

FITTER

NSQF LEVEL - 5

4th Semester

TRADE THEORY

SECTOR: Production & Manufacturing



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 : Production & Manufacturing
Duration : 2 - Years
Trade : Fitter 4th Semester - Trade Theory

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First Edition : October 2018

Copies : 1,000

Rs. 210/-

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Published by:

NATIONAL INSTRUCTIONAL MEDIA INSTITUTE
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Guindy, Chennai - 600 032.

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FOREWORD

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

The National Instructional Media Institute (NIMI), Chennai, has now come up with instructional material to suit the revised curriculum for **Fitter 4thSemester Trade Theory NSQF Level - 5 in Production & Manufacturing Sector under Semester Pattern**. The NSQF Level - 5 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 - 5 trainees will also get the opportunities to promote life long learning and skill development. I have no doubt that with NSQF Level - 5 the trainers and trainees of ITIs, and all stakeholders will derive maximum benefits from these IMPs and that NIMI's effort will go a long way in improving the quality of Vocational training in the country.

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

Jai Hind

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RAJESH AGGARWAL

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

New Delhi - 110 001

PREFACE

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

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

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

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

R. P. DHINGRA
EXECUTIVE DIRECTOR

ACKNOWLEDGEMENT

National Instructional Media Institute (NIMI) sincerely acknowledges with thanks for the co-operation and contribution extended by the following Media Developers and their sponsoring organisations to bring out this Instructional Material (**Trade Theory**) for the trade of **Fitter** under **Production & Manufacturing** Sector for ITIs.

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

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

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

INTRODUCTION

TRADE THEORY

The manual of trade theory consists of theoretical information for the Fourth Semester Course of the Fitter Trade. The contents are sequenced according to the practical exercise contained in NSQF LEVEL - 5 syllabus on Trade Practical. Attempt has been made to relate the theoretical aspects with the skill covered in each exercise to the extent possible. This correlation is maintained to help the trainees to develop the perceptual capabilities for performing the skills.

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

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

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

TRADE PRACTICAL

The trade practical manual is intended to be used in practical workshop. It consists of a series of practical exercises to be completed by the trainees during the Fourth Semester Course of Fitter 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 - 5 syllabus are covered.

The manual is divided into six modules. The distribution of time for the practical in the six modules are given below:

Module 1	Drill Jig	25 Hrs
Module 2	Repairing Technique	200 Hrs
Module 3	Hydraulics & Penumatics	100 Hrs
Module 4	Preventive Maintenance	75 Hrs
Module 5	Erection and Testing	75 Hrs
Module 6	Project Work / Inplant Training	50 Hrs
	Total	<u>525 Hrs</u>

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

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

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LEARNING / ASSESSABLE OUTCOME

On completion of this book you shall be able to

- Make drill jig and produce components on drilling machine by using jigs and check for correctness.
- Plan, dismantle, repair and assemble different damaged mechanical components used for power transmission and check functionality of mechanical components like pulley, gear, keys, jigs and shafts.
- Identify, dismantle, replace and assemble different pneumatics and hydraulics components like compressor, pressure gauge, filter, regulator, lubricator, valves and actuators.
- Construct circuit of pneumatics and hydraulics observing standard operating procedure and safety aspect.
- Plan and perform basic day to day preventive maintenance, repairing and check functionality of drilling machine, power saw and lathe.
- Plan, erect simple machine and test mechanical tool accuracy of drilling machine, power saw and lathe.

SYLLABUS

FOURTH SEMESTER

Duration: Six Months

Week No.	Ref. Learning Outcome	Professional Skills with Indicative hrs.	Professional Knowledge
79	Make drill jig & produce components on drill machine by using jigs and check for correctness.	159. Make a simple drilling jig. (20 hrs.) 160. Use simple jigs and fixtures for drilling. (5 hrs.)	Drilling jig-constructural features, types and uses. Fixtures-Constructural features, types and uses.
80	Plan, dismantle, repair and assemble different damaged mechanical components used for power transmission & check functionality. [Different Damage Mechanical Components – Pulley, Gear, Keys, Jibs and Shafts.]	161. Marking out for angular outlines, filing and fitting the inserts into gaps. (10 hrs.) 162. Exercises on finished material such as aluminium/ brass/ copper / stainless steel, marking out, cutting to size, drilling, tapping etc. without damage to surface of finished articles. (15 hrs.)	Aluminium and its alloys. Uses, advantages and disadvantages, weight and strength as compared with steel. Non-ferrous metals such as brass, phosphor bronze, gunmetal, copper, aluminium etc. Their composition and purposes, where and why used, advantages for specific purposes, surface wearing properties of bronze and brass.
81	-do-	163. Making an adjustable spanner: - Marking out as per Blue print, drilling, cutting, straight and curve filing, threading, cutting slot and cutting internal threads with taps. (25 hrs.)	Installation, maintenance and overhaul of machinery and engineering equipment. Power transmission elements. The object of belts, their sizes and specifications, materials of which the belts are made, selection of the type of belts with the consideration of weather, load and tension methods of joining leather belts
82-84	-do-	164. Dismantling and mounting of pulleys. (10 hrs.) 165. Making & replacing damaged keys. (15 hrs.) 166. Dismounting, repairing damaged gears and mounting and check for workability. (15 hrs.) 167. Repair & replacement of belts and check for workability. (10 hrs.)	Vee belts and their advantages and disadvantages, Use of commercial belts, dressing and resin creep and slipping, calculation. Power transmissions- coupling types flange coupling, -Hooks coupling universal coupling and their different uses. Pulleys- types-solid, split and „V? belt pulleys, standard calculation for determining size crowning of faces-loose and fast pulleys-jockey pulley. Types of drives-open and cross belt drives. The geometrical explanation of the belt drivers at an angle.
85	-do-	168. Making of template/gauge to check involute profile. (25 hrs.)	Power transmission –by gears, most common form spur gear, set names of some essential parts of the set-The pitch circles, Diametral pitch, velocity ratio of a gear set.

86	-do-	169. Repair of broken gear tooth by stud and repair broken gear teeth by dovetail. (25 hrs.)	Helical gear, herring bone gears, bevel gearing, spiral bevel gearing, hypoid gearing, pinion and rack, worm gearing, velocity ratio of worm gearing. Repair of gear teeth by building up and dovetail method.
87	-do-	170. Make hexagonal slide fitting. (20 hrs.) 171. Prepare different types of documentation as per industrial need by different methods of recording information. (5 hrs.)	Importance of Technical English terms used in industry –(in simple definition only) Technical forms, process charts, activity logs, in required formats of industry, estimation, cycle time, productivity reports, job cards.
88	-do-	172. Marking out on the round sections for geometrical shaped fittings such as spline with 3 or 4 teeth. Finishing and fitting to size, checking up the faces for universality. (25 hrs.)	Fluid power, Pneumatics, Hydraulics, and their comparison, Overview of a pneumatic system, Boyle's law. Overview of an industrial hydraulic system, Applications, Pascal's Law.
89	Identify, dismantle, replace and assemble different pneumatics and hydraulics components. [Different components – Compressor, Pressure Gauge, Filter Regulator Lubricator, Valves and Actuators.	173. Identify pneumatic components – Compressor, pressure gauge, Filter-Regulator-Lubricator (FRL) unit, and Different types of valves and actuators. (2 hrs.) 174. Dismantle, replace, and assemble FRL unit(5 hrs.) 175. Demonstrate knowledge of safety procedures in pneumatic systems and personal Protective Equipment (PPE)(2 hrs.) 176. Identify the parts of a pneumatic cylinder (1 hrs.) 177. Dismantle and assemble a pneumatic cylinder (8 hrs.) 178. Construct a circuit for the direction & speed control of a small-bore single-acting (s/a) pneumatic cylinder(7 hrs.)	Compressed air generation and conditioning, Air compressors, Pressure regulation, Dryers, Air receiver, Conductors and fittings, FRL unit, Applications of pneumatics, Hazards & safety precautions in pneumatic systems. Pneumatic actuators:- Types, Basic operation, Force, Stroke length, Singleacting and double-acting cylinders.
90	Construct circuit of pneumatics and hydraulics observing standard operating procedure& safety aspect.	179. Construct a control circuit for the control of a d/a pneumatic cylinder with momentary input signals(5 hrs.) 180. Construct a circuit for the direct & indirect control of a d/a pneumatic cylinder with a single & double solenoid valve(10 hrs.) 181. Dismantling &Assembling of solenoid valves(10 hrs.)	Pneumatic valves:- Classification, Symbols of pneumatic components, 3/2way valves (NO & NC types) (manually actuated & pneumatically-actuated) & 5/2-way valves, Check valves, Flow control valves, Oneway flow control valve Pneumatic valves: Roller valve, Shuttle valve, Two-pressure valve Electro-pneumatics: Introduction, 3/2way 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

91	Identify, dismantle, replace and assemble different pneumatics and hydraulics components. [Different components – Compressor, Pressure Gauge, Filter Regulator Lubricator, Valves and Actuators.]	<p>182. Demonstrate knowledge of safety procedures in hydraulic systems (Demo by video) (5 hrs.)</p> <p>183. Identify hydraulic components – Pumps, Reservoir, Fluids, Pressure relief valve (PRV), Filters, different types of valves, actuators, and hoses (5 hrs.)</p> <p>184. Inspect fluid levels, service reservoirs, clean/replace filters(5 hrs.)</p> <p>185. Inspect hose for twist, kinks, and minimum bend radius, Inspect hose/tube fittings(5 hrs.)</p> <p>186. Identify internal parts of hydraulic cylinders, pumps/motors(5 hrs.)</p>	<ul style="list-style-type: none"> - 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, cavitation, 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
92	Construct circuit of pneumatics and hydraulics observing standard operating procedure& safety aspect.	<p>187. Construct a circuit for the control of a s/a hydraulic cylinder using a 3/2-way valve (Weight loaded d/a cylinder may be used as a s/a cylinder), 4/2 & 4/3 way valves. (10 hrs.)</p> <p>188. Maintenance, troubleshooting, and safety aspects of pneumatic and hydraulic systems (The practical for this component may demonstrated by video) (15 hrs.)</p>	<ul style="list-style-type: none"> - 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 - Hydraulic valves: Check valves and Pilot-operated check valves, Load holding function - Flow control valves: Types, Speed control methods – meter-in and meterout - Preventive maintenance & troubleshooting of pneumatic & hydraulic systems, System malfunctions due to contamination, leakage, friction, improper mountings, cavitation, and proper sampling of hydraulic oils
93	Plan & perform basic day to day preventive maintenance, repairing and check functionality.[Simple Machines – Drill Machine, Power Saw and Lathe]	189. Dismantle, overhauling & assemble cross-slide & handslide of lathe carriage. (25 hrs.)	Method or fixing geared wheels for various purpose drives. General cause of the wear and tear of the toothed wheels and their remedies, method of fitting spiral gears, helical gears, bevel gears, worm and worm wheels in relation to required drive. Care and maintenance of gears.

94-96	-do-	<p>190. Simple repair of machinery: - Making of packing gaskets. (5 hrs.)</p> <p>191. Check washers, gasket, clutch, keys, jibs, cotter, Circlip, etc. and replace/repair if needed. (5 hrs.)</p> <p>192. Use hollow punches, extractor, drifts, various types of hammers and spanners, etc. for repair work. (15 hrs.)</p> <p>193. Dismantling, assembling of different types of bearing and check for functionality. (15 hrs.)</p> <p>194. Perform routine check of machine and do replenish as per requirement. (10 hrs.)</p>	<p>Method of lubrication-gravity feed, force (pressure) feed, splash lubrication. Cutting lubricants and coolants: Soluble off soaps, suds-paraffin, soda water, common lubricating oils and their commercial names, selection of lubricants. Clutch: Type, positive clutch (straight tooth type, angular tooth type) . Washers-Types and calculation of washer sizes. The making of joints and fitting packing. Chains, wire ropes and clutches for power transmission. Their types and brief description.</p>
97	Plan, erect simple machine and test machine tool accuracy. [Simple Machines – Drill Machine, Power Saw and Lathe]	<p>195. Inspection of Machine tools such as alignment, levelling. (10 hrs.)</p> <p>196. Accuracy testing of Machine tools such as geometrical parameters. (15 hrs.)</p>	<p>Lubrication and lubricants-purpose of using different types, description and uses of each type. Method of lubrication. A good lubricant, viscosity of the lubricant, Main property of lubricant. How a film of oil is formed in journal Bearings.</p>
98-99	-do-	<p>197. Practicing, making various knots, correct loading of slings, correct and safe removal of parts. (5 hrs.)</p> <p>198. Erect simple machines. (45 hrs.)</p>	<p>Foundation bolt: types (rag, Lewis cotter bolt) description of each erection tools, pulley block, crow bar, spirit level, Plumb bob, wire rope, manila rope, wooden block. The use of lifting appliances, extractor presses and their use. Practical method of obtaining mechanical advantage. The slings and handling of heavy machinery, special precautions in the removal and replacement of heavy parts.</p>
100-101	<p>In-plant training/ Project work</p> <ol style="list-style-type: none"> 1. Pulley Extractor 2. Cam Vice 3. Link Mechanism 4. Adjustable Fixture 5. Slider Crank 6. Hand Lever Punch 7. Setup hydraulic and pneumatic circuit and test the functioning of piston movement. 		
102-103	Revision		
104	Examination		

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Drilling jig constructional features, types and uses

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

- what is jig
- list the different types of drill jig and uses
- state constructional features of drill jig

Introduction to jigs

A jig is a device in which a work piece/component is held and located for a specific operation in such a way that it will guide one or more cutting tools to the same zone of machining.

Types of drill jigs

Drill jigs may be divided into two types

- Open
- Closed

Open jigs are used when the operation is to be done only on one side of the piece. Closed jigs (Box jig) are used when the operations are to be done on more than one side of the piece. Jigs are identified according to the way they are built. Most commonly used jigs are:

- Template jig
- Plate jig
- Table jig
- Sandwich jig
- Angle plate jig
- Modified angle plate jig
- Box jig
- Channel jig
- Leaf jig
- Indexing jig
- Solid jig
- Post jig
- Trunnion jig

Types of drill jigs

Template jigs

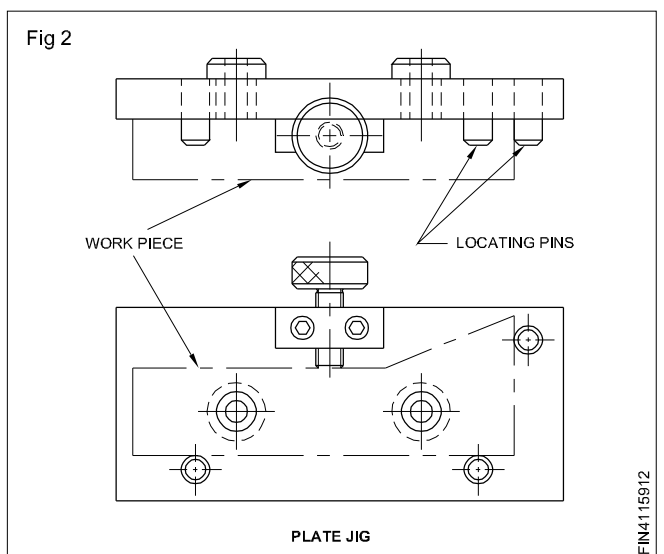
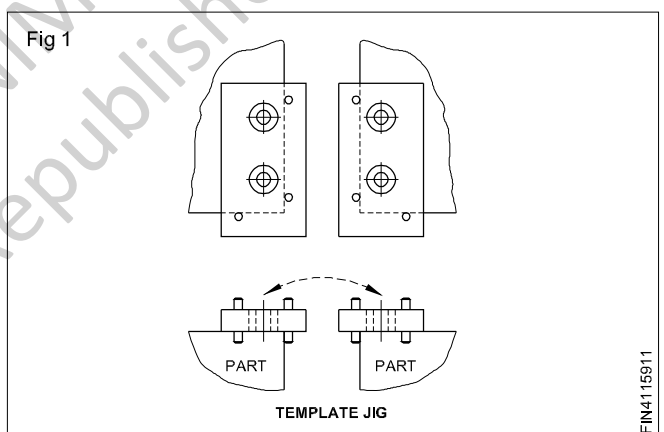
This type of jigs fits over on or into the work and is not usually clamped. They are simple and cheap. They may or may not have guide bushes. When bushes are not used the whole jig plate may be (Fig 1)

The design of a particular type of jig will be based on:

- the position wherein the drilling or its allied operation/ operations are to be performed
- the shape of the piece part.

Plate jig

This jig consists of a drill plate which rests on the component to be drilled. For correct positioning/locating, pins and clips are provided. For heavier piece parts, sometimes clamps are not used. Generally a base plate will not be available for this type of jigs. (Figs 1, 2 and 3)



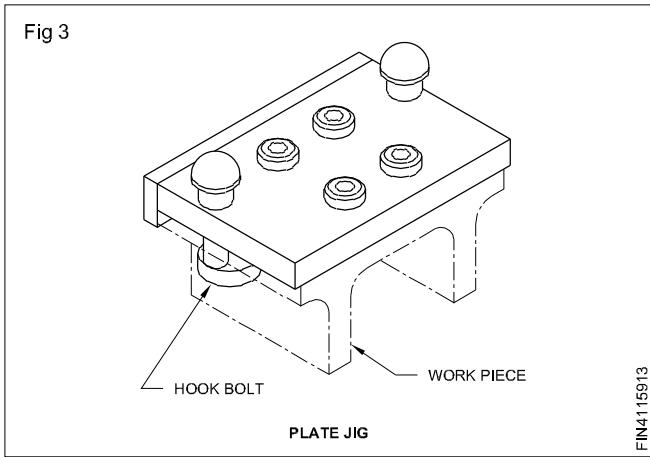
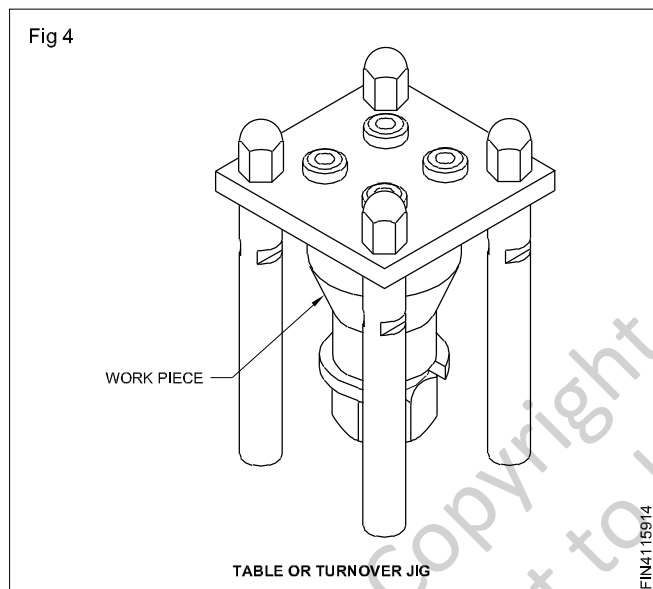


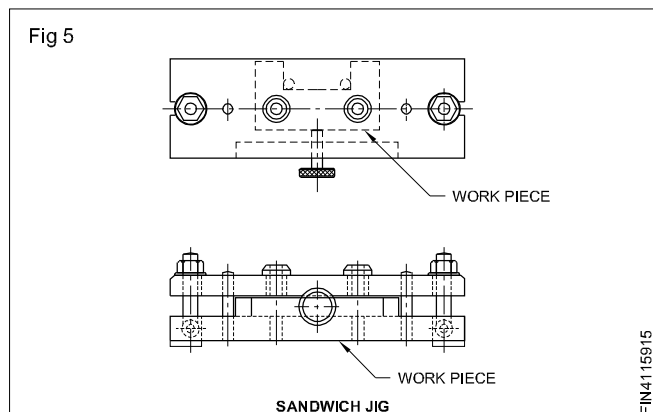
Table jig (Turnover jig)

This is used when it is necessary to locate the piece part from its face. For accurate seating of the jig on the machine table, four legs will be provided on this type of jig. (Fig 4)



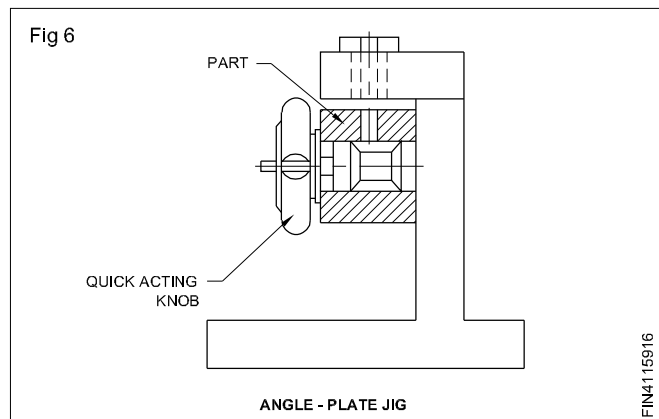
Sandwich jig

This is ideal for thin or soft workpieces which may bend or warp due to force while machining. In this type of jigs, the component will be sandwiched between the base plate and the drill plate. (Fig 5)



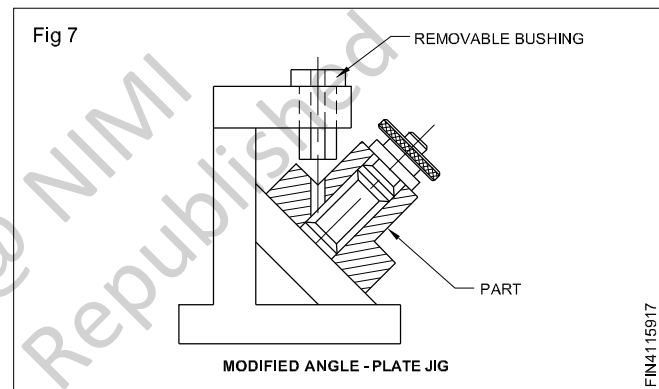
Angle plate jig

These jigs are used to hold work which are to be drilled at right angles to their mounting locators. (Fig 6)



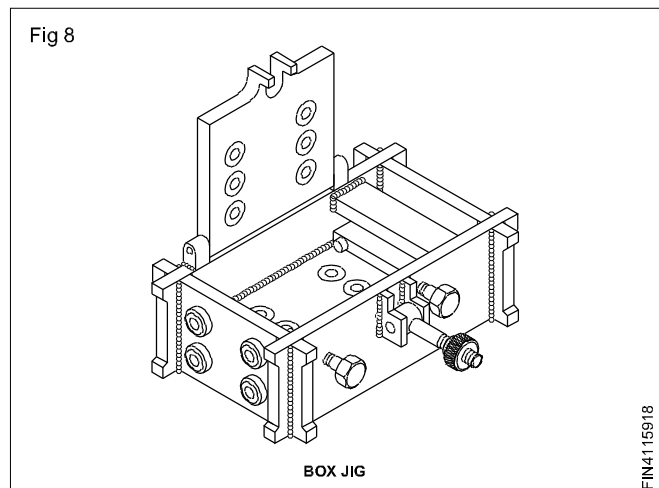
Modified angle plate jig

These jigs are used for drilling at angles other than 90°. (Fig 7)



Box jig

This is made in the form of a box or a frame work. The component is located and clamped at one position but drilling can be done from different directions as required. When a box jig contains bushings on two or more sides for drilling from different directions, it is called a tumble jig. (Fig 8) This jig is meant for small components only.



Channel jig

They are the simplest form of box jigs.

