, sound, and lubricant condition.:

Importance of condition monitoring:

Early fault detection : condition monitoring helps detect potential issues at an early stage, allowing maintenance teams to take preventive actions before a failure occurs. This minimizes costly downtime and unplanned shutdowns.

Optimized maintenance : by providing insights into the actual conditions of equipment ,condition monitoring enables maintenance to be scheduled based on need rather than on a fixed calendar, reducing unnecessary maintenance and associated costs.

Enchaced safety : Timely detection of faults or deteriorating conditions can prevent accidents and injuries bu allowing for the maintenance or replacement of faulty equipment before it poses a safety hazard.

Improved reliability : Condition monitoring ensures that critical machinery operates at peak performance, which is particularly important in industries where reliability and consistency are key factors.

Extended Equipment Lifespan: Regular monitoring and maintenance can extend the lifespan of machinery and equipment, reducing the need for costly replacements.

Cost Savings: By reducing unexpected breakdowns, optimizing maintenance efforts, and avoiding unnecessary repairs, condition monitoring leads to significant cost savings in terms of labor,downtime, and spare parts.

Energy Efficiency: Monitoring systems can detect issues affecting the energy efficiency of equipment, leading to reduced energy consumption and operational costs.

Techniques for Condition Monitoring:

Vibration Monitoring:

Vibration analysis measures the amplitude and frequency of vibrations in machinery. Changes in vibration patterns can indicate imbalance, misalignment, worn bearings, or other mechanical problems.

Temperature Monitoring:

Infrared thermography and contact temperature sensors are used to monitor the temperature of components. Elevated temperatures can signal issues like overheating, electrical faults, or friction.

Sound Monitoring:

Sound analysis assesses the noise generated by equipment. Unusual or increasing noise levels can indicate problems like bearing wear, loose parts, or misalignment.

Lubricant Condition Monitoring:

Oil analysis checks the condition of lubricants in machinery. It identifies contamination, oxidation, and the presence of wear particles, helping assess the health of the equipment.

Ultrasound Monitoring:

Ultrasound technology detects high-frequency sounds that are not audible to the human ear. It is used for early detection of issues like leaks, electrical discharges, and bearing problems.

Electric Current Monitoring:

Current analysis monitors the electrical parameters of motors and other equipment to detect issues such as imbalances, overload, or phase problems.

Condition Monitoring Sensors:

Advanced sensors, including accelerometers, thermocouples, and ultrasonic transducers, are used to collect data for analysis.

Concept of Industry and Digital Manufacturing:

The concept of industry and digital manufacturing represents the transformation of traditional industrial processes through the integration of advanced technologies and digital tools. It encompasses various principles and practices aimed at improving efficiency, flexibility, and productivity in manufacturing and industrial settings. Here's an overview of these concepts:

1 Industry 4.0:

Industry 4.0, often referred to as the Fourth Industrial Revolution, is a paradigm shift in manufacturing. It focuses on the inter connectedness of machines, systems, and data to create smart factories. Key components include the Internet of Things (IoT), artificial intelligence (AI), cloud computing, and data analytics.

Industry 4.0 enables real-time data collection, analysis, and decision-making, leading to more efficientand responsive manufacturing processes. It promotes the use of cyber-physical systems (CPS) and the digital twin concept-, where a virtual replica of a physical product or system is created and monitored.

2 Digital Manufacturing:

Digital manufacturing is the application of digital technologies to optimize and streamline the entire manufacturing process, from design and prototyping to production and supply chain management.

It includes various technologies such as computer-aided design (CAD), computer-aided manufacturing(CAM), digital twin simulations, and 3D printing. These technologies enhance product design, reduce time to market, and improve manufacturing flexibility.

3 Smart Manufacturing:

Smart manufacturing involves the use of intelligent automation, data analytics, and IoT to create more agile and efficient manufacturing operations. It leverages real-time data and predictive analytics to optimize production processes, reduce waste, and enhance quality control.

Smart manufacturing integrates the physical and digital worlds to enable real-time monitoring, adaptive control, and autonomous decision-making in factories.

4 Benefits of Digital Manufacturing:

Improved Efficiency: Digital manufacturing reduces lead times, minimizes errors, and increases overall efficiency by enabling seamless data exchange and automation.

Quality Control: Real-time monitoring and data analytics help maintain product quality and detect defects early in the production process.

Cost Reduction: By optimizing processes and reducing waste, digital manufacturing can lead to significant cost savings.

Customization and Flexibility: Digital tools allow for more flexible and customized production, accommodating changing market demands.

Sustainability: The ability to monitor and optimize resource usage can lead to more sustainable manufacturing practices.

5 Challenges and Considerations:

Data Security: The increased reliance on digital tools necessitates robust data security measures to protect sensitive information and systems from cyber threats.

Workforce Training: Employees need training to adapt to new digital technologies and workflows.

Integration: Ensuring seamless integration of various digital tools and systems within an organization can be complex and requires careful planning.

Cost: Initial investment in digital manufacturing technology can be significant, but the long-term benefits often outweigh the costs.