The workpiece is held between two sides and machined from the third. (Fig 9)

Latch or leaf jig

This type of jig will have a hinged cover with the latch clamps for easy loading and unloading of components. The cover with latch must be positively located and clamped so that the bushes are accurately located with respect to the component. (Fig 10)

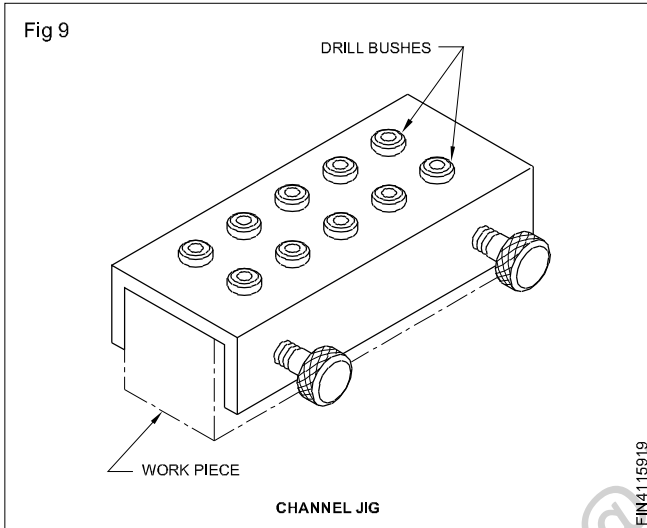
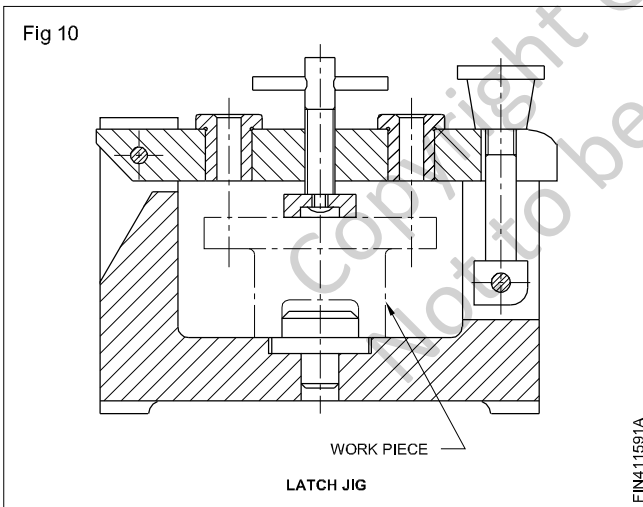
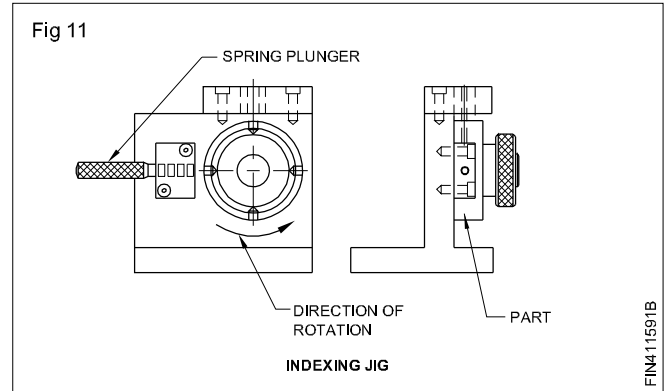


Fig 10



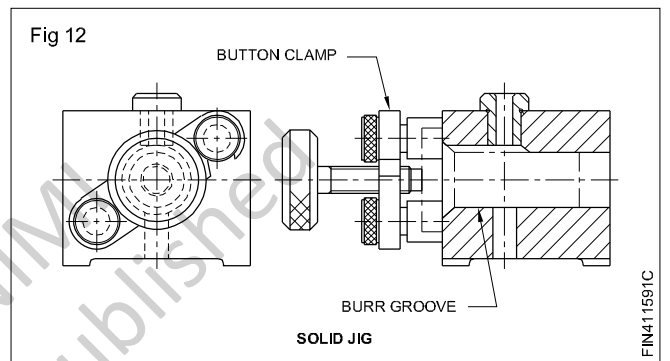
Indexing jig

Indexing jigs are used to accurately space holes on other machined area around a part. The jig uses the part being machined as a reference plate. A spring loaded plunger indexes the part. (Fig 11)



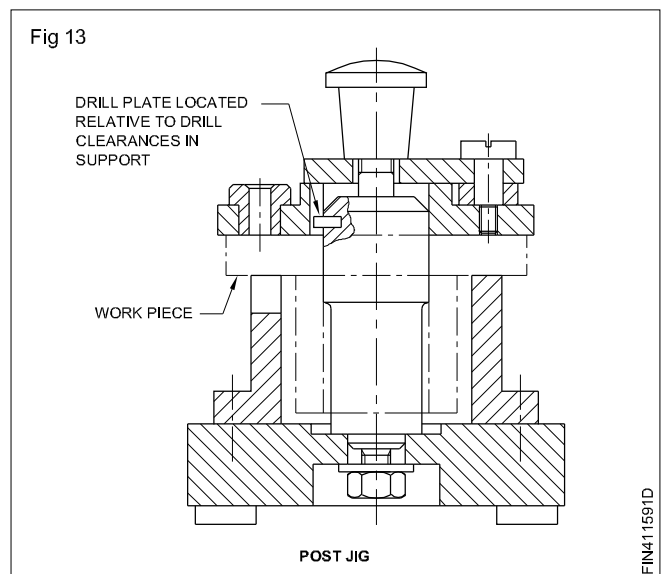
Solid jig

This can be used while drilling small piece parts. The body of this type of jig is machined from a solid block of steel. (Fig 12)



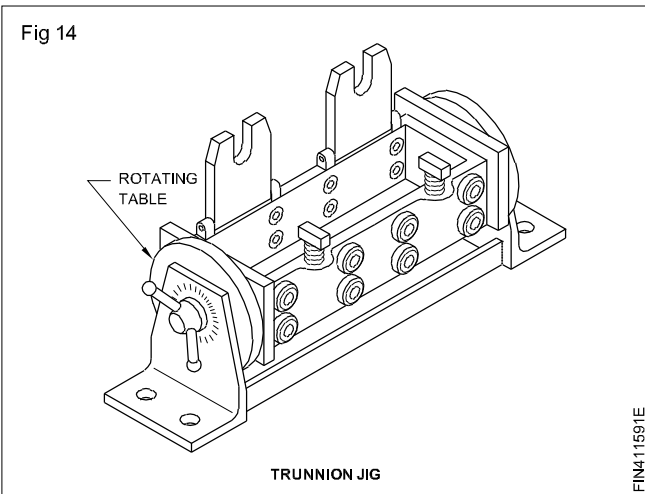
Post jig

This is used for location from a bore. The post should be as short as possible to facilitate loading and at the same time it must be long enough to support the workpiece. (Fig 13)



Trunnion jig

This can be used when large or awkwardly shaped workpieces are to be drilled from different directions. This is a further modification of the box jig which is carried on trunnions and rotated from station to station and positioned, using an indexing device. (Fig 14)

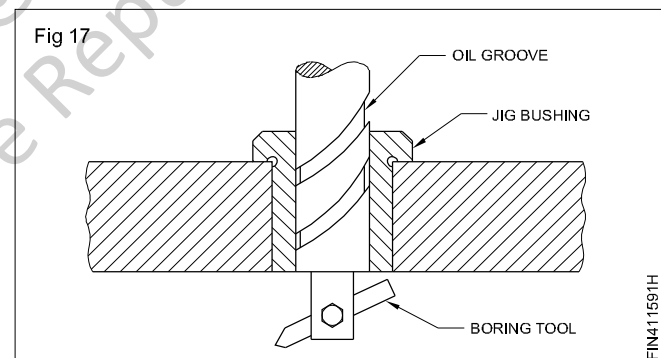
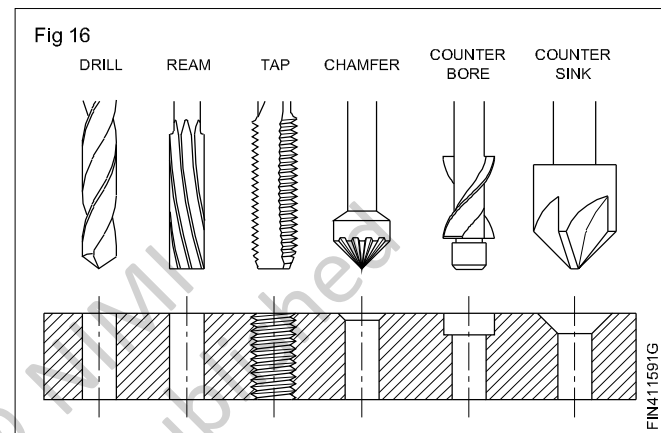
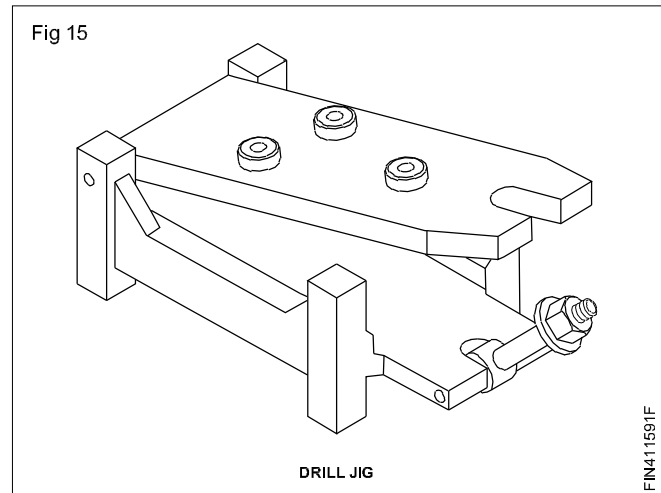


A jig is a special device which holds, supports, locates and also guides the cutting tool during operation. Jigs are designed to accommodate one or more components at a time.

Jigs are available for drilling or boring.

Drilling jigs are used to drill, ream, tap and to perform other allied operations. (Fig 16)

Boring jigs are used to bore holes which are either too large to drill or of odd size. (Fig 17)



Constructional features of drill jig

Objectives: This shall help you to

- list the different parts of a drill jig and also their uses
- state the different types of drill bushes and their uses
- state the different types of locators and clamps used in jigs.

The basic features of a drill jig are (Fig 1)

- base plate or jig body
- drill plate or jig plate
- drill bushes locating pins
- clamps.

Base plate

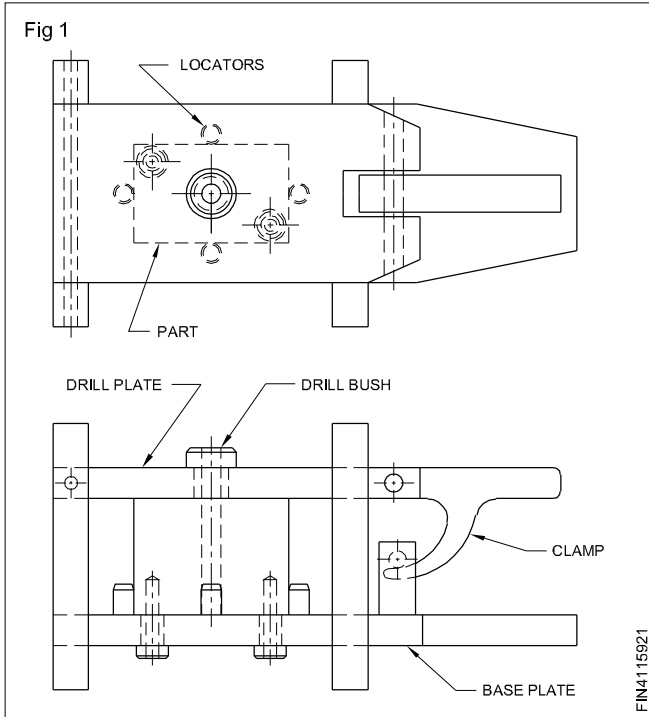
This provides a rigid support for mounting piece parts, locating pins etc.

In some drill jigs like plate and clamp jigs there will be no base plate.

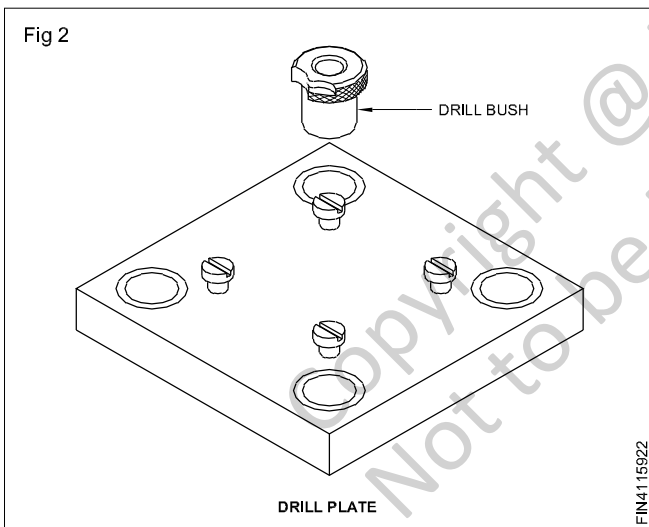
Drill plate

It holds the drill bushes. Cutting tools are guided by means of the drill bushes. Unbushed holes made on the drill plate are sometimes used for small runs.

Drill bushes



They are used to locate and guide drills, reamers, taps and any other revolving tools commonly used to make or modify holes. (Fig 2)



These are hardened and ground to exact sizes to ensure the needed repeatability in the jig. Standard size bushes are also available.

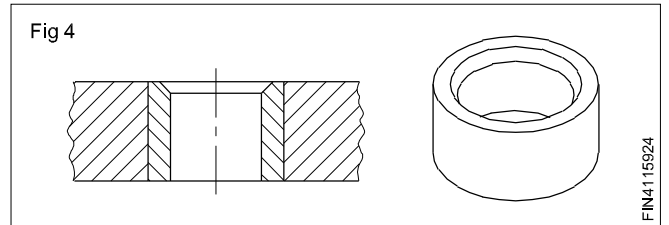
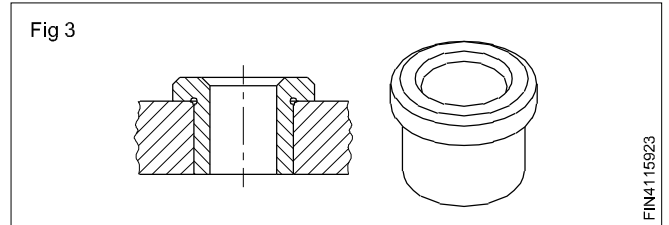
Types of drill bushes

- Press fit bushes
- Renewable bushes
- Liner bushes

Press fit bushes are made in two forms.

- Head
- Headless

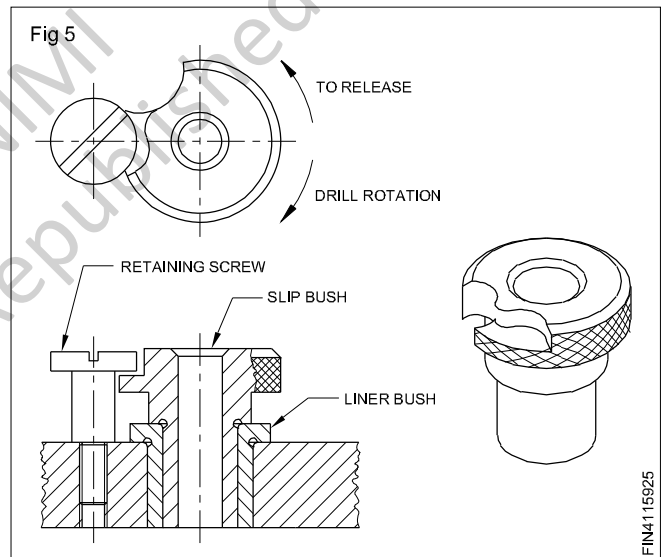
These bushes are used where frequent change of bushes is not anticipated. (Figs 3 and 4)



Renewable bushes are divided into two groups.

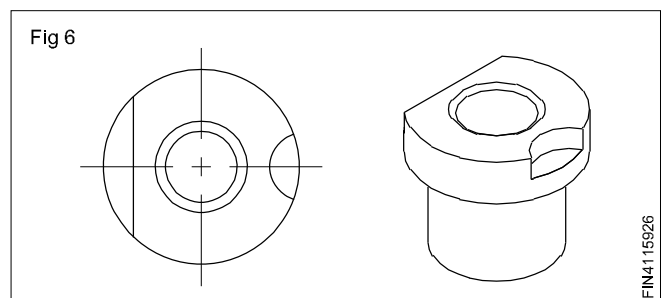
Slip renewable bushes (slip bushes)

These bushes are used when more than one operation is performed in the same location. (Eg:drilling and reaming) These bushes are used with press-fitted liner bushes and a lock clamp. (Fig 5)

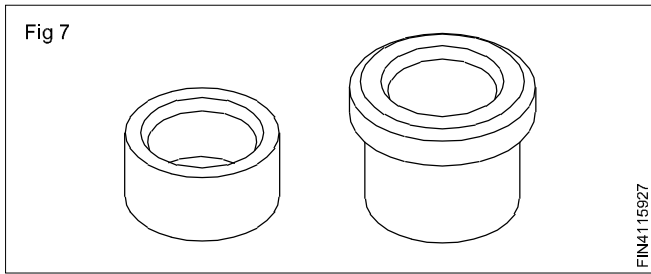


Fixed renewable bushes

These bushes are used where only one operation is to be performed with each bush, whereas several bushes may be used during the life of the jig. These are also held in a liner and retained by a screw. (Fig 6)



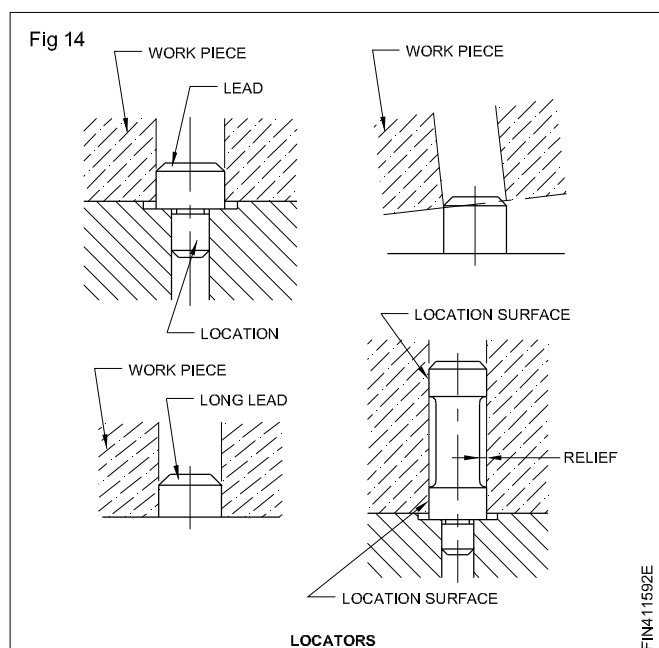
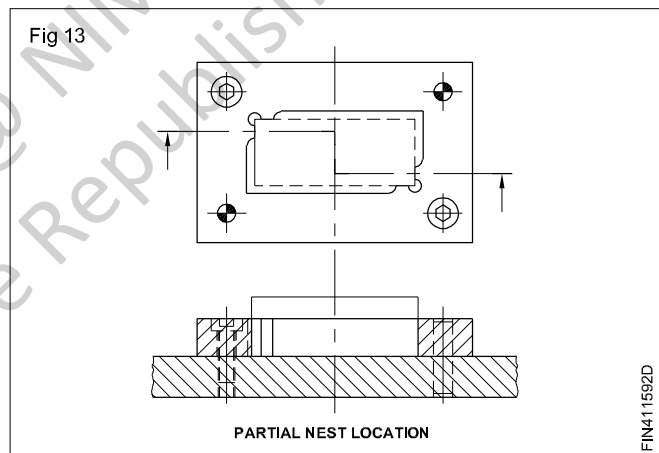
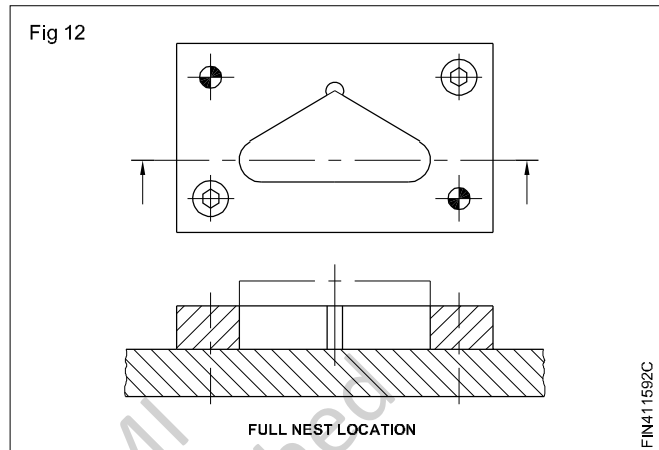
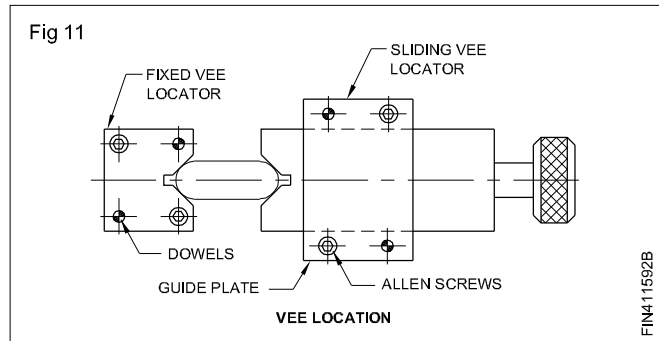
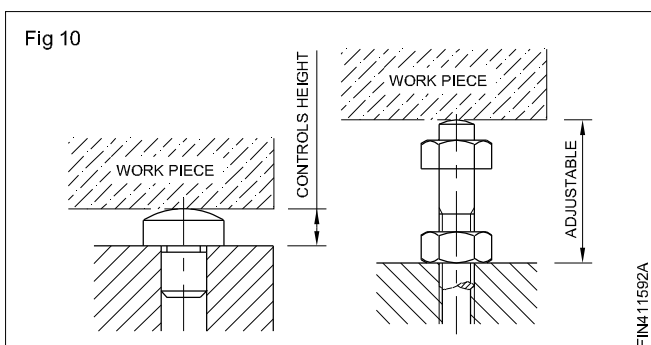
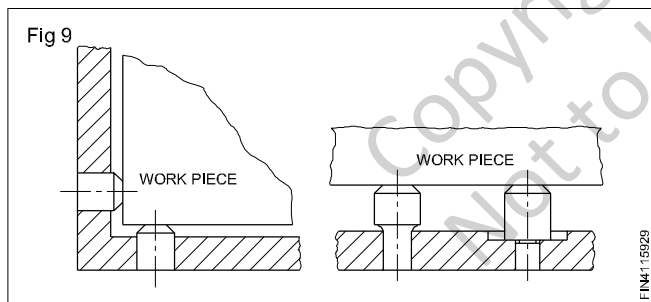
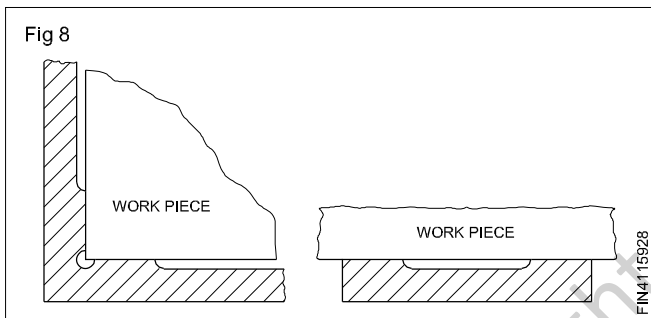
Liner bushes are used to provide a hardened hole where renewable bushes are located. Liner bushes are press-fitted to the jig plate.(Fig 7)

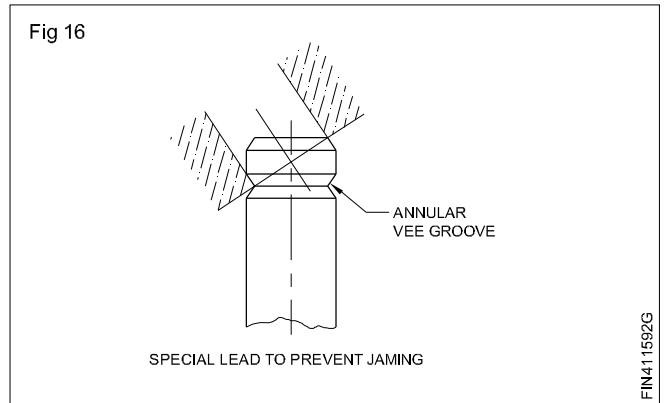
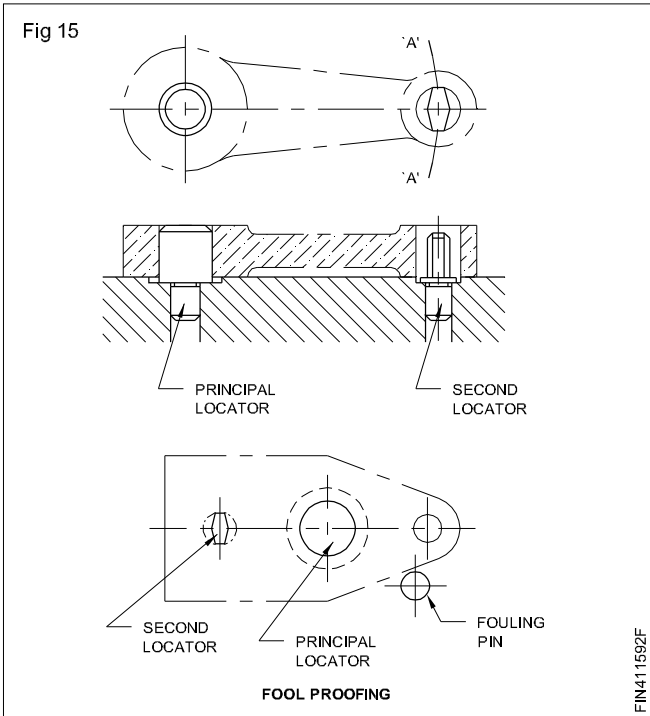


Locating pins or locaters are used

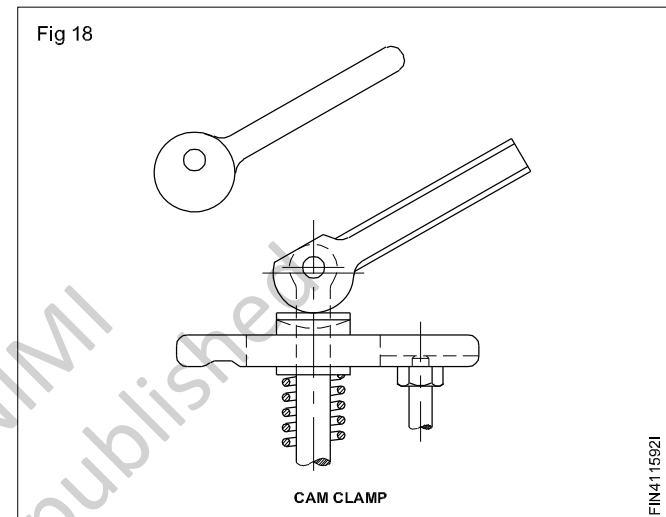
- to restrict the movement of the component
- to position the piece part with respect to the tool
- to facilitate easy loading and unloading of component piece parts
- to assist the operator for correct loading (fool proofing).

Different types of locating pins are used according to the shape of the component and also according to the hole locaters. A few types of locating pins are shown in Figs 8 to 16.





- cam clamp (Fig 18)



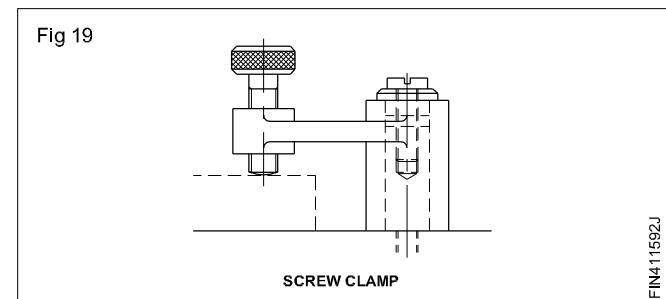
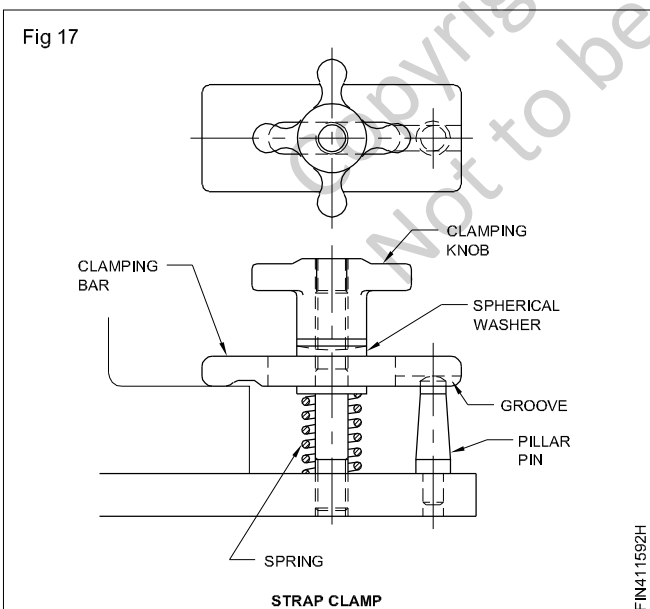
- screw clamp (Fig 19)

Clamps

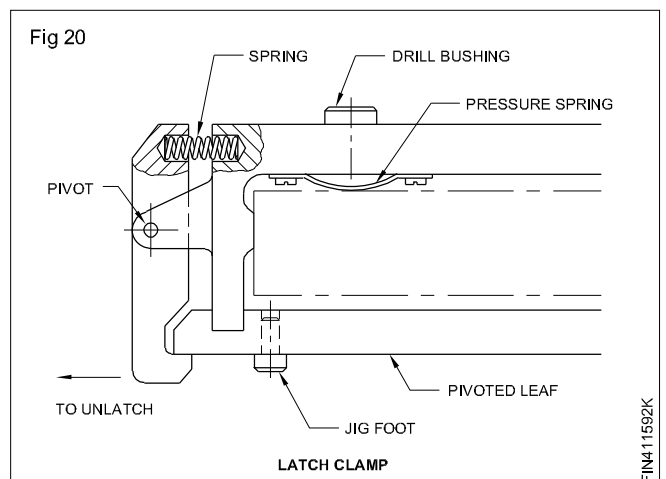
Clamps in jigs are meant for holding the component in position against the cutting force. They also help in rapid loading and unloading of the components. Clamps are fitted in such a way that they do not interfere with the cutting operation.

The commonly used types of clamps are:

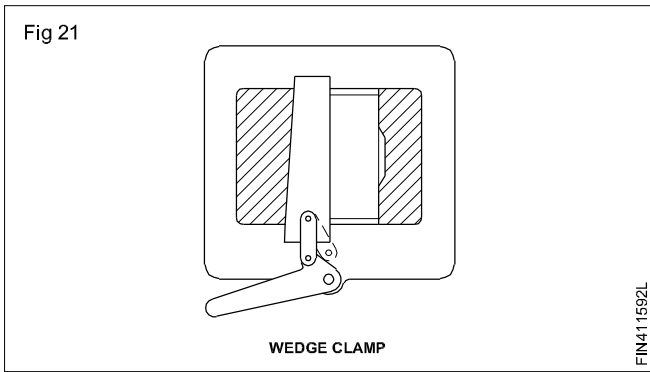
strap clamp (Fig 17)



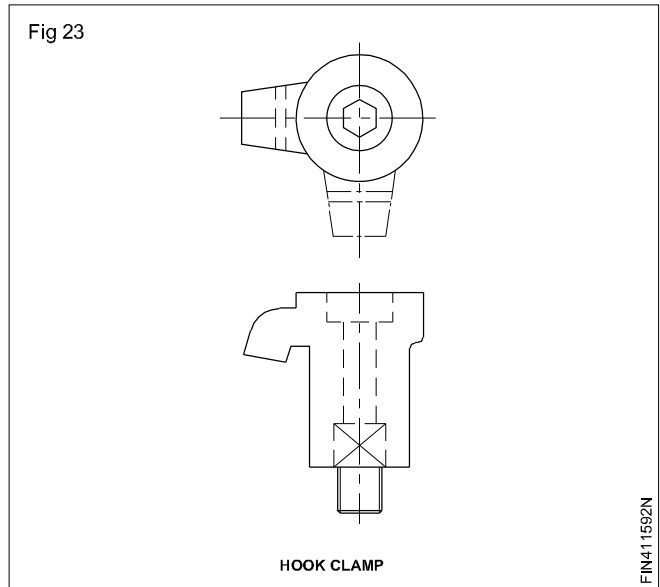
- latch clamp (Fig 20)



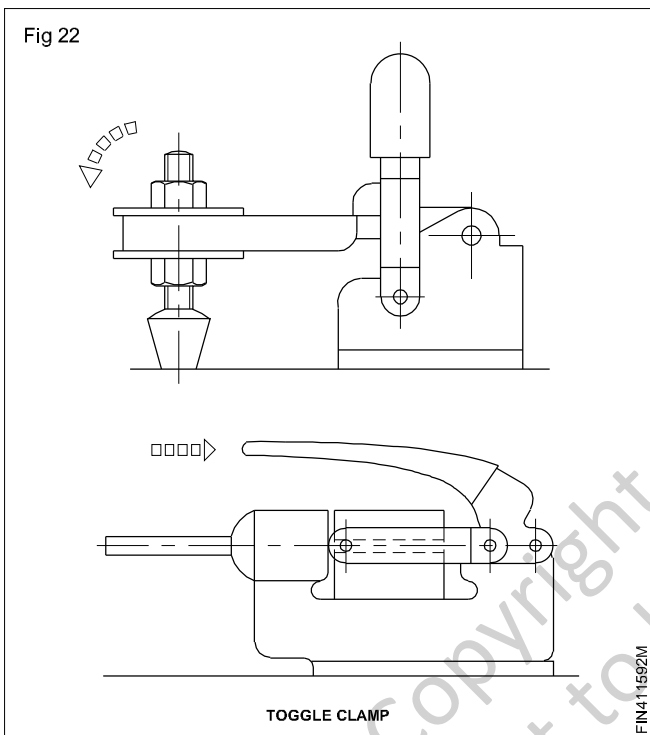
- wedge clamp (Fig 21)



- hook clamp (Fig 23)



- toggle clamp (Fig 22)



Fixtures - constructional features, types and uses

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

- what is fixture
- list the different type of fixture and uses
- state the constructional features of fixtures
- state the functions of setting blocks and blancing weight in fixture.

Introduction to fixture

A fixture is a production tool used to locate accurately and to hold securely one or more work- pieces so that the required machining operations can be performed. A fixture should be securely fastened to the table of the machine upon which the work is done. The main purpose of a fixture is to locate the work quickly and accurately, support it properly ,and hold it securely.

Classification of fixtures

Fixtures are classified by the type of machine on which they are used. If a fixture is made for a milling machine it is called a milling fixture. Some of the most commonly used fixtures are turning fixture, milling fixture, welding fixture, boring fixture, assembly fixture, inspection fixtures etc.

The elements of jigs and fixtures are

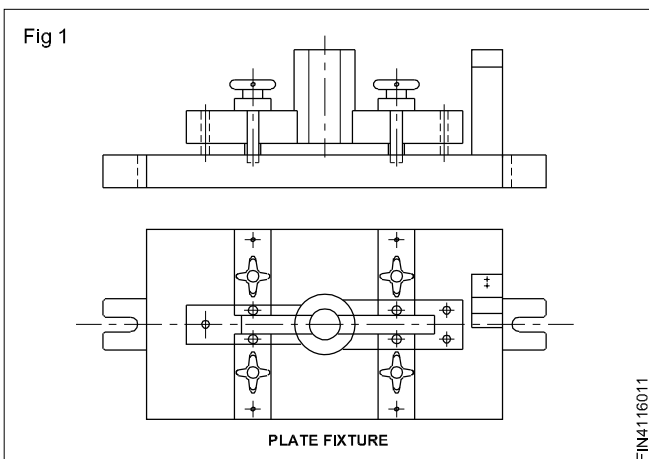
- location
- clamping
- tool guiding or setting
- body base or frame

Types of fixtures

Types of fixtures are determined mainly by how the tool is used. Because of the increased tool forces, fixtures are built stronger and heavier than jigs. The most common type of fixtures are

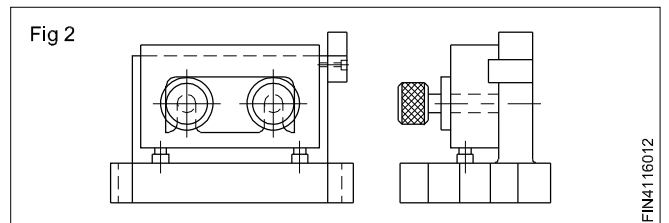
Plate fixture

These are the simplest form of fixtures. It is made from a flat plate which has locator and clamps to locate and hold the part (Fig 1).



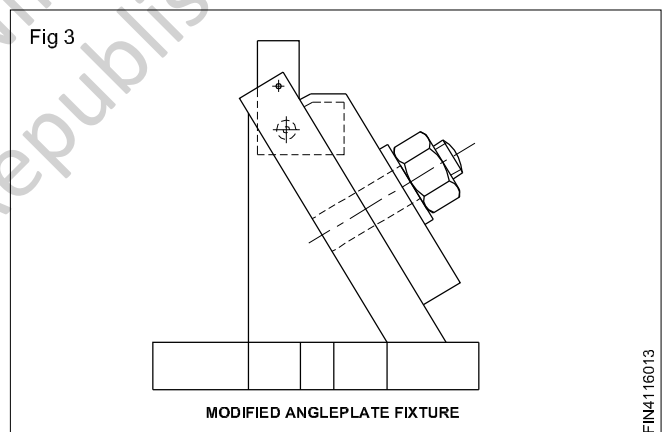
Angle plate fixture

This fixture is used for machining the part at right angle to the locator. (Fig 2)



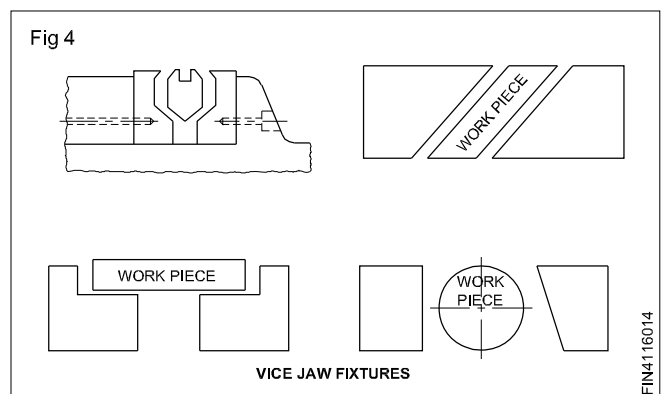
Modified angle plate fixture

This fixture is used for machining the part at angles other than 90°. (Fig 3)



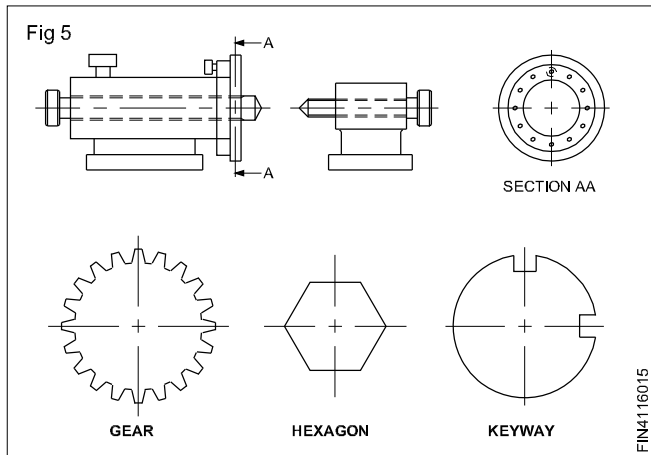
Vice jaw fixture

This fixture is used for machining small parts. The standard vice jaws are replaced with jaws that are made to suit the work. (Fig 4)



Indexing fixtures

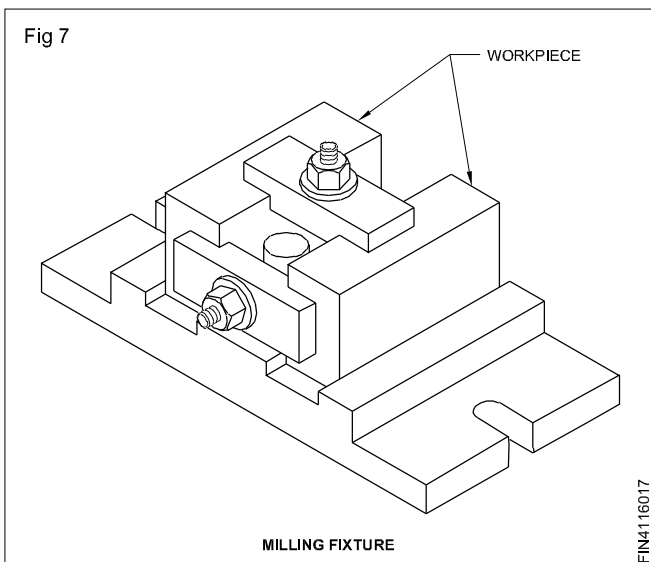
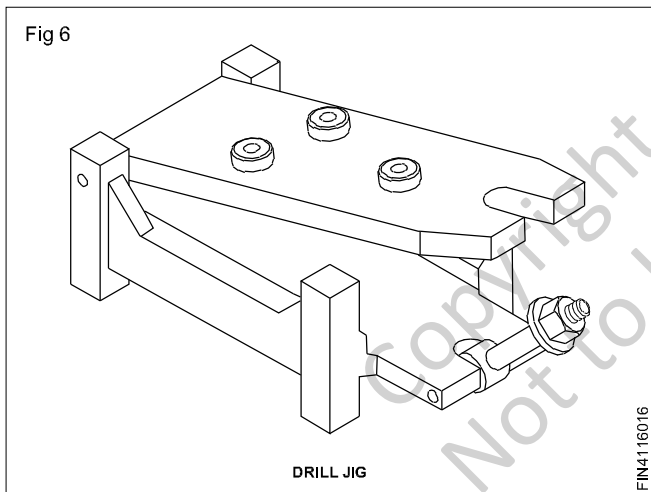
These fixtures are used for parts that require machining on evenly spaced surfaces. (Fig 5)



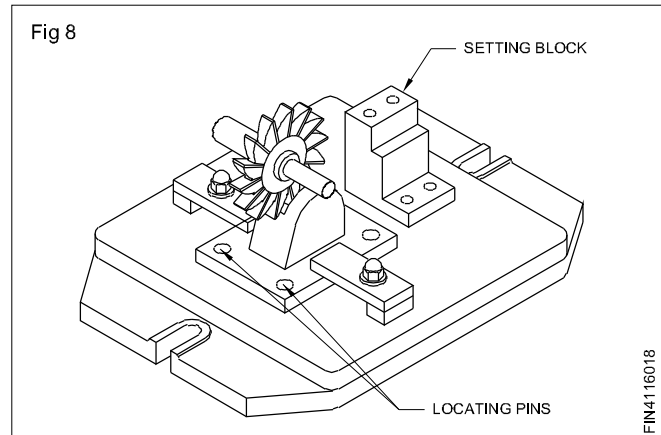
Use of fixtures

A great deal of importance is placed today on improving productivity in manufacturing processes. Application of jigs and fixtures has contributed a lot towards this direction.

Jigs and fixtures (Figs 6 and 7) are devices used in manufacturing or assembling. They also facilitate in carrying out special operations accurately.

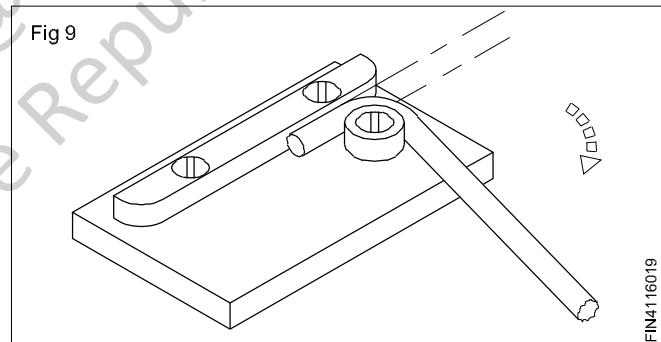


fixture is a production tool that locates and holds the work-piece. It does not guide the cutting tools, but the tools can be positioned before cutting with the help of setting blocks and feeler gauges etc. (Fig 8)



Fixtures of different types are made for:

- milling
- turning
- grinding
- welding
- assembly
- bending etc. (Fig 9)



Constructional features of a fixture

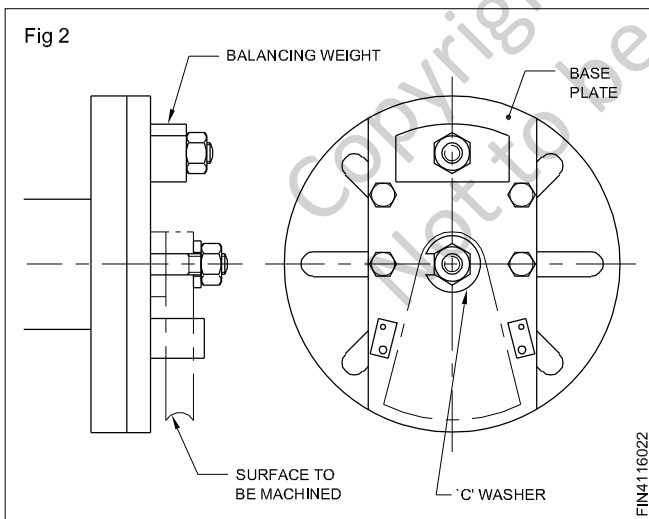
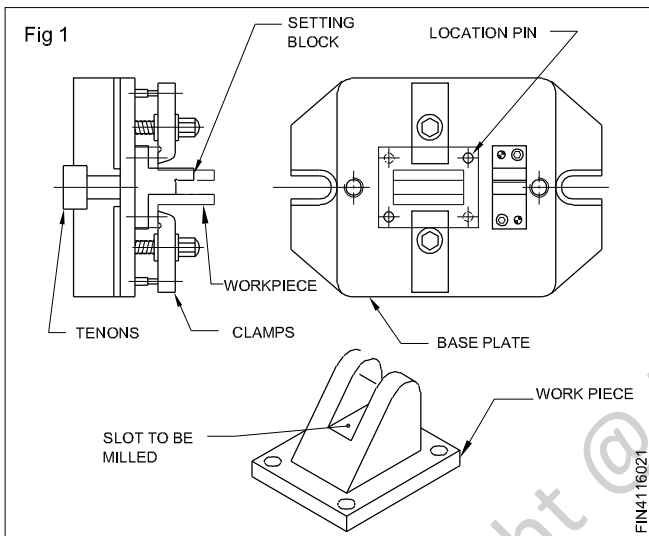
Objective: This shall help you to

- define various constructional features of a fixture.

common types of fixtures used for the machining operations are:

- milling fixture (Fig 1)
- turning fixture (Fig 2)
- grinding fixture etc.

These fixtures consist of a base plate, standard clamps and locators, setting blocks and balancing weights.

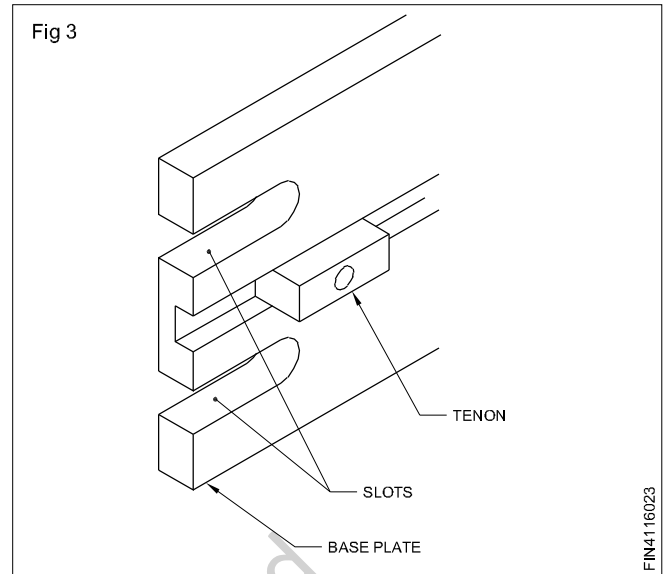


Base plate

The base plate for a milling fixture is provided with tenons at its bottom for proper location of the fixture with the machine table through Tee slots. (Fig 3) Two or four hold-down slots are provided in the base plate for rigid clamping of the fixture with the machine table.

Standard clamps and locators

These are provided for clamping and locating the

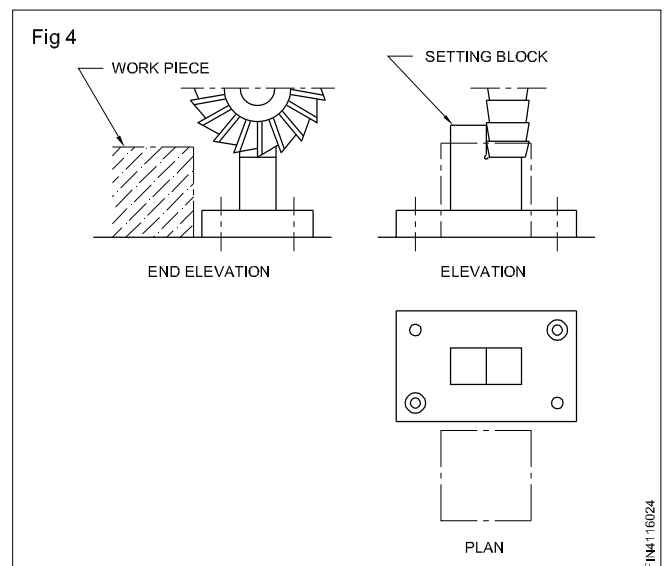


workpieces with the fixture as in the case of drill jigs. The clamps used in the fixtures are very rigid and sturdy.

The setting blocks

These are used to position the fixture and work relative to the cutter before machining.

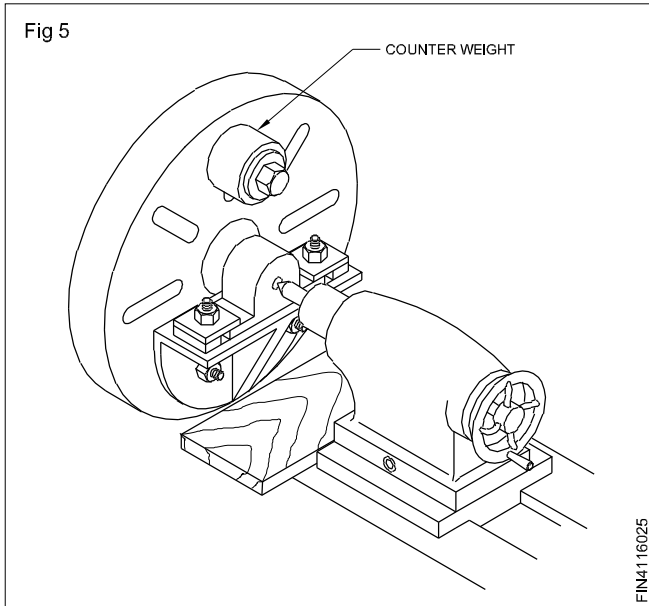
A feeler is introduced between the cutter and the setting faces of the block for correct positioning of the cutter with the fixture. (Fig 4)



Balancing weight

This is used dynamically balancing the irregular workpiece fixed to the turning or cylindrical grinding fixture.

In the case of a turning fixture, normally the base plate of the fixture is clamped to the face plate. (Fig 5)

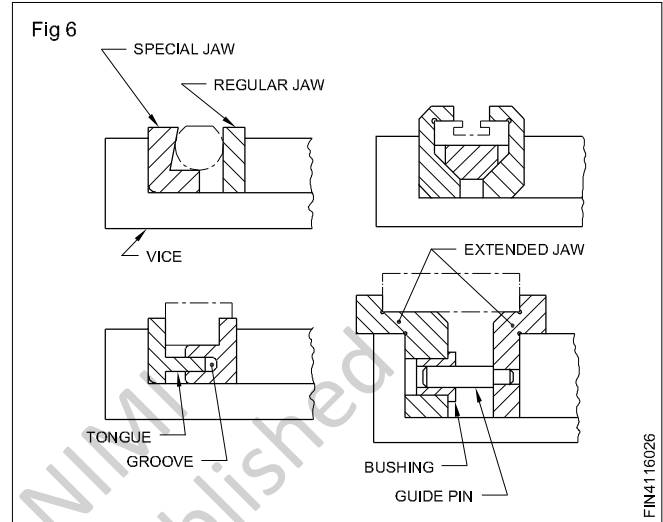


Vice fixture

Standard machine vices, attached with special jaws, provide an easy method of holding parts for machining. (Fig 6)

Other types of tooling used for positioning parts relative to each other for fabricating purposes are also commonly referred to as fixtures. Bending fixtures, assembly fixtures and welding fixtures are examples of this type.

The construction of a fixture depends upon the machining and fabricating methods employed.



Difference between jigs and fixtures

Jigs	Fixtures
<p>jig holds and positions the work piece, guides the cutting tool</p> <p>Jig is not fixed to the machine table</p> <p>Jigs are used in drilling machine for drilling, tapping, counter boring, and countersinking etc.</p>	<p>Fixture only hold and position the work piece, does not guide the cutting tool</p> <p>Fixture is usually fixed to the machine table</p> <p>Fixtures are used in grinding, milling, turning, bending and assembling.</p>

Aluminium and its alloys

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

- state the properties and uses of aluminium
- name the commonly used aluminium alloys and their uses
- name the ores from which aluminium is produced.

Aluminium is a non-ferrous metal which is extracted from 'BAUXITE'. Aluminium is white or whitish grey in colour. It has a melting point of 660°C. Aluminium has high electrical and thermal conductivity. It is soft and ductile, and has low tensile strength. Aluminium is very widely

used in aircraft industry and fabrication work because of its lightness. Its application in the electrical industry is also on the increase. It is also very much in use in household heating appliances. Some typical aluminium alloys, their composition and applications are given in the table that follows.

Aluminium alloys - Composition - Uses

Composition(%) (Only the percentage of alloying elements is shown. The remaining is aluminium)						Category	Applications
Copper	Silicon	Iron	Manganese	Magnesium	Other elements		
0.1 max.	0.5 max.	0.7 max.	0.1 max.	-	-	Wrought. Not heat treatable.	Fabricated assemblies, Electrical conductors. Food and brewing, processing plants. Architectural decorations.
0.15 max.	0.6 max.	0.75 max.	1.0 max.	4.5 to 5.5	0.5 Chromium	Wrought. Not heat treatable.	High strength ship building and engineering products. Good corrosion resistance.
1.6	10.0	-	-	-	-	Cast, not heat treatable.	General purpose alloy for moderately stressed pressure die-castings.
-	10.0 to 13.0	-	-	-	-	Cast, not heat treatable.	One of the most widely used alloys. Suitable for sand, gravity and pressure die castings. Excellent foundry characteristics. Used for large marine, automotive and general engineering castings.
4.2	0.7	0.7	0.7	0.7	0.3 Titanium (option)	Wrought. Heat treatable.	Traditional 'Duralumin'. General machining alloy. Widely used for stressed components in aircraft.
-	0.5	-	-	0.6	-	Wrought. Heat treatable.	Corrosion-resistant alloy for lightly stressed components such as glazing bars, window sections and automotive body components.
1.8	2.5	1.0	-	0.2	0.15 Titanium 1.2 nickel	Cast. Heat treatable.	Suitable for sand and gravity die casting. High rigidity with moderate strength and shock resistance. A general purpose alloy
-	-	-	-	10.5	0.2 Titanium	Cast. Heat treatable.	A strong, ductile and highly corrosion-resistant alloy used for aircraft and marine castings, both large and small.

Advantages of using aluminium over steel

Advantages

- lighter
- strength comparable to steel
- corrosion resistance
- good machinability
- can be anodized
- better thermal and electrical conductivity

Disadvantages

- less strength (compared to the higher strength steel alloys)
- not good for threaded fasteners
- more difficult to paint
- weldments require post welding heat treat to recover mechanical properties
- more difficult to weld
- fatigues
- high cost
- lower modulus of elasticity, therefore, increased deformation
- low elongation values

Aluminium and aluminium alloys

Aluminium is one of the most widely used metals in the world. It possesses an exciting range of properties. Moreover, aluminium combines with alloying elements like copper, manganese, silicon, magnesium and zinc, and forms a very useful series of alloys.

Lead and its alloys

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

- state the properties of lead
- state the various uses of lead
- state the uses of babbitt metal.

Lead is a very commonly used non-ferrous metal and has a variety of industrial applications.

Lead is produced from its ore 'GALENA'. Lead is a heavy metal that is silvery in colour when molten. It is soft and malleable and has good resistance to corrosion. It is a good insulator against nuclear radiation. Lead is resistant to many acids like sulphuric acid and hydrochloric acid.

It is used in car batteries, in the preparation of solders etc. It is also used in the preparation of paints.(Fig 1)

Important properties

- Aluminium is a light weight metal. Its density is about 2.7 gm/cm³. It is about one third as light as steel.
- While pure aluminium has a low strength of 7 kgf/mm², the alloys are moderately strong. Some alloys have strength as high as 45 kgf/mm² in the heat-treated condition.
- The above two properties together provide it with high strength to weight ratio, which makes it suitable for aerospace application.
- Some of the alloys have excellent toughness at low temperatures, making them suitable for cryogenic (below 0° C) application.
- Some alloys have excellent corrosion resistance.
- Aluminium and its alloys have high thermal conductivity.
- Aluminium and its alloys also have high electrical conductivity.

Applications

- Household furniture and utensils.
- Containers, tanks and vessels.
- Automobile structures, bus bodies, road and railway tankers and wagons.
- Buildings and other architectural structures.
- Portable bridges.
- Aircraft, missiles and other aerospace components.
- Radiators and other heat exchangers.
- Electrical conductor cables and bus bars.

Aluminium alloy system

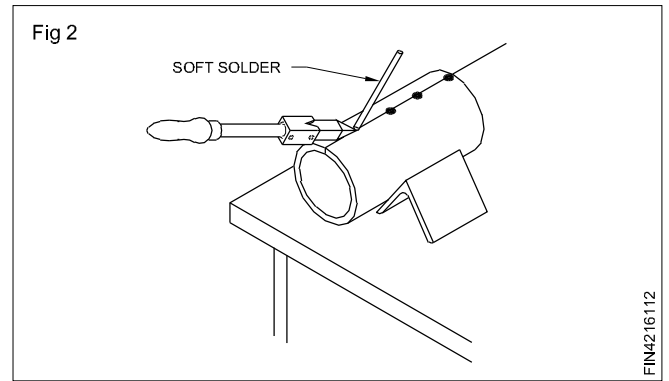
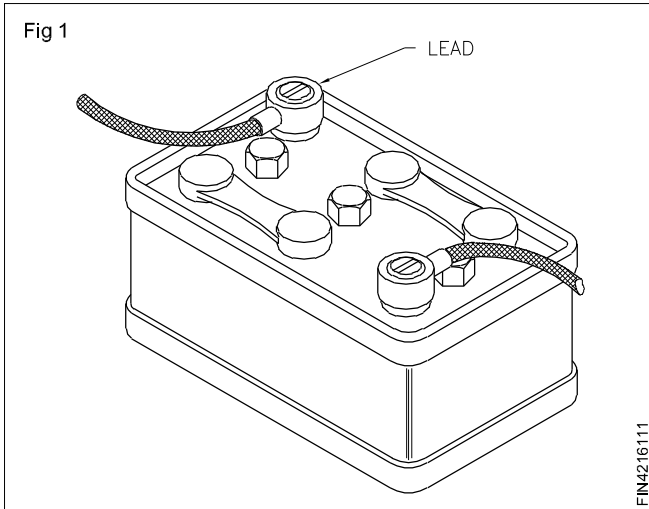
Aluminium alloys are classified on the basis of the principal alloying element present in a particular alloy.

Lead Alloys

Babbitt metal

Babbitt metal is an alloy of lead, tin, copper and antimony. It is a soft, anti-friction alloy, often used as bearings.

An alloy of lead and tin is used as 'soft solder'.(Fig 2)



Zinc

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

- state the properties and uses of zinc
- state the uses of zinc alloys.

Zinc is a commonly used metal for coating on steel to prevent corrosion. Examples are steel buckets, galvanized roofing sheets, etc.

It is brittle and softens on heating; it is also corrosion resistant. Due to this reason it is used for battery containers and is coated on roofing sheets etc.

Zinc is obtained from the ore-calamine or blende.

Galvanized iron sheets are coated with zinc.

Its melting point is 420°C.

Tin and its alloys

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

- state the properties and uses of tin
- name the common tin alloys and state their uses.

Tin

Tin is produced from cassiterite or tinstone. It is silvery white in appearance, and the melting point is 231°C. It is soft and highly corrosion-resistant.

Eg. Tin with copper to form bronze. Tin with lead to form solder. Tin with copper, lead and antimony to form babbitt metal.

It is mainly used as a coating on steel sheets for the production of food containers. It is also used with other metals, to form alloys.

Copper and its alloys

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

- name the commonly used copper alloys
- state the properties and uses of copper
- state the composition and uses of different types of brasses
- state the composition and uses of different types of bronze.

Metals without iron (Ferrum) are called non-ferrous metals. Eg. Copper, Aluminium, Zinc, Lead and Tin.

Properties

Reddish in colour. Copper is easily distinguishable because of its colour.

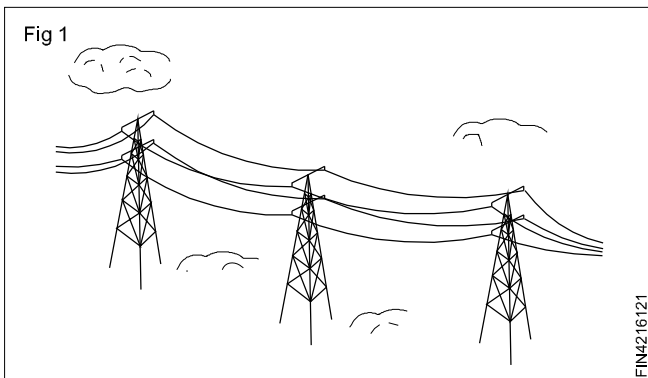
Copper

This is extracted from its ores 'MALACHITE' which contains about 55% copper and 'PYRITES' which contains about 32% copper.

The structure when fractured is granular, but when forged or rolled it is fibrous.

It is very malleable and ductile and can be made into sheets or wires.

It is a conductor of electricity. Copper is extensively used as electrical cables and parts of electrical apparatus which conduct electric current. (Fig 1)



Copper is a good conductor of heat and also highly resistant to corrosion. For this reason it is used for boiler fire boxes, water heating apparatus, water pipes and vessels in brewery and chemical plants. Also used for making soldering iron.

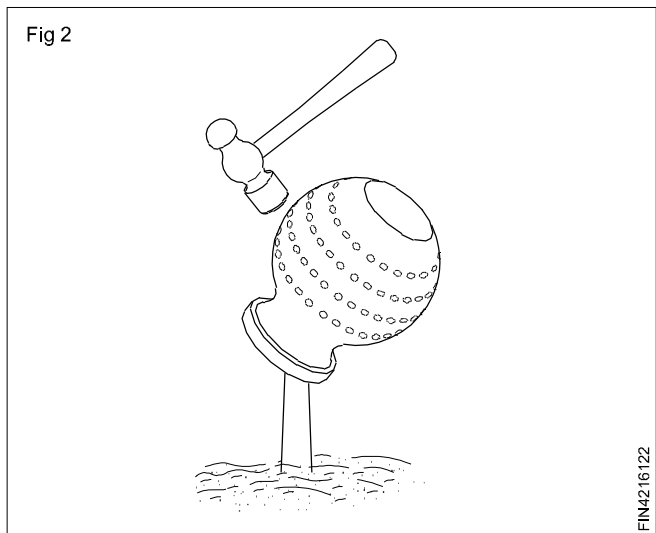
The melting temperature of copper is 1083°C.

The tensile strength of copper can be increased by hammering or rolling. (Fig 2)

Copper alloys

Brass

It is an alloy of copper and zinc. For certain types of brass small quantities of tin or lead are added. The colour of brass depends on the percentage of the alloying elements. The colour is yellow or light yellow, or nearly white. It can be easily machined. Brass is also corrosion-resistant.



Brass is widely used for making motor car radiator core and water taps etc. It is also used in gas welding for hard soldering/brazing. The melting point of brass ranges from 880 to 930°C.

Brasses of different composition are made for various applications. The following table-1 gives the commonly used brass alloy compositions and their application.

Bronze

Bronze is basically an alloy of copper and tin. Sometimes zinc is also added for achieving certain special properties. Its colour ranges from red to yellow. The melting point of bronze is about 1005°C. It is harder than brass. It can be easily machined with sharp tools. The chip produced is granular. Special bronze alloys are used as brazing rods. Bronze of different compositions are available for various applications. Table-2 gives the type compositions and applications

Table 1 - Composition of different types of brass

Name	Composition (%)			Applications
	Copper	Zinc	Other elements	
Cartridge brass	70	30	-	Most ductile of the copper/zinc alloys. Widely used in sheet metal pressing for severe deep drawing operations. Originally developed for making cartridge cases, hence its name.
Standard brass	65	35	-	Cheaper than cartridge brass and less ductile. Suitable for most engineering processes.
Basic brass	63	37	-	The cheapest of the cold working brasses. It lacks ductility and is only capable of withstanding simple forming operations.
Muntz metal	60	40	-	Not suitable for cold working, but suitable for hot-working. Relatively cheap due to its high zinc content. It is widely

Muntz metal	60	40	-	Not suitable for cold working, but suitable for hot-working. Relatively cheap due to its high zinc content. It is widely used for extrusion and hot-stamping processes.
Free-cutting brass	58	39	3% lead	Not suitable for cold working but excellent for hot working and high speed machining of low strength components.
Admiralty brass	70	29	1% tin	This is virtually cartridge brass plus a little tin to prevent corrosion in the presence of salt water.
Naval brass	62	37	1% tin	This is virtually Muntz metal plus a little tin to prevent corrosion in the presence of salt water.
Gilding metal	95	5	-	Used for jewellery.

Table 2 - Composition of different types of bronze

Name	Composition (%)				Applications
	Copper	Zinc	Phosphorus	Tin	
Low tin bronze	96	-	0.1 to 0.25	3.9 to 3.75	This alloy can be severely cold-worked to harden it so that it can be used for springs where good elastic properties must be combined with corrosion resistance, fatigue-resistance and electrical conductivity. Eg. Contact blades
Drawn phosphor/bronze	94	-	0.1 to 0.5	5.9 to 5.5	This alloy is used for turned components requiring strength and corrosion resistance, such as valve spindles.
Cast phosphor/bronze	89.75 to 89.97	-	0.03 to 0.25	10	Usually cast into rods and tubes for making bearing bushes and worm wheels. It has excellent anti-friction properties.
Admiralty gun-metal	88	2	-	10	This alloy is suitable for sand casting where fine-grained, pressure-tight components such as pump and valve bodies are required.
Leaded gun-metal (free cutting)	85	5 (5%lead)	-	5	Also known as 'red brass' this alloy is used for the same purposes as standard, admiralty gun-metal. It is rather less strong but has improved toughness and machining properties.
Leaded (plastic) bronze	74	(24%lead)	-	2	This alloy is used for lightly loaded bearings where alignment is difficult. Due to its softness, bearings made from this alloy 'bed in' easily.

Installation, maintenance and overhaul of machinery

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

- explain installation procedure
- state maintenance of machine
- describe overhauling procedure

Installation

The sequence of installation methods are as follows.

- foundations
- fitting and moving
- levelling
- testing

Foundations

Machinery foundation is a built up structure designed to support the machine and to take up the static and dynamic load of the machine, besides keeping the machine in alignment

The machine foundation must fulfil the following requirements.

- It must support the machines at a given height and must be able to take up the static and dynamic loads.
- It should preserve the alignment of the machine
- It should absorb the vibration of the moving parts

Lifting and moving

For lifting and moving the machines, the equipments like hoists, derricks and cranes are employed and also ropes are used to tie the machine

Levelling

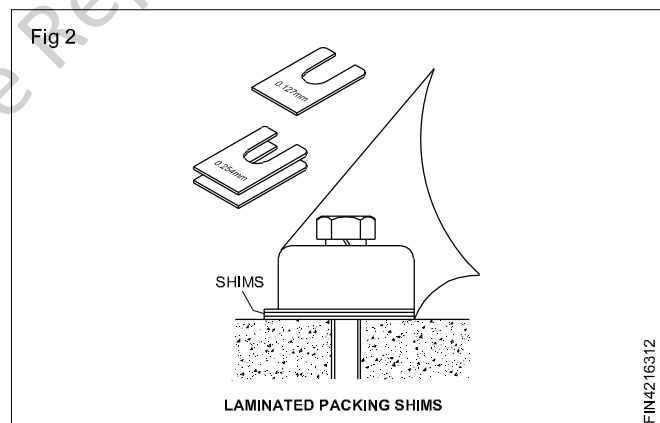
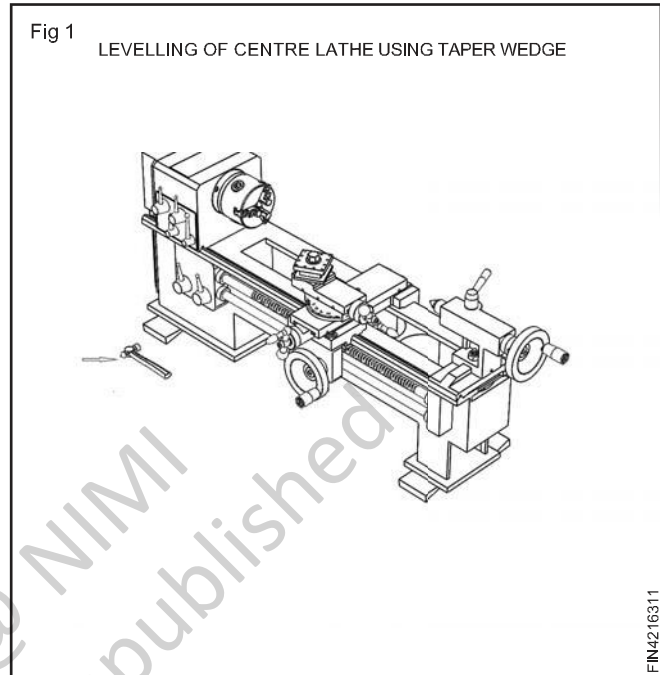
It is necessary to provide a good solid foundation upon which the machine is set and accurately levelled. Performance of any machine tool depends upon its level and foundation.

Levelling of a machine is done using:

- steel wedges
- levelling blocks
- jacking screws.

The steel wedges (Fig 1) can be used with or without steel packing at three or more points under the machine bed. By tapping, adjust the wedges so that the machine is levelled longitudinally and transversely preparatory to tightening down and grouting.

Accurate levelling can be achieved by the use of laminated shims. (Fig 2)

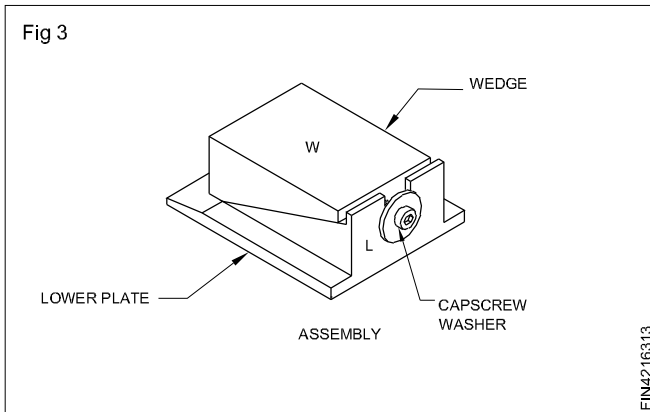


These packing shims are obtainable in sets in which each individual shim is of a different gauge and combinations of these can be used to obtain the desired thickness.

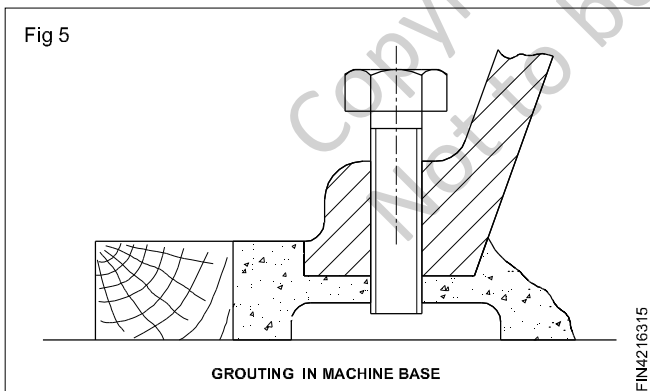
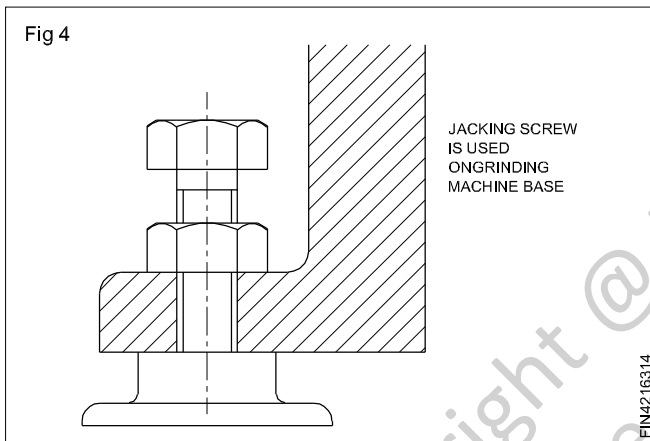
When a machine is placed on these levelling blocks (Fig 3) the machine bed does not touch the foundation but rests entirely on the levelling blocks thus permitting the machine to be raised or lowered to the required height and levelled up.

It also permits the machine to be re-levelled at any time.

The machine is also levelled by the use of the jacking screws provided as shown in Fig 4, where the screw is



seen to bear upon a steel plate let into the floor. Extrasensitive levels are used for setting lathes, grinders and precision machines. To protect subsequent movement of the machine, a cement fillet is made all round the machine base as indicated in Fig 5. While grouting with cement, care should be taken not to upset the level of the machine during the process.



Some machines are also mounted on antivibration pads. In this case, the machine is levelled using levelling bolts.

Testing

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 test are invaluable for checking machines after 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 at least 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

Test charts

A test chart is prepared for each machine by the manufacturer of the machine. It consists of instruction for testing names of the measuring instruments used, sketches and details of permissible error and actual error. It provides a convenient basis for conducting tests.

Periodic acceptance test

The machine tool is expected to produce accurate workpieces not only when it is new but throughout its working life. A machine tool must be able to produce workpieces within specified limits. For this reason the wear of the machine must not exceed certain limits. It must be watched, and parts which are faulty, due to wear or other damage, must be replaced or repaired without delay.

The periodic acceptance tests are to be carried out after overhaul and re-conditioning of the machine tool. Apart from the regular general inspection of the machine tool, immediate steps must be taken when faulty workpieces are produced by a machine i.e. when machined dimensions lie outside the specified limits. In such cases, the accuracy and performance of the machine must be tested without delay. Faults can be eliminated only if the causes of the errors are known.

Maintenance is a process adapted to extend 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 are 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 damaged 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 be useful to estimate the lifetime of different parts of machine tool equipments and to access the frequency of periodical 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.

Abnormal sound coming out of a running machine predicts a trouble. Overheat of a bearing predicts a trouble. Simple hand touch can point out many abnormal 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 personel.

Overhauling

Ensure that all the lubrication points are lubricated regularly as recommended in the manual.

Use Servoway-32 oil for the pillar. Anti-frictional bearings on the main spindle head are to be lubricated by Servogem Grease - 2 once in 3 months.

If the spindle is supported by plain bearings,use Servo -System 32 oil.

Check the belt tension once in three months. If necessary, adjust the tension.

When replacing with a new belt, if required,check the tension of the belt after a week,and adjust, if necessary.

The machine should be overhauled once in 2 or 3 years depending upon the usage.

Anti-friction bearing should not be cleaned using compressed air as compressed air normally contains water particles which will corrode the bearing. Also while using compressed air, dust, dirt and other absasive particles will be whirling in the surrounding areas and enter into the bearing causing damage to the race - ways and rolling elements.

Antifriction bearings should be handled in dust free environment.

Types of belts and fasteners

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

- name the different types of belts
- state the belt tension
- state method of adjusting belt tension
- name the different types of belt fasteners.

Types of belts

Basically five types of belts are used for the transmission of power.

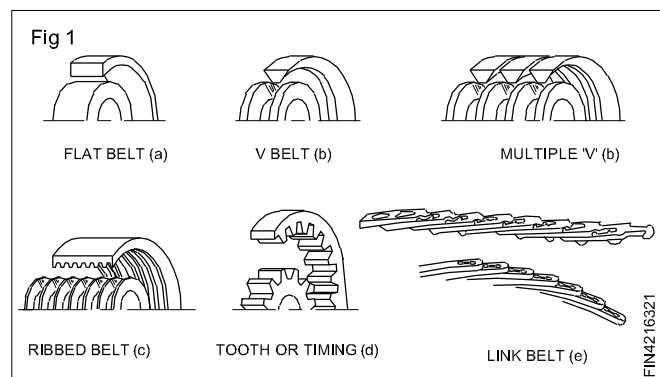
- Flat belt (Fig 1a)
- V-belt and multiple V-belt (Fig 1b)
- Ribbed belt (Fig 1c)
- Toothed or timing belt (Fig 1d)
- Link belt (Fig 1e)

The choice of a particular belt depends upon speed ratio, centre distance, flexibility, strength, economy and maintenance consideration of the driving system.

V-belts

'V'belt drives are generally used when the distance between the shafts is too short for flat belt drives. Owing

to the wedge action between the belt and the sides of the groove

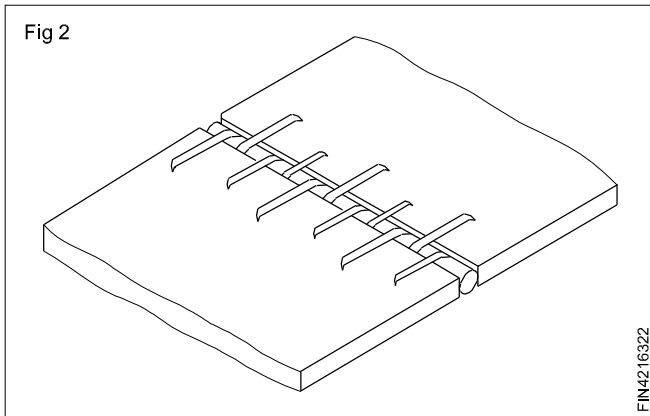


Types of fasteners

The belt fasteners commonly used in addition to the alligator type are as follows.

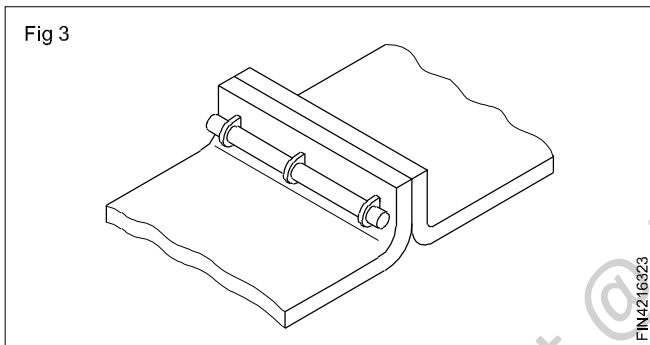
Wire type belt fastener

Fig 2 shows the wire type fastener generally used on light duty machines.



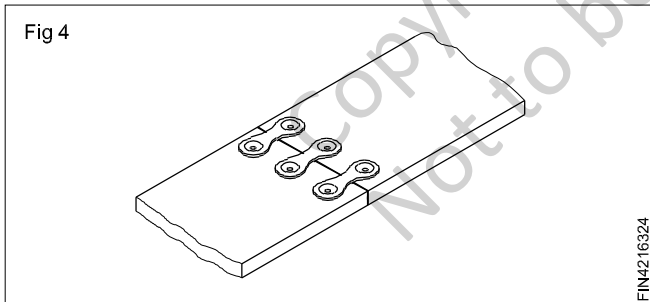
'Lagrelle' type belt fastener

Fig 3 shows a lagrelle type fastener used on heavy duty machines.



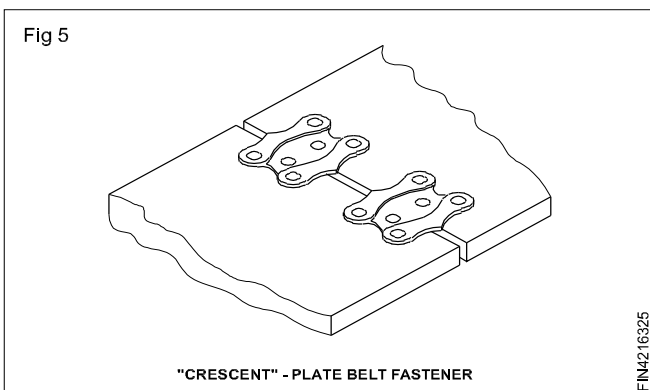
Jackson-type belt fastener

The Jackson-type fastener illustrated in Fig 4 is used on medium duty machines.



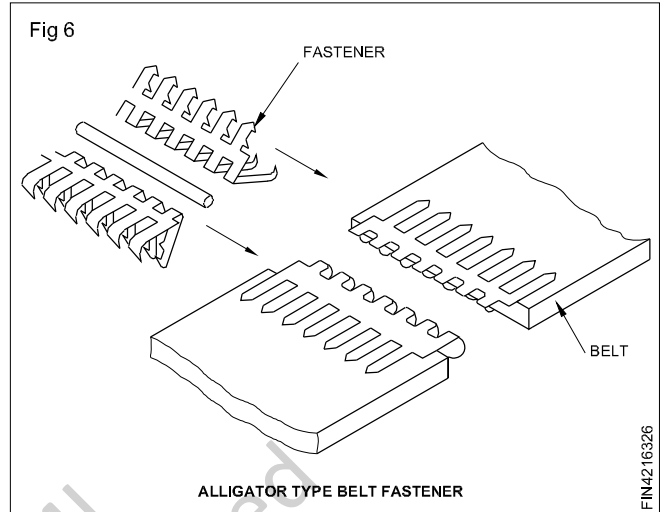
Crescent plate belt fastener

Fig 5 shows a mechanical type belt fastener which is used on medium duty machines.



Belt fasteners (Alligator type)

Alligator type fasteners are used in joining belting for industrial purposes. The belt fastener is made of steel sheets conforming to IS:513-1973. The pins shall be made from mild steel wire conforming to IS: 280-1972. Belt fasteners are shown in Fig 6 and the position of the pin in a joint is illustrated in Fig 7.



Specification

The fastener designation and pin size, thickness of belt and other dimensions are given in the table as per IS: 5593-1980.

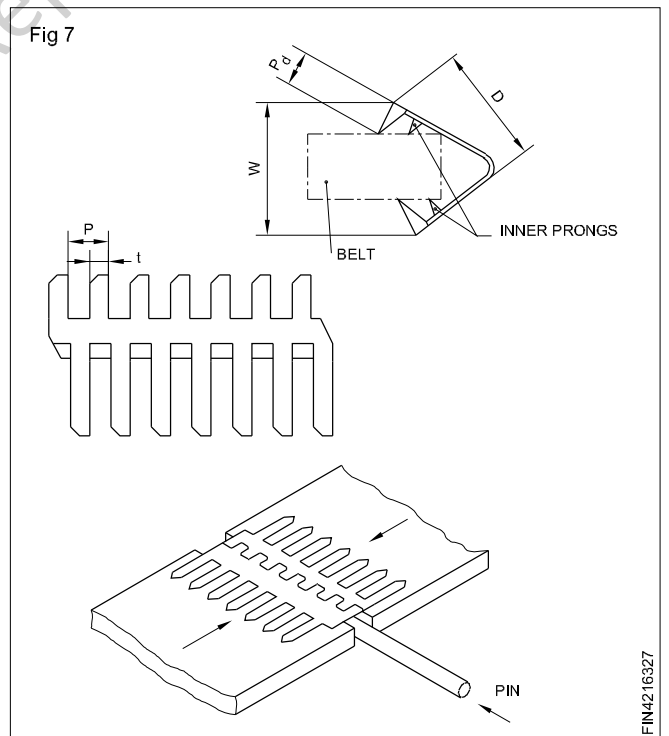


Table - 1

Fastener Designation	Thickness of belt	Metal thickness (Sheet)	Point depth P_d	Approx overall width W	Approx overall depth t_1 Min D	Width of bar prong P	Pitch of prong
15	3 to 4	1.0	5.0	18	13	2.5	6
20	4 to 5	1.1	6.5	22	17	3	8
25	5 to 5.5	1.2	7.0	25	21	3	8
27	5.5 to 7	1.2	8.0	29	24	3	8
35	7 to 8	1.8	9.5	32	30	4	10
45	8 to 9.5	1.8	11.0	38	31	5	12
55	9.5 to 11	2.0	14.0	48	40	6.5	16
65	11 to 13	2.0	16.0	54	41	6.5	16

Fastener designation	Pin size mm
15,20,25	2.64
27,35	3.25
45,55,65	4.06

Belts tension

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

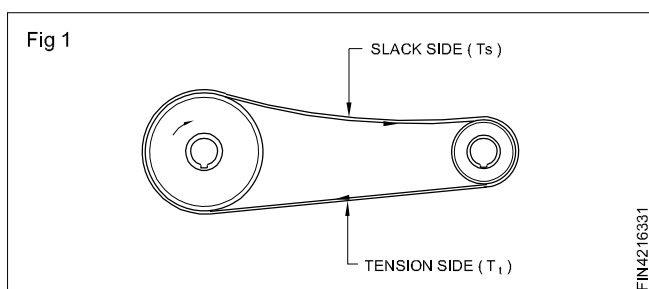
- state the need for tensioning belts
- state the methods of adjusting belt tension
- state the importance of the arc of contact in a belt drive
- state the important factors for improving the efficiency in a belt drive
- calculate the deflection force necessary for a belt drive
- state the care and maintenance of belts.

Belt tension

Belts must be tensioned correctly to transfer the torque from the driving pulley to the driven pulley to prevent unnecessary wear.

Too much of belt tension curtails belt and bearing life. As the belts stretch in use, it is necessary to check and adjust the belt drive tension.

When a drive is transmitting power the belt pulls or the belt tensions. There is the tight side tension (T_t) and a slack side tension (T_s). (Fig 1)



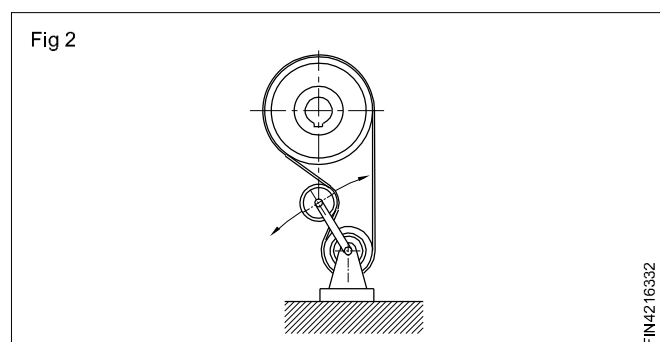
Tension ratio

The ratio of the tight side to the slack side tension is commonly referred to as the tension ratio. A higher ratio between the tight side and slack side tension makes the belt loose and slip.

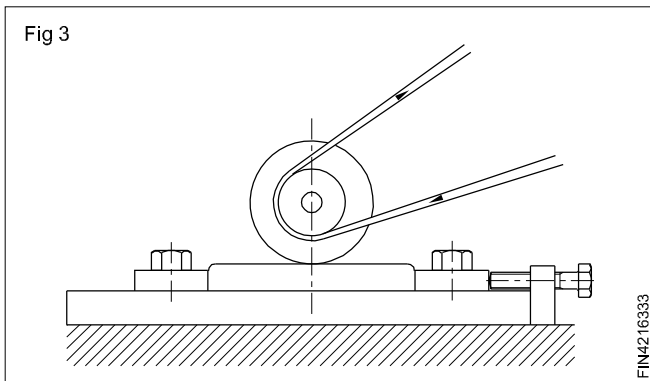
This causes lack of effective pull for transmitting the required power.

Adjustment of tension

When the distance between two pulleys is fixed, the tension of a belt is adjusted by an idler. (Fig 2)

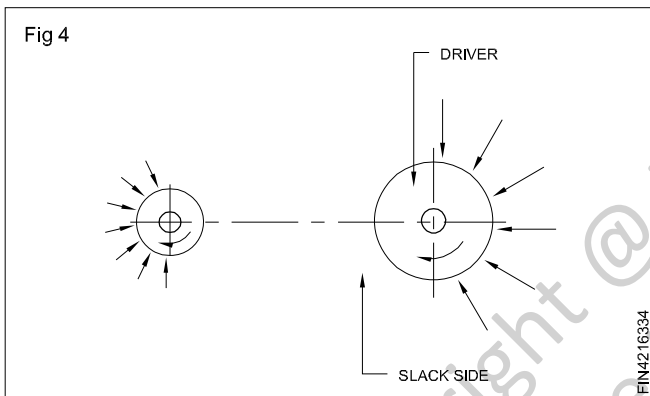


When the distance between two pulleys is not fixed, the tension of the belt is adjusted by the adjustment screw. (Fig 3)

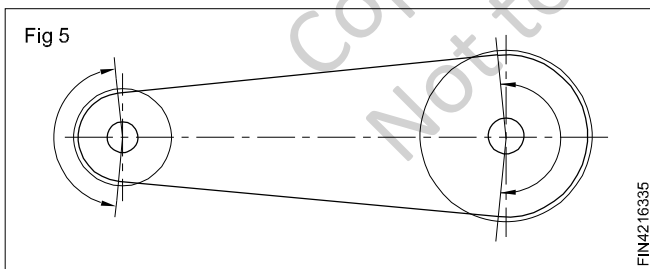


Arc of contact

Tension is necessary to create friction between the pulleys and the belt. Torque transmission depends on the contact area of the belt over the pulleys. (Fig 4)



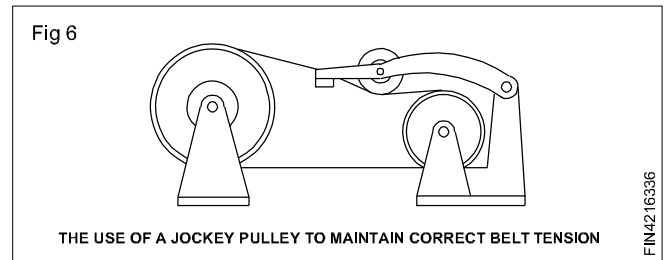
If the wrapping angle is big, the pulley can transmit high torque. (Fig 5)



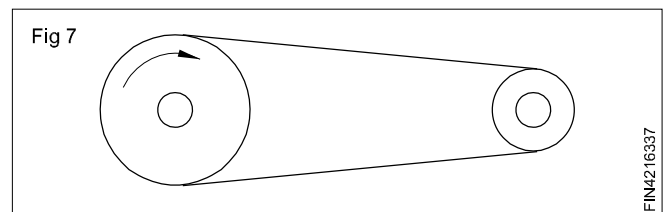
Belt efficiency

To provide maximum arc of contact the following points should be considered.

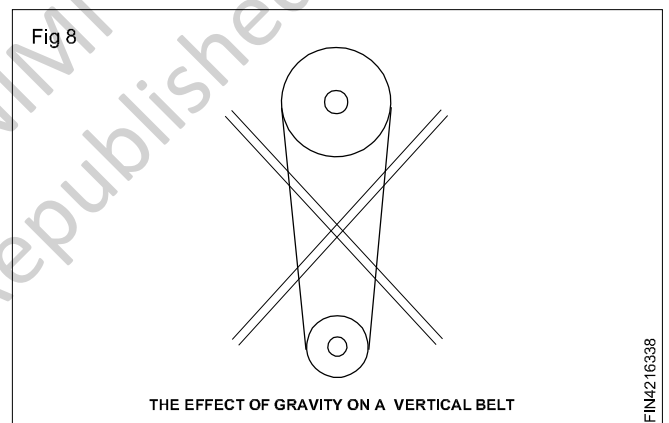
- Heavy belts of multi ply construction should not be used on small diameter pulleys.
- If the arc of contact is insufficient because of the short centre distance between the pulleys, a jockey pulley should be introduced as near to the small pulley as possible. (Fig 6)



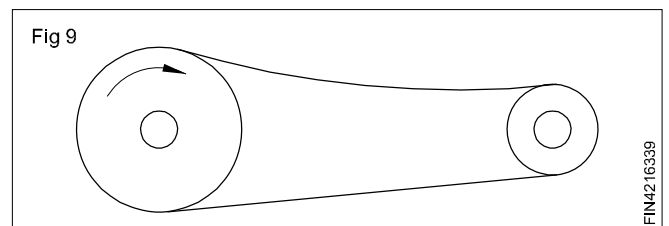
Excessive tension in the belt reduces the arc of contact, and introduces additional stresses which drastically reduce the life of the belt and bearings. (Fig 7)



Vertical drives should definitely be avoided because the belt tension necessary to withstand gravitational pull (Fig 8) and accompanying slippage would result in adverse effects.

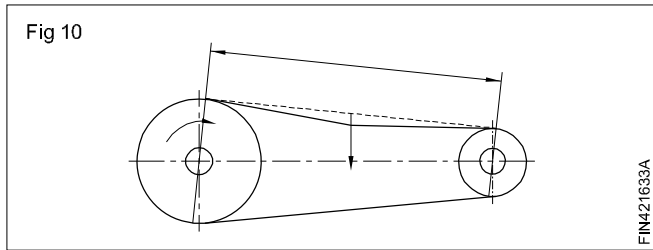


On the open belt drive, the slack side (Fig 9) must be at the top and the centre distance between the pulleys should be the maximum.



To measure tension of V-belt drives

To determine the force required to deflect one belt per 25 mm span length, apply a force perpendicular to the span at the centre of the belt large enough to deflect one belt to 0.5 mm span from its normal position. (Fig 10)



- Compare this deflection force with the range of forces given in Table 1.
- If it is less than the minimum recommended deflection force, the belts should be tightened.
- If it is more than the maximum recommended deflection force, the drive is tighter than it need be.

Care and maintenance

- Keep the pulley faces and belts free from foreign material which may cause slips.
- When the 'V' belts begin to show signs of wear they should be replaced. Replace all the belts in a multiple 'V' belt drive rather than a single one.
- Check and adjust drive tension periodically.
- Store belts in a cool, dark and dry place.

The belt tension should be adjusted in such a way that the deflection force is in between the maximum and minimum.

TABLE 1

Recommended deflection force per belt for classical 'V' belts

V-Belt cross-section	Small sheave dia. range cm	Speed ratio range	Recommended deflection force Kg	
			Min.	Max.
A	7.62-8.13	2.0-4.0	1.08	1.54
	8.64-9.14		1.14	1.68
	9.65-10.67		1.32	1.91
	11.68-17.78		1.59	2.26
B	11.68	2.0-4.0	2.00	2.86
	12.67-13.71		2.22	3.22
	14.22-16.25		2.45	3.53
	17.27-23.87		2.81	4.08
C	17.78	2.0-4.0	3.4	5.00
	19.05-20.32		3.81	5.44
	21.59-25.4		4.30	6.36
	26.67-40.64		5.00	7.72
D	30.48-33.02	2.0-4.0	7.71	10.91
	34.29-39.37		8.6	12.27
	40.64-55.88		10.00	14.09
E	54.86-60.96	2.0-4.0	14.54	21.36

Maintenance features of the Vee belt		
Trouble	Cause	Remedy recommended
Belt Slips	Less tension. Overload. Oiliness in the groove of the pulley or belt.	Increases the tension. Reduce the load. Degrease.
Frequent belt spoilage	Excessive heat. Shock load. Misalignment. Damaged sheave. Foreign particles. Drive overloaded.	Provide ventilation or use neoprane jacket type belt. Avoid shock load as far as possible and increase the belt tension. Align the pulleys. Change the damaged pulley. Provide belt guards. Check that all the belts in the drive have the same tension. If not, provide matching belts.
Belt whips excessively	Centre distance between the pulleys is more. Pulsating load.	Provide an idler. Introduce a fly wheel in the drive system.
Belt squeals.	Drive overloaded. Inadequate arc of contact. High starting torque.	Check that all the belts in the drive are evenly loaded. Provide an idler. Increase the belt tension.

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Vee belts and their advantages and disadvantages

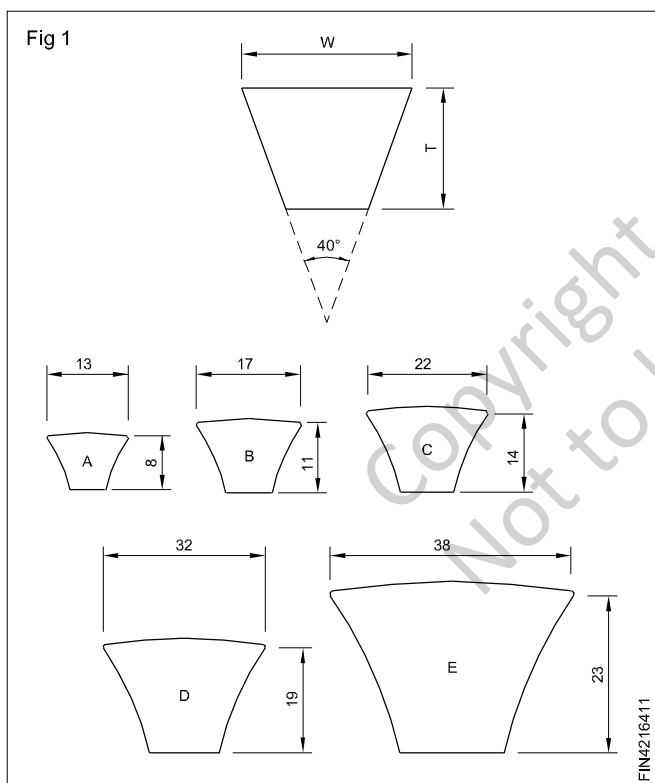
Objectives : At the end of this lesson you shall be able to

- name of different types of belt
- state the advantages of 'V' belt
- state the classification of 'V' belt
- state the designation of V- belt

V- belts

'V' belt drives are generally used when the distance between the shafts is too short for flat belt drives. Owing to the wedge action between the belt and the sides of the groove in the pulley, the V belt is less likely to slip, hence more power can be transmitted.

The endless V belt is shaped roughly like a trapezium in cross-section, and is made of cord and fabric, and is treated with rubber and moulded together in a uniform manner and shape. The cross-sectional symbol of a V-belt is shown in Fig 1.



Advantages of V-belt drive

- It is compact, so installation is possible in limited space.
- It is used when the centre distance between the driver and the driven pulleys is short.
- Less vibration and noise.
- Cushions the motor and bearing against load fluctuation.
- Easy replacement and maintenance.

Classification of 'V' belts

The 'V' belts are classified into 5 groups as per IS.2494-1974 namely A,B,C,D and E. The nominal included angle of the V-belt shall be 40°.

Table 1 given below lists the standard sizes of V-belts from Section A to E.

TABLE - 1

Cross-section Symbol	Nominal Top Width W (mm)	Nominal Thickness (T)
A	13	8
B	17	11
C	22	14
D	32	19
E	38	23

Individual manufacturer's belts may deviate slightly from these dimensions for various constructional reasons. Crowning, if any, in belts should be disregarded for the measurement of thickness.

Designation of V-belt as per IS.2494

The V belts conforming to this standard shall be designated by the cross-section symbol, nominal inside length and the number of IS: standard.

Example

C 3048 IS: 2494

C = V-belt cross-section

3048 = Nominal inside length in mm. in untensioned state.

‘V’ belts creep, slip

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

- list the use of commercial ‘V’ belt
- brief the term creep and slip
- explain the purpose of belt dressing
- calculate length of open belt

Use of commercial belt

A belt is a loop of flexible material used to link two or more rotating shafts mechanically, most often parallel. Belts may be used as a source of motion, to transmit power efficiently or to track relative movement. Belts are looped over pulleys and may have a twist between the pulleys, and the shafts need not be parallel.

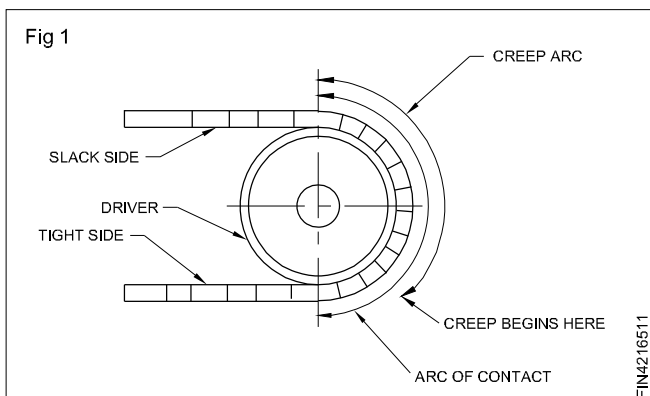
In a two pulley system, the belt can either drive the pulleys normally in one direction (the same if on parallel shafts), or the belt may be crossed, so that the direction of the driven shaft is reversed (the opposite direction to the driver if on parallel shafts). As a source of motion, a conveyor belt is one application where the belt is adapted to carry a load continuously between two points.

Commercial belts are mainly used in home appliances like, grinder, mixer and washing machine etc.

Creep and slip of belt (Fig 1)

As the belt turns on a pulley it tends to stretch on the contact area of the driving pulley and shorten on the driven pulley. This localised movement of the belt is a direct result of the elastic stretch and is known as creep. Greater the load more will be the creep. The figure shows the condition of belt as a result of creep.

Slip is the actual difference caused between the surface speed of the belt and pulley. The effect of slip may be reduced by decreasing the pulley ratio and maintaining proper alignment. Creep, being the physical characteristic of the belt, cannot itself be controlled. Slip and creep jointly cause power loss.



Belt dressing

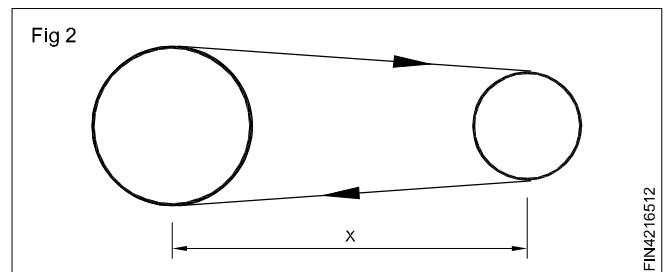
Due to the continuous rubbing of the belt on the surface of the pulley the belt gets dried up due to friction, and heat is generated. This causes the belt to slip.

To keep the belt supple and free from cracks, belt dressing is applied. Tallow or powdered resin are good dressing materials which are applied on the inner face of the belt. This improves the gripping property of the belt.

Open belting (Fig 2) calculation

- If
- L = length of open belting
 - D = dia. of larger pulley
 - d = diameter of smaller pulley
 - x = centre distance between the pulleys

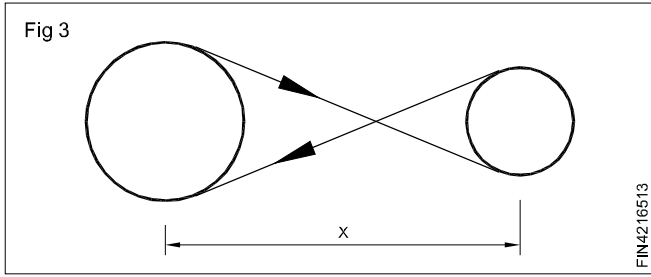
$$\text{then, } L = \frac{D + d}{2} \times 3 \frac{1}{7} + 2x$$



Cross-belting (Fig 3)

- If
- L_c = length of cross-belting
 - C = circumference of larger pulley
 - c = circumference of smaller pulley
 - R = radius of larger pulley
 - r = radius of smaller pulley
 - x = centre distance between the pulleys

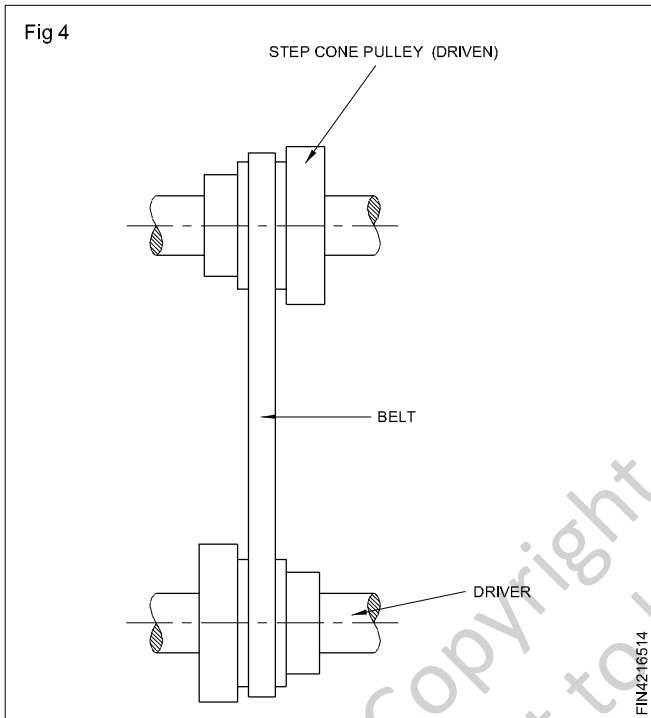
$$\text{then, } L_c = \frac{C}{2} + \frac{c}{2} + 2\sqrt{x^2 + (R+r)^2}$$



stepped drives (Fig 4)

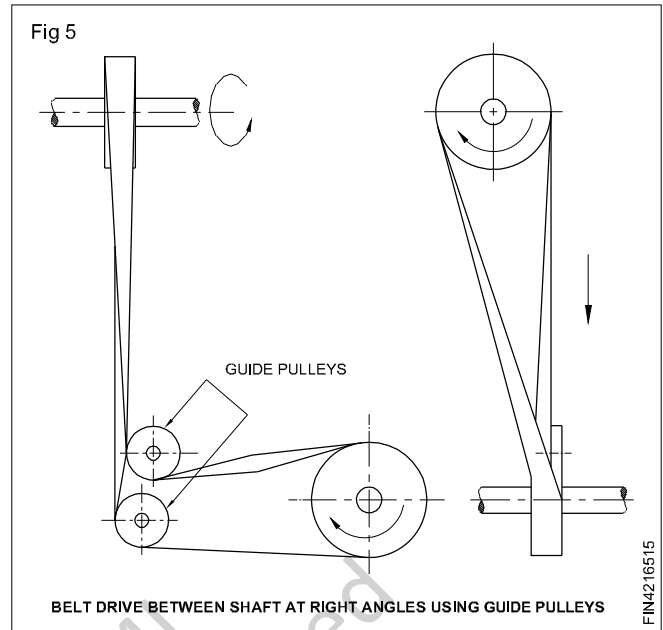
Stepped drives are used to obtain different speed ratios. Pulleys of different sizes are employed.

Three different speeds can be obtained by changing the belt position from one step to another.



Right angled drive (Fig 5)

This drive is employed between shafts at right angles using tide pulleys. In this the horizontal drive is converted into vertical drive with the help of the guide pulleys



Couplings - Types of couplings

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

- state the types of couplings
- state the purpose of couplings.

Introduction

Power is transmitted from one end to the other commonly by means of shafts

If the distance between the two ends is large (say 8- 10 m), it would be inconvenient and expensive to have one such long length of shaft both from manufacturing and transport point of views.

Hence, it is recommended to connect a number of pieces by means of suitable couplings to transmit power from one end to the other.

Types

Shaft couplings may be broadly classified as:

- 1 Rigid or fast coupling
- 2 muff coupling
- 3 Flange coupling
- 4 Flexible coupling
- 5 Pin bush coupling
- 6 Chain coupling
- 7 Gear coupling
- 8 Spider coupling
- 9 Tyre coupling
- 10 Grid coupling
- 11 Old ham coupling
- 12 Fluid coupling
- 13 Universal coupling

1 Rigid or fast coupling

This type of couplings provide rigid connection between the two shafts without permitting any relative motion between them.

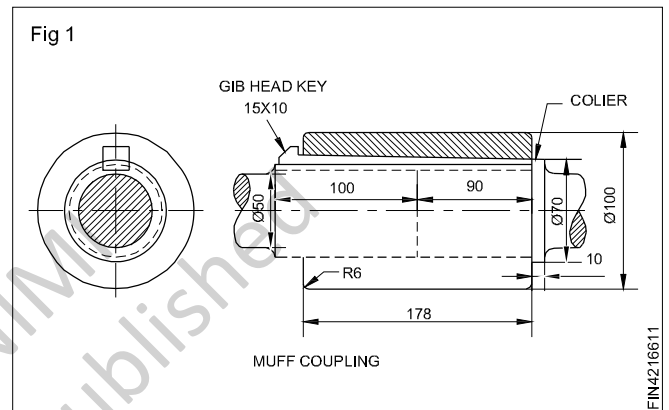
The important types of rigid couplings are

- unprotected type flanged coupling
- protected type flanged coupling
- Solid or forged flanged coupling
- Muff couplings
- Compression coupling

2 Muff coupling

In muff or sleeve coupling shown in fig 1, the ends of the two shafts to be coupled butt against each other and a cast iron muff or sleeve envelops them.

A gib - headed sunk key is provided to hold the sleeve and the shafts together, thus forming a rigid coupling.

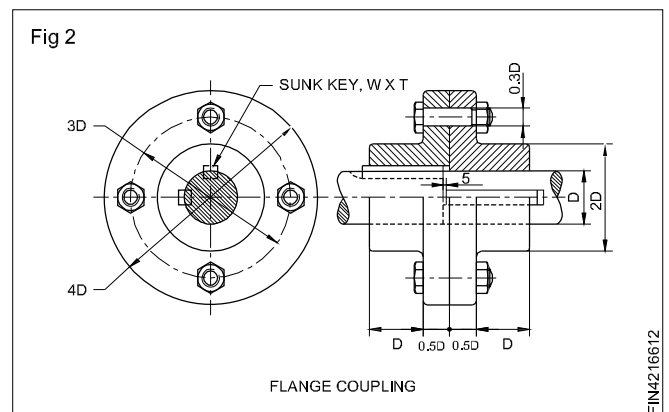


3 Flanged coupling

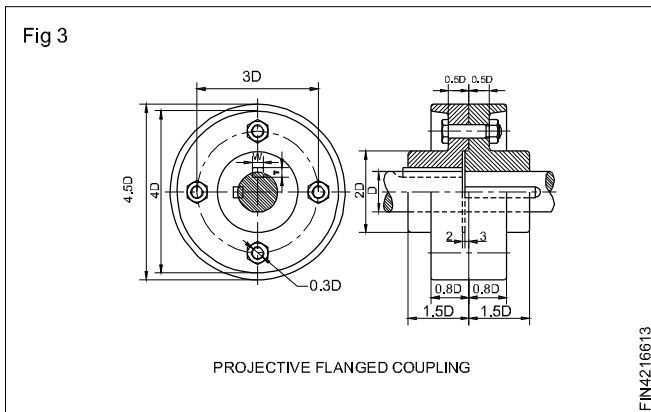
These are the standard forms of couplings, most extensively used. In a flanged coupling, flanges are either fitted or provided at the ends of shafts. The flanges are fastened together by means of a number of bolts and nuts. The number and size of the bolts depend upon the power to be transmitted and hence, the shaft diameter.

3.1. Flanged coupling with detachable flanges

In this, two flanges are keyed, one at the end of each shaft, by means of sunk keys (Fig 2) For ensuring correct alignment, a cylindrical projection may be provided on one flange which fits into the corresponding recess in the other.

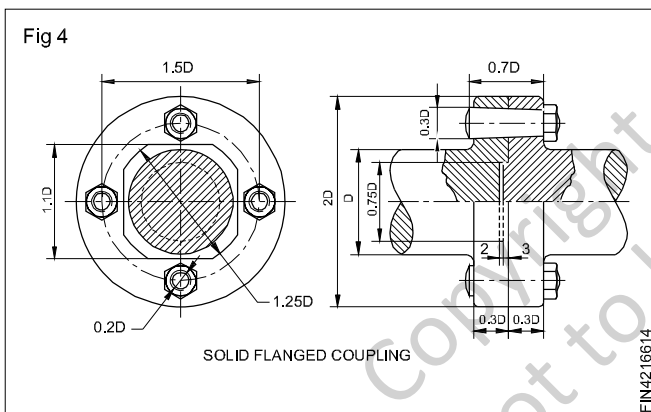


In the design shown in figure, the bolt heads and nuts are exposed and liable to cause injury to the workman. Hence, as a protection, the bolt heads and nuts may be covered by providing an annular projection on each flange. A flanged coupling, using these flanges is called a protected flanged coupling (Fig 3).



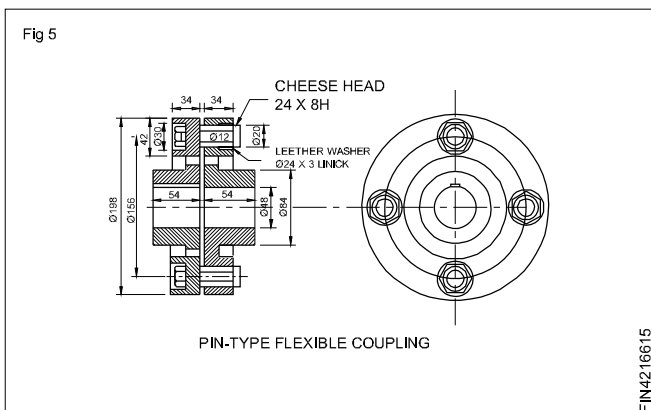
3.2. Solid flanged coupling

Couplings for marine or automotive propeller shafts demand greater strength and reliability. For these applications, flanges are forged integral with the shafts. The flanges are joined together by means of a number of headless taper bolts (Fig 4)



4 Flexible Coupling

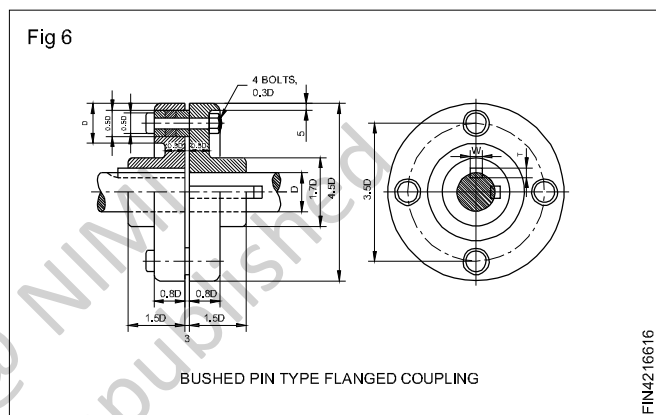
- Flexible couplings are used where slight relative movement is required or the axis of shafts run slightly out of line.



- Here the motion from one half of the coupling to the other half is imparted with the help of driving pins rigidly bolted to one flange and loosely fitting corresponding holes in the other.
- Brass bush and rubber covering is provided on the driving pins for absorbing shocks and as insulators.

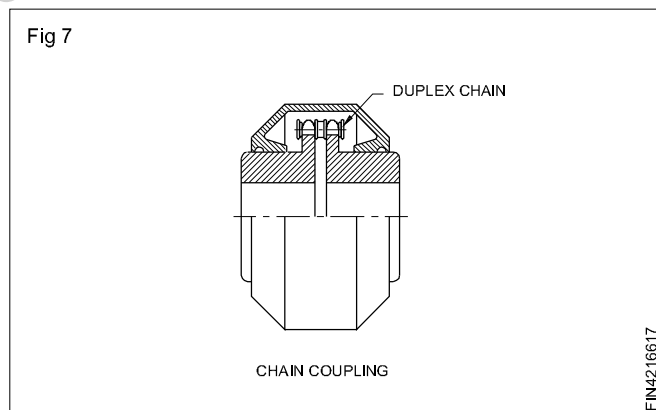
5 Bushed Pin type Flanged Coupling (Fig 6)

It is the modified version of a protected flanged coupling. In this, bolts are replaced by bushed pins. The smaller ends of the pins are rigidly fastened by nuts to one of the flanges, while the enlarged ends are covered with flexible material like leather or rubber bushes, in the other flange. The flexible medium takes care of mis - alignment, if any, and acts as a shock absorber. These couplings are used to connect prime mover or an electric motor and a centrifugal pump.



6 Chain Coupling (Fig 7)

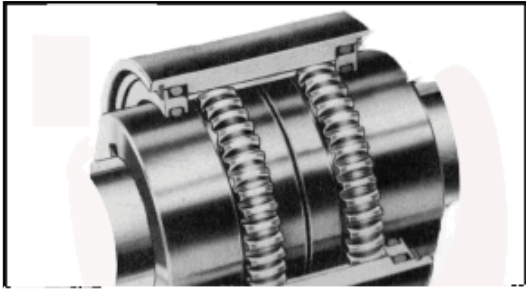
Flanges replaced a sprocket on each shaft. The coupling is by a duplex chain wrapped over both adjacent coupling.



7 Gear Coupling (Fig 8)

Both coupling halves have a raised rim machined as an external gear. The sleeve which couples the two shafts comprises two halves bolted together, each half having a machine internal gear. This coupling requires lubrication. The coupling is capable of high speeds and high power capacity.

Fig 8

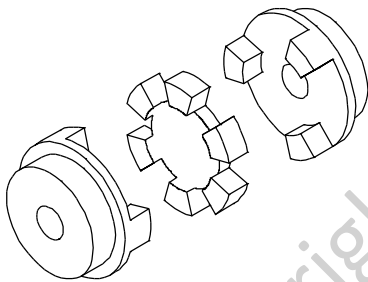


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8 Spider (Fig 9)

Both half of the couplings have three shaped lugs. When the coupling halves are fitted together the lugs on one half fit inside the spaces between the lugs on the other side. A rubber insert with six legs fits within the spaces between the lugs. The drive is by the lugs transmitting the torque through the rubber spider spacer. This coupling is only used for low power drives.

Fig 9

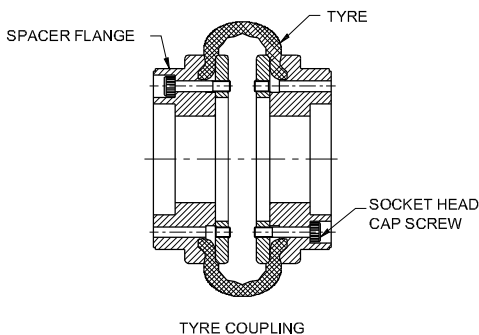


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9 Tyre Coupling (Fig 10)

Tyre coupling device is used to reduce vibration in engines and also reduces the torque oscillation. It is available in different versions such as F or H type. And customers can find tyre coupling in various dimensions and in taper lock fitting models. It is applicable in compressors, pumps, blowers. etc.,

Fig 10

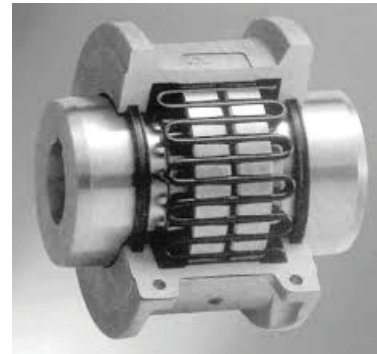


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10 Grid Coupling (Fig 11)

Metal coupling that provides positive protection against the damaging effects of shock loads and vibration. Both Grid couplings are an excellent choice where torsional flexibility /vibration damping are primary concerns.

Fig 11



FIN421661B

- Easy to assemble/replace
- Part - for - part interchangeable with industry standard grid coupling designs.
- Coupling sizes 2020 through 2140 in - stock in a range of standard bore sizes.
- Shot - peened tapered grid flex element for long llife.

Typical Applications:

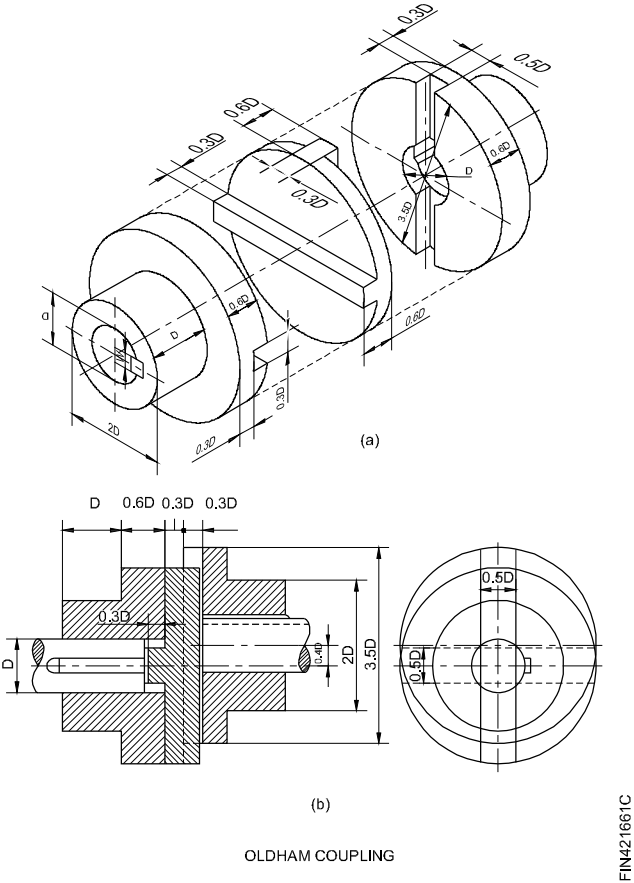
- Pumps
- Gear Boxes
- Electric Motors
- Fans/Blowers
- Conveyors
- Compressors

11 Oldham Coupling (Fig12)

It is used to connect two parallel shafts whose axes are at a small distance apart. Two flanges, each having a rectangular slot, are keyed, one on each shaft. The two flanges are positioned such that, the slot in one is at right angle to the slot in the other.

To make the coupling, a circular disc with two rectangular projections on either side and at right angle to each other, is placed between the two flanges. During motion, the central disc, while turning, slides in the slots of the flanges. Power transmission takes place between the shafts, because of the positive connection between the flanges and the central disc.

Fig 12

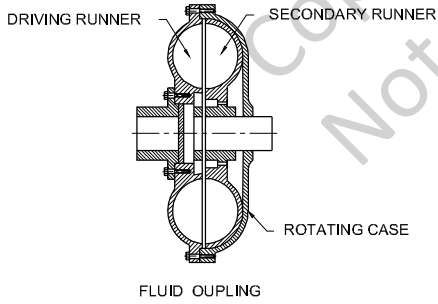


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12 Fluid Coupling (Fig 13)

Based on both coupling halves having vanes within a housing (case) containing viscous fluid which rotates with the driving shaft. The rotation is transmitted from one side (Driving) to the other (secondary) via the viscous fluid. The coupling provides a soft start.

Fig 13



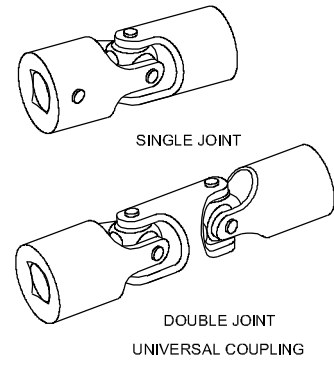
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13 Universal Coupling (Fig 14)

Coupling which allows large angle between drive halves (20-30°). Generally based on a yoke mounted on each shaft. Between to yokes in mounted a trunnion cross.

Needle bearings are used at the bearing points between the cross and the yokes. These type or units are used in pairs on carden shafts. Uses widely on rear wheel drive vehicle propshafts.

Fig 14

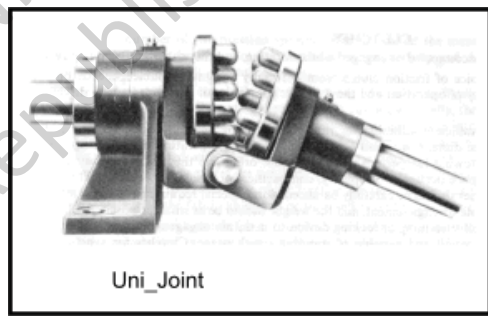


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14 Universal Coupling - Uni - Joint (Fig 15)

The other name of universal coupling is hook coupling. Simplest type of coupling which allows large angle between drive halves. Each side of coupling includes protruding pins. The halves of the coupling are fastened in a pivoting assembly. At all angles up to about 40° the pins interlock with each other and rotation on one half forces the other half to rotate. Low power use only. Not smooth. Not reliable. Really only suitable for remote manual operations.

Fig 15



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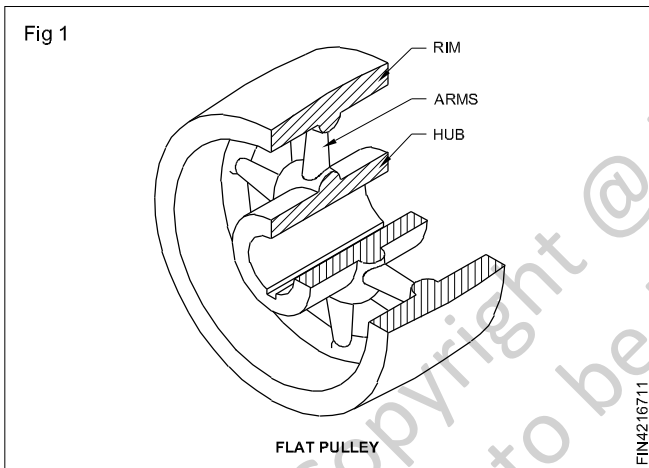
Pulleys - types - solid - split and 'V' belt pulleys

- Objectives :** At the end of this lesson you shall be able to
- state the different types of pulleys and their uses
 - state the purpose of crowning of a pulley
 - state the importance of wrapping angles in a belt drive
 - state the maintenance aspects of V belts
 - state the advantages of a chain drive.

Pulley for flat belt

Pulleys for flat belts are made from cast iron or mild steel and are available in solid or split form.

The flat pulleys have a wide rim with a crowned surface for retention of the belt. The hub is strongly designed and provides the means of securing the pulley to the shaft. The arms unite the hub and rim into a rigid assembly. The arms of a pulley may be of circular or elliptical cross-section, but larger at the hub than at the rim. (Fig 1)



Crowned face of pulley

The rim of a pulley for flat belt is generally made convex and this is called the crowned face of the pulley. The crown faced pulley will keep the belt centralised even if there is any slight tendency to run off. Shifting the belt from the fast pulley to the 'loose' pulley will be quick and easy. Excessive crowning will be injurious to belting.

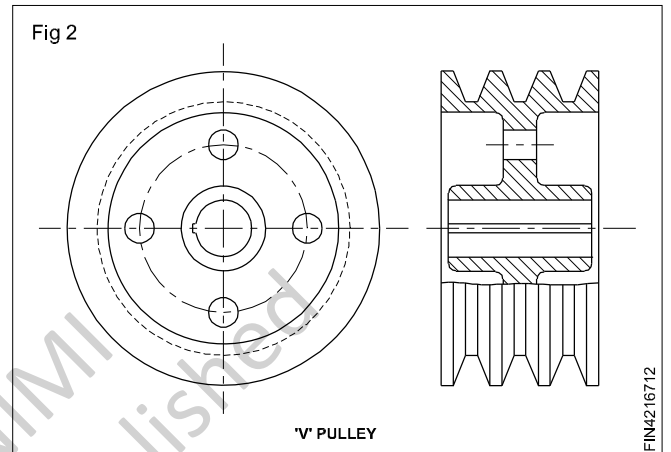
'V' groove pulley

These pulleys have one or more 'V' grooves to carry the V belts. Fig 2 shows a V belt pulley having three V grooves. These pulleys are widely used in transmission of motion in machine tools and are made from cast iron, wrought iron, mild steel or wood.

Fast and loose pulley

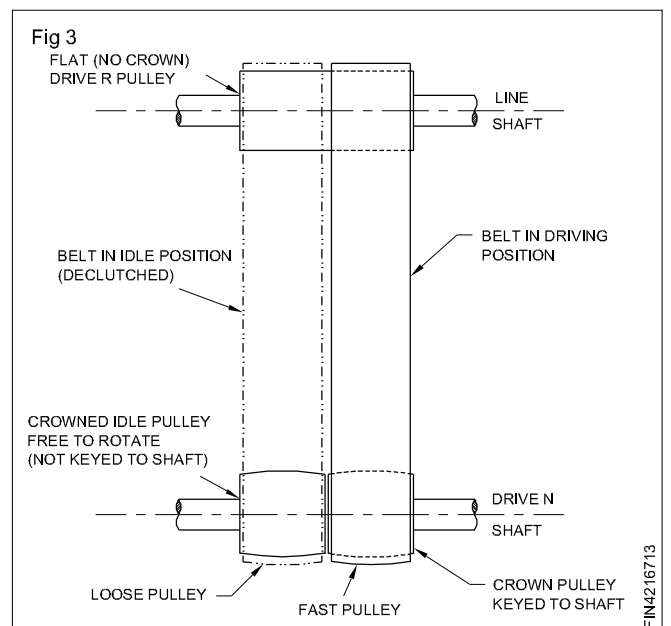
Pulleys are usually secured to their shafts by means of a key or grub screw. The function of the pulley keyed to the shaft is to convey rotation from the driving to the driven pulley by means of a belt. This is called a fast pulley.

The loose pulley is not keyed to the shaft and is free to rotate on the shaft.



Function

A machine can be easily stopped or started whenever required by the use of a pair of fast and loose pulleys. This pair is mounted on a counter- shaft near the machine to be operated. When the driving belt from the main shaft is on the fast pulley, the countershaft is in motion. If the belt is shifted from the fast pulley on to the loose pulley, the countershaft will stop rotation. Fig 3 shows the position of the fast and loose pulleys in a driving system.



Determining the size of crowning faces of pulley

Objectives: This shall help you to

- define the importance of crowning
- state the specification of standard pulleys.

Crowning one or several pulleys in belt system is the most common way of tracking a belt. For flat power transmission belts and narrow conveyor belts(up to 8 in.), a radius crown is used. For wider conveyor belts, a trapezoidal crown is typically applied. Note: Never utilize an apex crown!

Radius Crown Specifications for Flat Belt Pulleys

A radius crown represents a great way to track a belt. Dimensionally, it does not take a big crown height in order for the belt to track properly, and exceeding the seemingly small amounts below will actually do more harm than good!

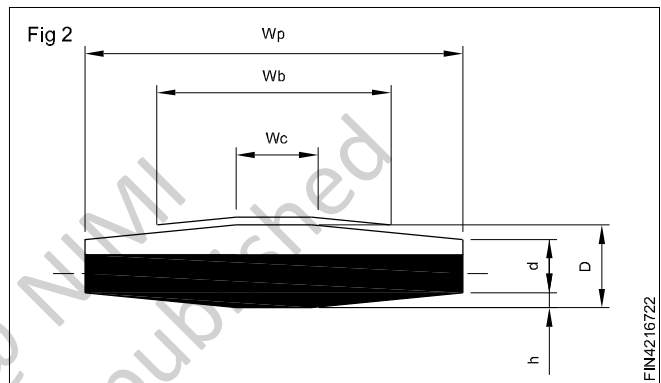
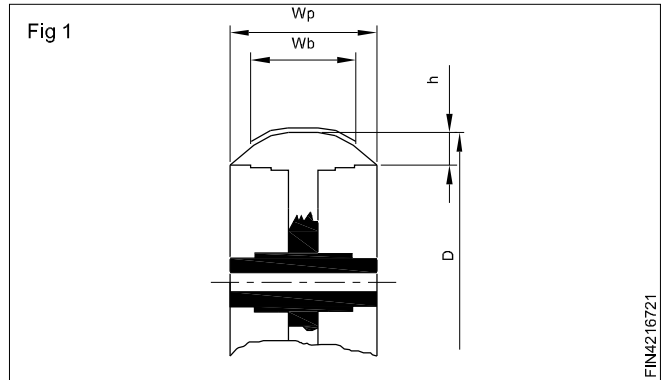
In a system with multiple pulleys, crown the pulleys that turn the same way.

The min. pulley face width

$$W_p = (\text{belt width } W_b \times 1.1) + 0.5 \text{ in.}$$

The max. belt width

$$W_b = (\text{pulley face width } W_p - 0.5 \text{ in}) / 1.10$$



Standard Radius crown heights h

Pulley Face Width W_p	Pulley Diameter D					
	1-6	6-12	12-18	28-40	40-60	>60
in	in	in	in	in	in	in
1-5	0.031	0.047	0.051	0.067	0.078	0.098
5-10	0.039	0.051	0.059	0.078	0.090	0.110
10-16	0.043	0.055	0.063	0.087	0.098	0.118
>16	0.047	0.059	0.078	0.098	0.118	0.137

Convert to metric units

pulley Diameter D	Crown Height h
1 to 2.75	0.012
2.75 to 4	0.017
4 to 6	0.022
6 to 8	0.026
8 to 11	0.034
11 to 14	0.042
> 14	0.045

Note:

The cylindrical part of the pulley W_c is half of the belt width W_b . Also, it is recommended for the pulley width w_b for the pulley crown to function properly. For pulley widths less than 8 in., use a radius crown and refer to the flat belt pulley specifications above.

Belt length

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

- Calculate the length of the belt for open belt drive.

In belting technology, there are a few special expressions and technical data which need a brief explanation.

Belt length

The length of power transmission flat belts can be expressed in three ways:

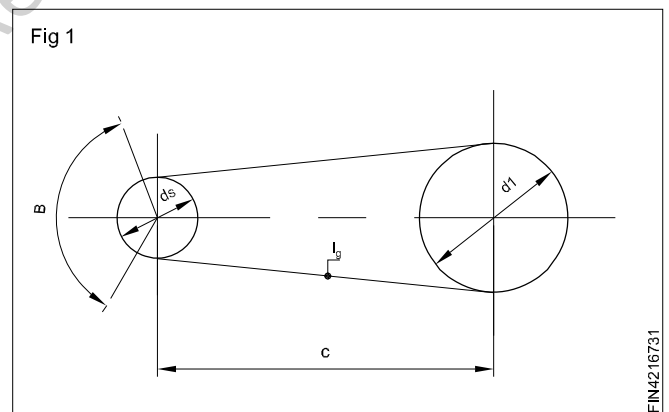
- Geometric belt length (l_g)
- Effective belt length (l_{eff})
- Shortened belt length (l_s)

For common two pulley drives, the difference between geometric and effective belt length is negligible. However, in specific applications, e.g. short centre distance and / or relatively thick belts, limited take-up etc., greater calculation accuracy is necessary.

Please note that the theoretical considerations below are automatically taken into consideration when using the POWER - SeleCalc calculation program.

Geometric belt length (l_g)

The geometric belt length means the inner circumference of an un-tensioned belt drive on the assumption that the belt is infinitely thin. The belt thickness and the position of the neutral layer are not considered.



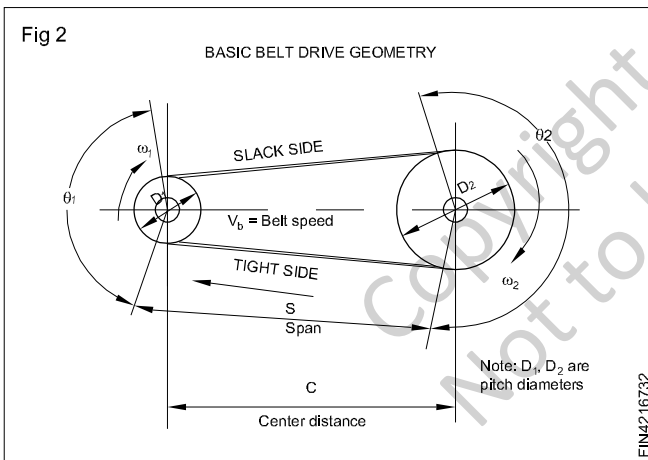
Exact formula for the calculation of the geometric belt length of a two pulley drive:

$$l_g = 2c \sin\left(\frac{\beta}{2}\right) + \frac{\pi}{2} \left[d_s d_l + \frac{(d_l - d_s)(180 - \beta)}{180} \right] (\text{mm})$$

c = center distance (mm)

d_s = diameter of small pulley (mm)

According to SANS 1669 Bag centre	Belt Face	900	1050	1200	1350	1500	1650	1800	2100	2400
		1050	1200	1350	1500	1700	1850	2000	2300	2600
		1700	1850	2050	2300	2450	2600	2900	3200	
Pulley Diameter	Shat Dia Pulley Dia	Resultant tensions (KN)								
200	100/315	21	18	16	13	10	10	9	8	7
250	110/400	30	26	23	19	16	14	13	12	10
315	120/400	45	37	33	27	22	20	19	16	14
400	130/400	60	51	45	37	30	28	26	22	19
500	140/500	80	70	60	50	41	37	35	30	25
630	150/500	100	90	80	66	54	49	45	40	35
800	160/500	119	119	105	86	70	64	60	50	45
1000	170/630	144	144	133	110	88	81	75	65	55
1250	180/630	170	170	165	138	112	100	95	82	70
	190/630	200	200	200	170	138	130	120	100	90



- The belt is placed around the two sheaves while the center distance between them is reduced, then sheaves are moved apart
- Friction causes the belt to grip the driving sheave, increasing the tension in one side, called the "tight side", of the drive
- The opposite side of the belt is still under tension (at a smaller value) that is called the 'slack side'.

d_1 = diameter of large pulley (mm)

β = arc of contact on small pulley [°]

$$\beta = 2 \arccos \frac{(d_1 - d_2)}{2c} = [^\circ]$$

Elements of spur gear

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

- state the basic elements of a spur gear
- calculate spur gear tooth proportions with the given data.

Spur gear elements

A spur gear is the simplest form of gears. The tooth proportions of the spur gears are expressed in terms of modules.

Module

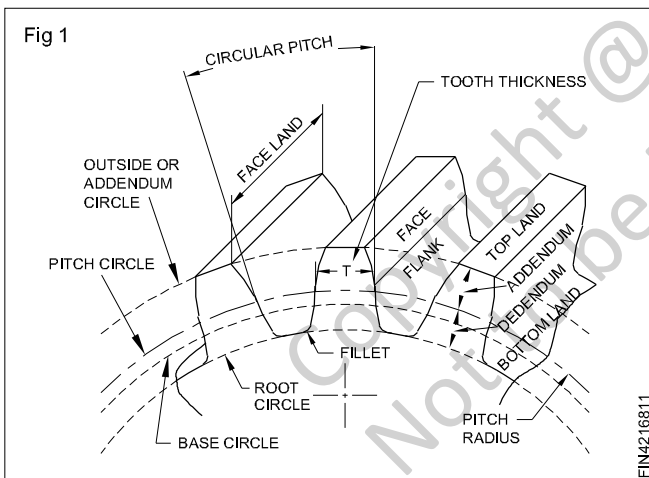
It is defined as the ratio of the pitch diameter to the number of teeth of a gear. The module is denoted by the letter 'm' and is expressed in millimetres. The module is one of the major determining parameters of a gear.

Basic Elements (Fig 1)

Pitch circle

It is the imaginary circle on which two mating gears seems to be rolling.

The gear calculations are based on this circle.



Circular pitch: 'CP or 'P'

It is the distance from the point of one tooth to the corresponding point of the adjacent tooth measured on pitch circle.

Pitch circle diameter (PCD)

The diameter is called pitch circle diameter (PCI) or simply pitch diameter.

It is denoted by the letter 'd' with proper subscripts eg. d1 for pinion and d2 for the mating gear.

Addendum circle

Addendum circle or outside circle bounds the outer edges of the teeth of a gear and its diameter is denoted by 'da'.

Root circle

The root circle or dedendum circle bounds the bottom of the teeth and its diameter is denoted by 'df'.

Base circle ('db')

This is the circle from which the involute tooth profile is developed. Its diameter is denoted by db.

Addendum (ha) (Fig 2)

It is the radial distance between the pitch circle and the addendum circle and is denoted by ha.

Dedendum (hf) (Fig 2)

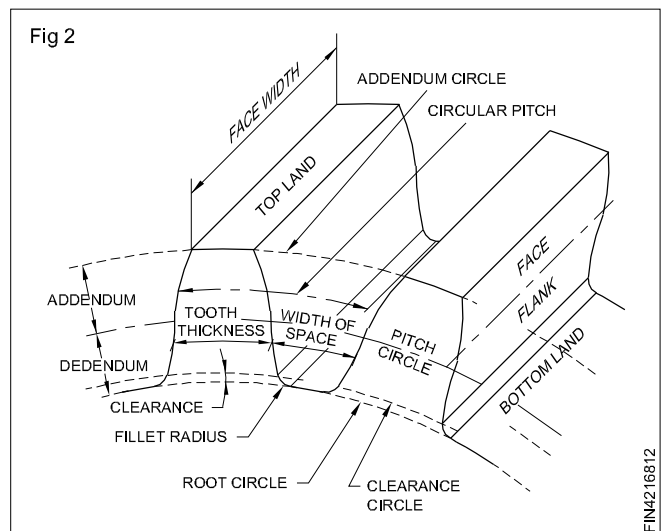
It is the radial distance between the pitch circle and the root circle, and is denoted by hf.

Land (Fig 2)

The land and the bottom land are surfaces at the top of the tooth and the bottom of the tooth space respectively.

Working depth (Fig 2)

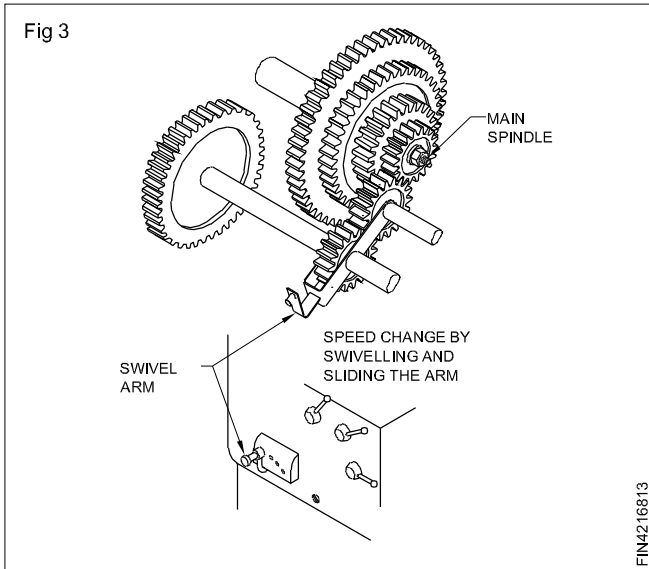
This is the distance of engagement of two mating teeth and is equal to the sum of addendums of the mating teeth of the two gears in the case of standard systems and is expressed as '2ha'.



Velocity ratio of gear train

The gear train transmits motion without slip.

Different speeds can be obtained by shifting gear position in the gear- box. Fig 3 shows the feed change by swivelling and sliding the swivel arm in the Norton gearbox of lathes.



Formula for velocity ratio of gear train

$$N_1 T_1 = N_2 T_2$$

where

N_1 = RPM of driver gear

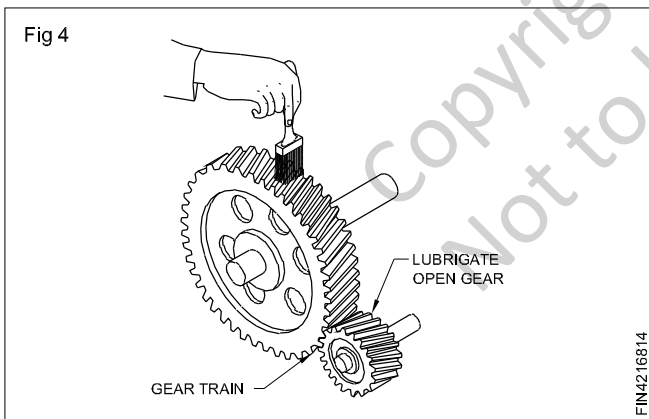
T_1 = number of teeth in the driver gear

N_2 = rpm of the follower/driven gear

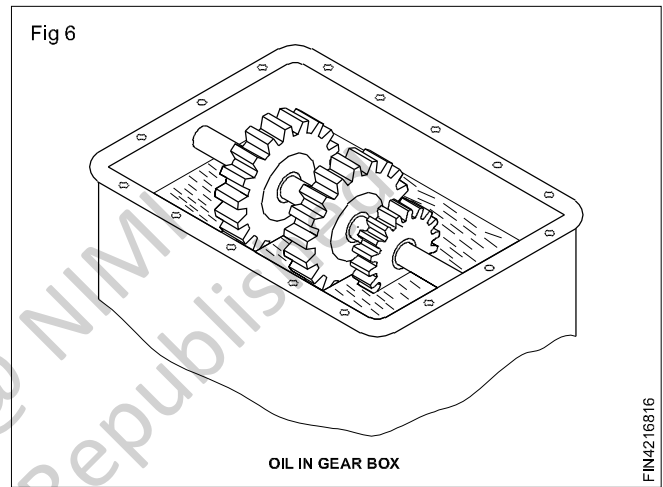
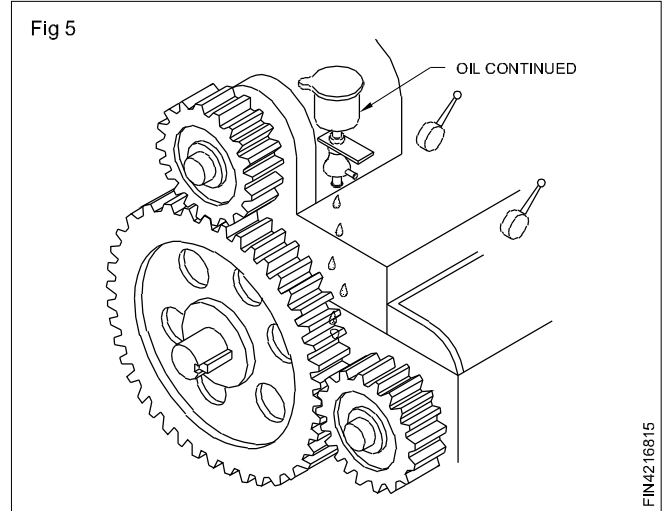
T_2 = number of teeth in the driven gear.

Lubrication of gear train

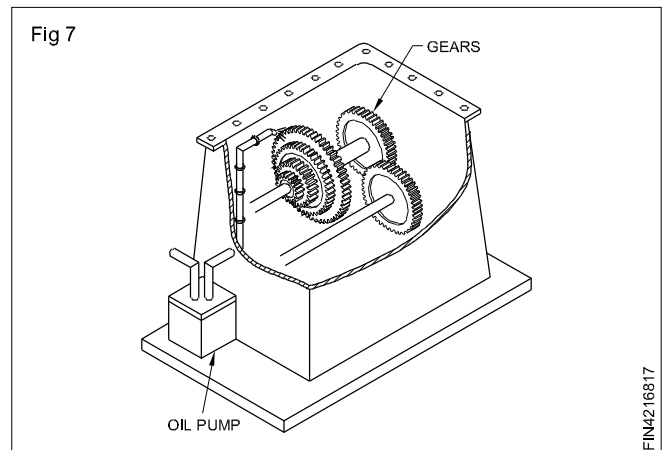
The low speed gears which are visible may be lubricated with an oilcan or brush. (Fig 4) The drop oil method of lubrication is shown in Fig 5.



The enclosed gear trains should be packed in grease or run in an oil bath. (Fig 6)



In the case of big gearboxes mounted with different levels of gear sets, they are provided with oil pumps for lubrication purposes. (Fig 7)



Types of gears

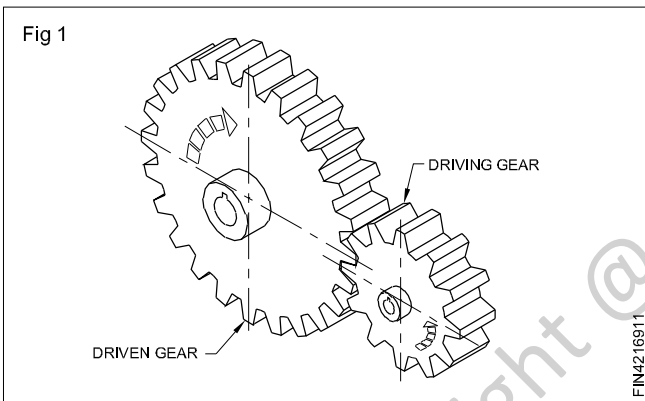
Objectives : At the end of this lesson you shall be able to

- state the purpose of gears
- name the most common forms of gears and state their uses
- determine the velocity ratio of a gear train
- state the care and maintenance of gears.

Purpose of gears

Gears are used to transmit torque/motion from the driving shaft to the driven/follower shaft:

- to change the velocity ratio
- to change the direction of rotation. (Fig 1)
- to get a positive drive.



Gears are made from cast iron, steel, non-ferrous, plastic or fibre material.

Types

Spur gear

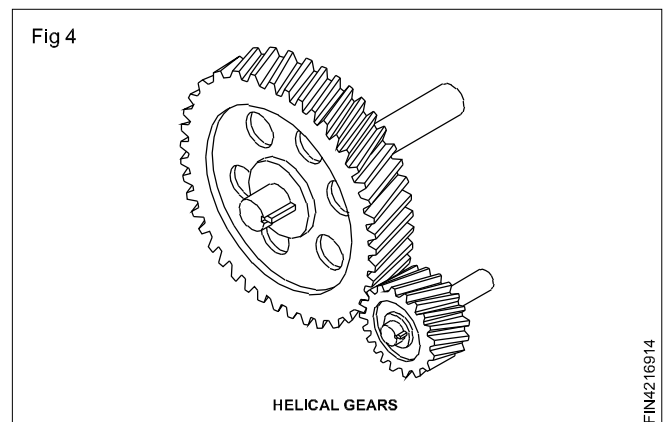
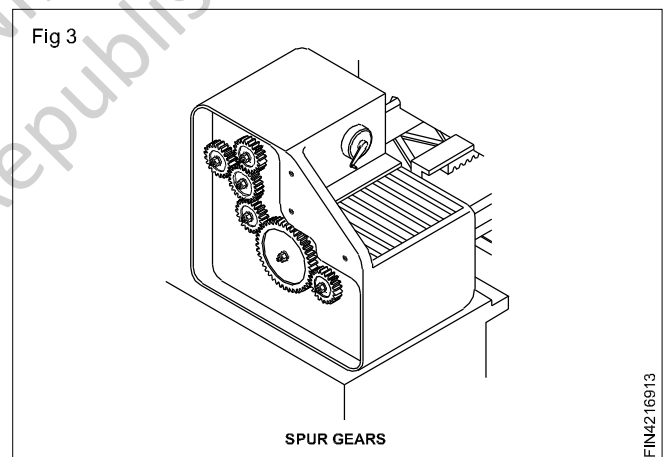
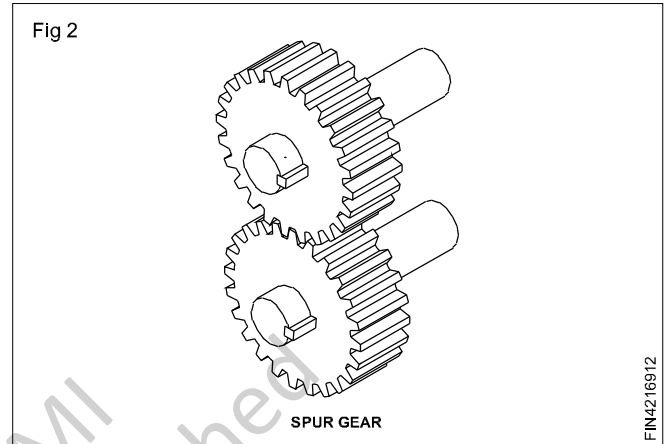
The teeth are cut parallel to the axis of rotation. The spur gears are used to transmit power between two parallel shafts.

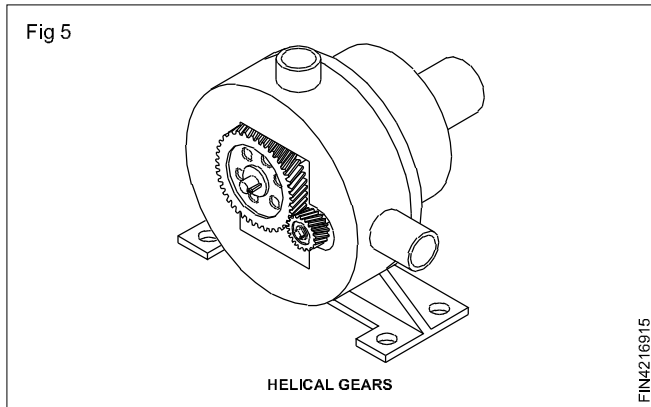
Fig 2 shows two spur gears mating each other and Fig 3 illustrates the application of gears in the centre lathe to transmit motion from the main spindle to the lead screw.

Helical gear

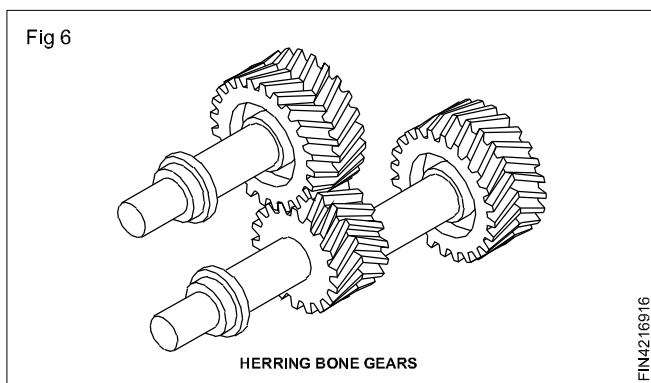
In a helical gear, the teeth are cut at an angle to the axis of rotation. It may be used to transmit power between two parallel shafts. Helical gears run more silently than a spur gear.

Fig 4 shows a set of helical gears mounted on two parallel shafts. These are widely used in automobile vehicles. The application of helical gears in an oil pump is illustrated in Fig 5.



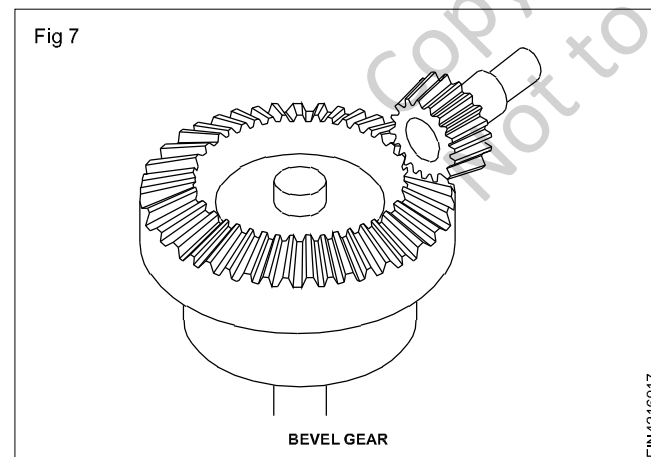


The end thrust is exerted by the driving and driven gears in the case of helical gears and the thrust may be eliminated by using double helical gears. These gears are called herring-bone gears. (Fig 6)

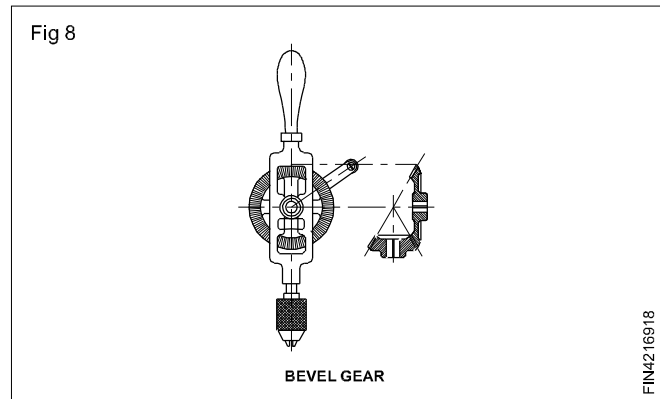


Bevel gear

The bevel gears shown in Fig 7 are used to transmit motion between shafts at various angles to each other. The teeth profile may be straight or spiral.

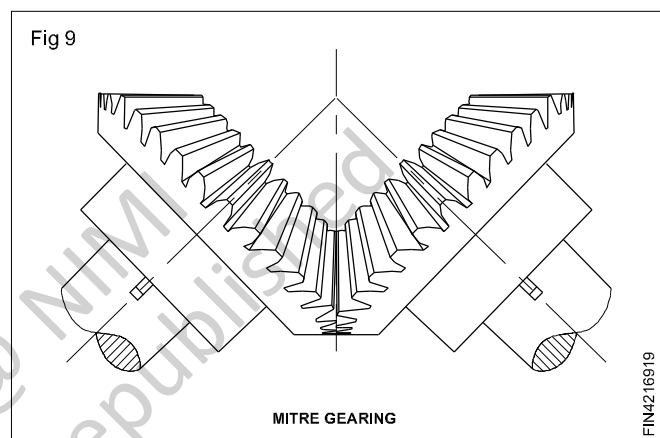


In a hand driller, the bevel gears transmit motion when the shafts are at right angles to each other. (Fig 8)



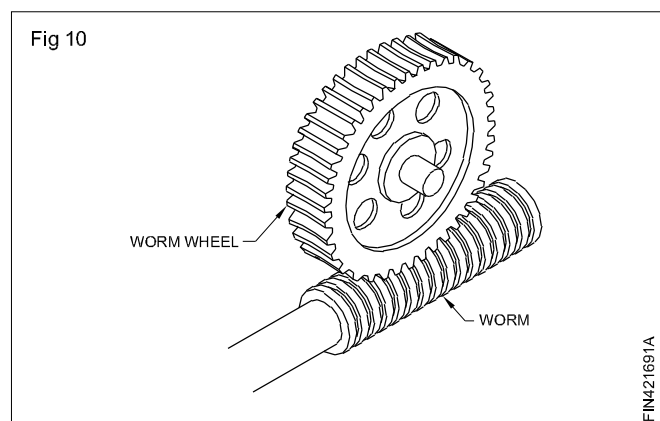
Mitre gears

If two bevel gears are symmetrical to each other and transmit motion at right angles, such gears may be called 'mitre gears'. (Fig 9)



Worm shaft and worm gear

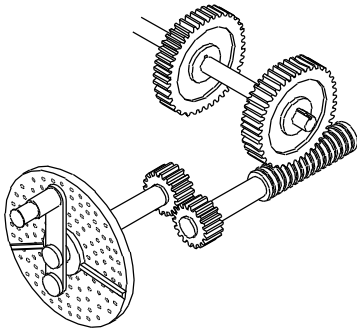
The worm shaft has spiral teeth cut on the shaft and the worm wheel is a special form of gear teeth cut to mesh with the worm shaft. (Fig 10)



These are widely used for speed reduction purpose.

The application of worm and worm gear in the index-head gear mechanism is shown in Fig 11.

Fig 11



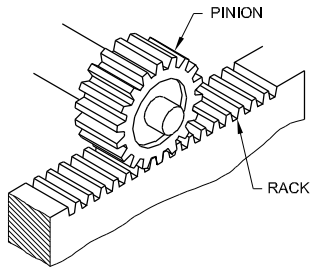
FIN421691B

This system transmits motion at right angles to the axis of motion at different planes.

Rack and pinion

The rack and pinion can change rotary into linear movement and vice versa. (Fig 12)

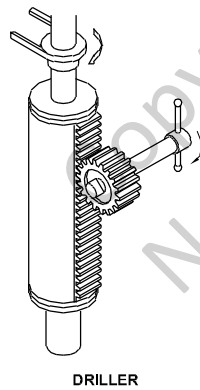
Fig 12



FIN421691C

This mechanism is used in drilling machines as illustrated in Fig 13.

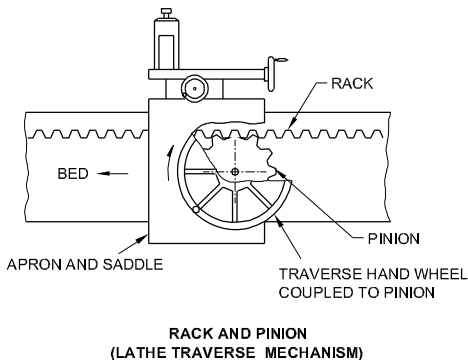
Fig 13



FIN421691D

Fig 14 shows the application of the rack and pinion in lathe traverse mechanism.

Fig 14

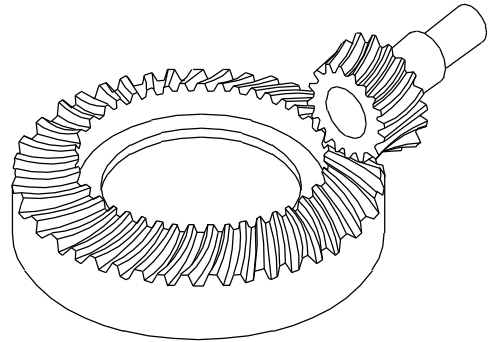


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Hypoid gears

The hypoid gears are used in automotive differential gearboxes. A pair of hypoid gears (illustrated in Fig 15) is similar to the spiral bevel gear but with the shafts offset. The tooth action between each gear is a combination of rolling and sliding action along a straight line. The pitch surfaces are hyperboloids of revolution; as such the gears are called hypoid gears.

Fig 15



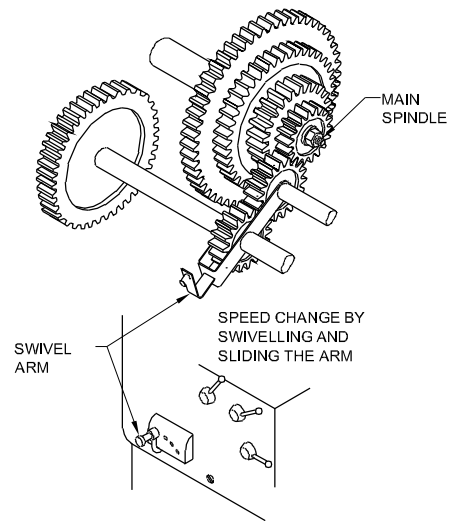
FIN421691F

Velocity ratio of gear train

The gear train transmits motion without slip.

Different speeds can be obtained by shifting gear position in the gear-box. Fig 16 shows the feed change by swivelling and sliding the swivel arm in the Norton gearbox of lathes.

Fig 16



FIN421691G

Velocity ratio of worm gear

It is the ratio of number of turns of the worm to 1 turn of the worm wheel.

$$\text{Speed ratio} = \frac{z_2}{z_1}$$

Where z_2 = Number of teeth on the worm wheel.

Z_1 = Number of starts on the worm.

Methods of machining worm

- On a centre lathe
- On a worm milling machine
- On a gear hobbing machine

Methods of machining a wormwheel

- On a milling machine
- On a hobbing machine

Repair broken gear tooth (Dovetail blank method)

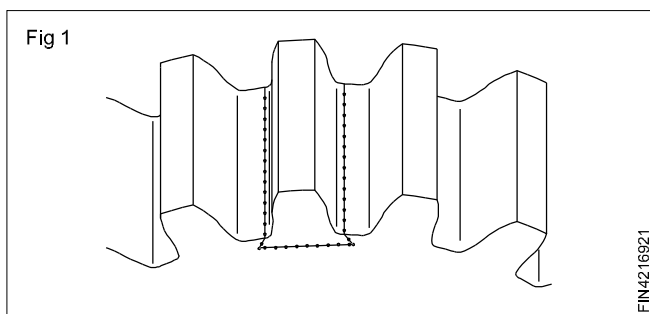
Objective: At the end of this lesson you shall be able to

- **repair broken gear tooth by dovetail method.**

Support the gear against a Vee block and clamp it by parallel camp.

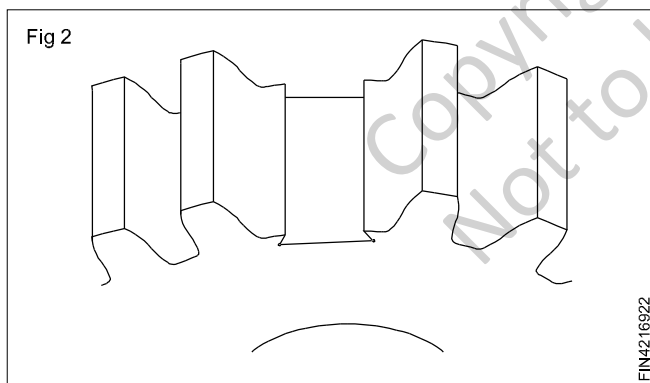
Mark the dovetail groove on the gear wheel form both sides using a venier height gauge and vernier bevel protractor.

Punch the marking lines.(Fig 1)



Drill 3mm dia. relief holes one each on the corner of the dovetail.

Remove material from the gear to shape and size of dovetail as per marking. (Fig 2)



File the blank to the profile of the gear tooth as per punch mark.

File the dovetail portion of the blank.

Fit the blank into the dovetail groove of the gear wheel. If necessary, file the blank till it fits in.

Apply Prussian blue on the dovetail groove to check the high spots in the blank piece.

Remove the high spots and make a snug fit in the dovetail groove.

Drill 5.9mm dia. -2 holes up to a depth of 33 mm on the blank and gear wheel in assembled condition.

Ream the holes using a hand reamer.

Dismantle the assembly and remove the chips from the holes of the gear and the blank.

Assemble again and fit the dowel pins in the holes by a slight tapping.

File the profile of the gear tooth to the correct shape.

Use a template to check the profile.

File on the sides of the blank, flush with the gear.

Repair broken gear tooth (Welding method)

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

- **repair broken gear tooth using the welding method.**

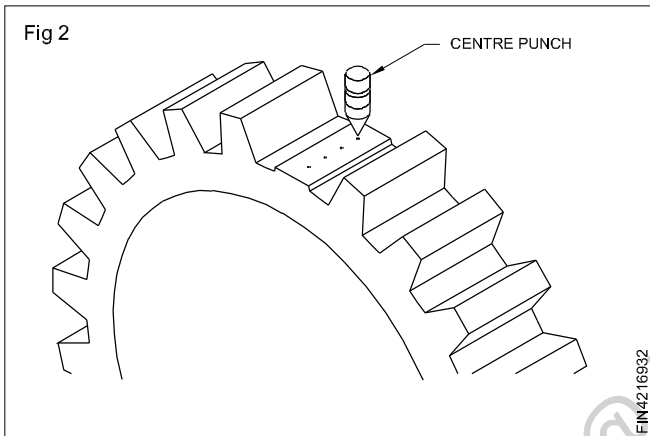
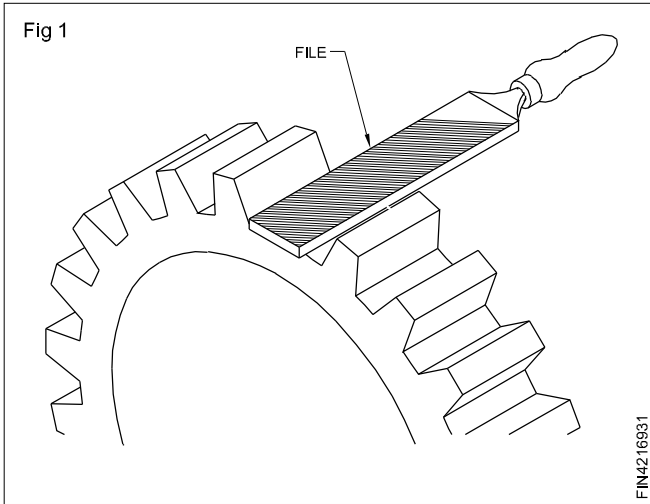
File the broken tooth surface flat. (Fig 1)

Mark for four holes on the surface with 10 mm centre distance between the holes.

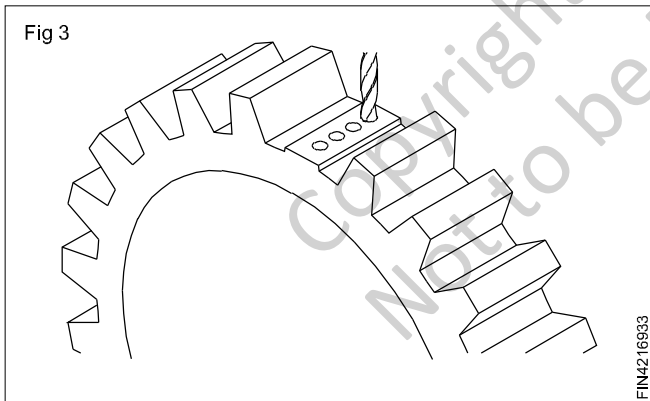
Punch the centres for drill holes. (Fig 2)

Drill 5mm dia. holes on the centres to a depth of 9 mm. (Fig 3)

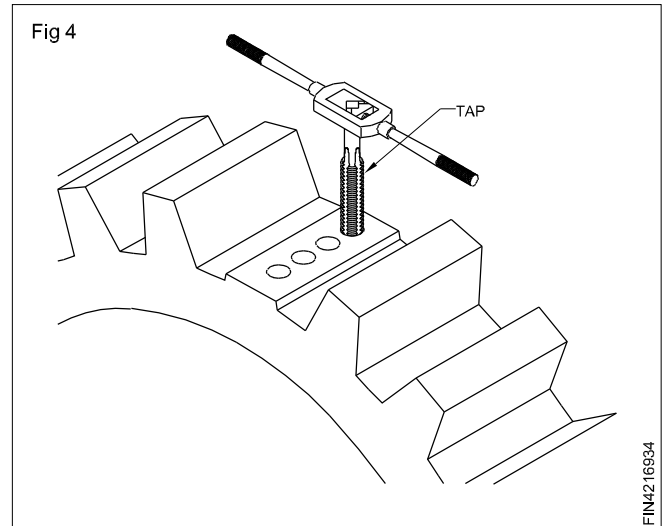
Remove the chips from the holes.



Drill the holes of ϕ 5 mm for M6 tap(Fig 3)

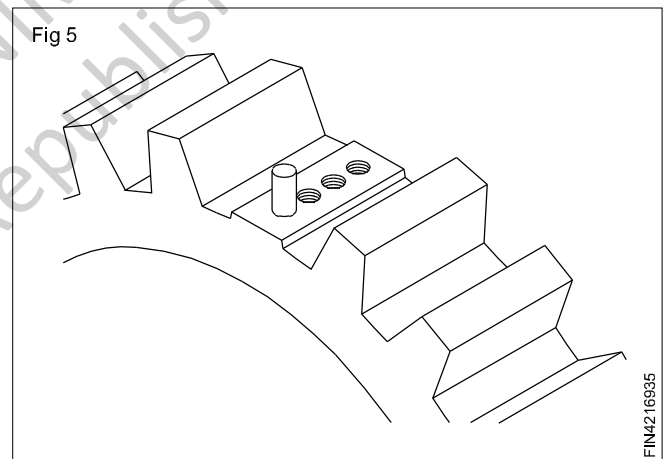


Tap the holes using a M6 hand tap. (Fig 4)

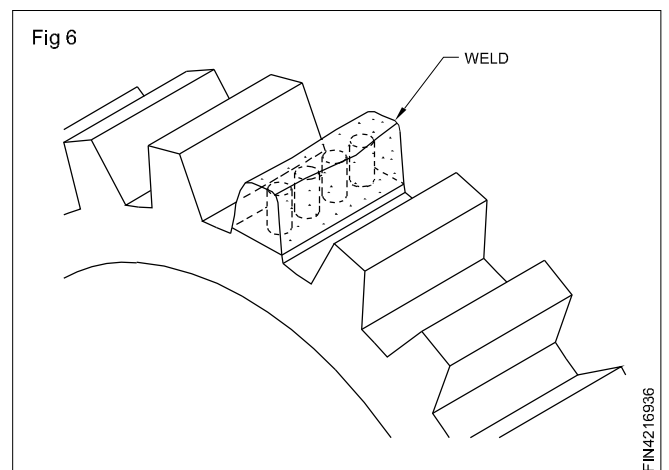


Remove the chips and clean the tapped holes.

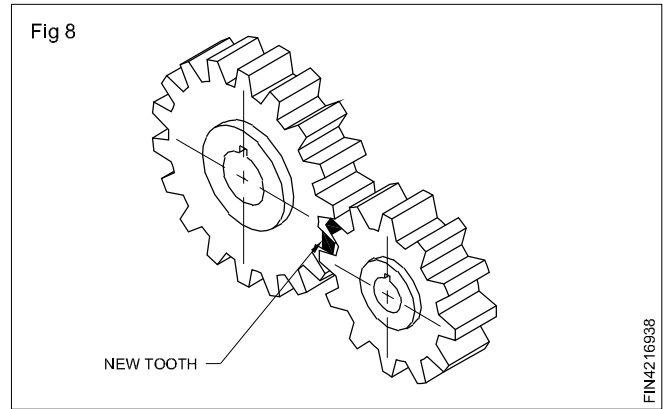
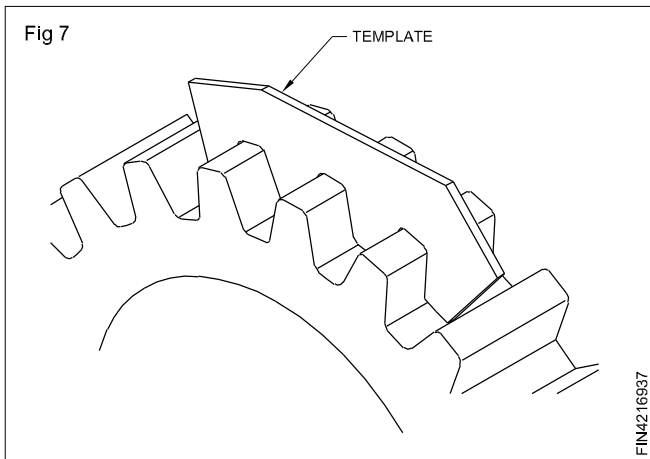
Fix up four hexagonal headed M6 bolts into the tapped holes and tighten them securely. (Fig 5)



Cut off the hexagonal head of the bolts by hacksawing. Build up material by welding enough to make the tooth profile by filing. (Fig 6)



File the built up material to tooth profile. Use a template frequently to check the profile to have correct shape and pitch. (Figs 7 & 8)



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Importance of technical English terms used in industries

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

- **state importance of english for employability skills**
- **state importance of english for soft skills.**

English as a language is important for professional courses It enhances:

- **Employability skills:** Trainees who possess the ability to understand, read, write and speak the language get better opportunity to get a job and retain in to scale heights in their career not only in the corporate, but also in the public sector.
- **Soft skills:** Apart from the hard skills that is the ability to acquire technical skills it has become very much necessary to master the art of soft skills equally in the under graduation level to develop the art of articulation in the world of competitive environment when the world has become very small with the access of

internet and electronic media at our doorsteps. Being articulate it would be easier to build interpersonal relationship for smooth flow of communication to ensure productivity. The openness of the environment would ensure the confidence in decision making capability. Openness of the ambience would lead to smart work which steer one to be multitasking.

- English as a language gained popularity not until 14 th century. Today it is a language of survival and sustenance
- Dominance of the British in every part of the world during the 19th and early 20th century by setting up colonies due to industrial revolution made the language richer and richest.

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Different types of documentation as per industrial needs

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

- state the purpose of documentation
- list the different types of documentation
- explain the documents format - batch processing, BOM, cycle time, productivity report, manufacturing inspection report.

Documentation

Documentation and records are used throughout the manufacturing process as well as supporting processes (quality control) must meet the basic requirements. Documentation is a set of documents provided on paper, or online, or on digital or analog media, such as audio tape or CDs. Examples are user guides, white papers, online help, quick reference guides.

The stages of recording the documents is to

- prepare, review, update and approve documents.
- identify changes and current revision status of documents.
- use of applicable documents available at points of use with the control documents of external origin
- identify and distribute relevant versions to be identifiable and remain legible.
- prevent unintended use of obsolete documents and archiving.

The different types of documentation as per industrial needs includes

- Processing charts
- Bill of materials (BOM)
- Production cycle time format
- Productivity reports

- Manufacturing stage inspection report
- Job cards format
- Work activity log
- Batch production record format
- Estimation of work
- Maintenance log format

Process chart

A process chart is a graphical representation of the activities performed during manufacturing or servicing jobs. Graphical representation of the sequence of operations (workflow) constituting a process, from raw materials to finished product.

Process charts are used for examining the process in detail to identify areas of possible improvements.

The different types of process charts are

- Operation process chart
- Flow process chart (man/ material/ equipment type)
- Operator chart (also called two handed process chart)
- Multiple activity chart
- Simo chart

The following symbol set derived from Gilbreth's original work as the standard for process charts.

Symbol	Letter	Description	Examples
O	O	Operation	Saw cut, paint, solder, package
→	M	Transport	Conveyor / Fork lift / OTR truck
□	I	Inspection	Visual/dimension
D	D	Delay	WIP/Hold/ Queue
∇	S	Storage	Warehouse/tracked storage location

The application of symbols on a flow process chart is shown in the figure

Summary					
Flow process chart(Machines)		Present		Proposed	
		*	Time	*	Time
Industry : _____					
Product : _____					
		Operation			
		Inspection			
		Transport			
		Delays			
		Storage			

Details	O→□ D▽	Qty	Time (in mins)	Analysis	Actions recommended
Raw material from stores	O→□ D▽				
To cutting machine	O→□ D▽				
Cutting of material to size	O→□ D▽				
Filling, Finishing	O→□ D▽				
To inspection for finished size	O→□ D▽				
To stores (Finished job)	O→□ D▽				

Batch record forms

The documents used and prepared by the manufacturing department provide step-by-step instructions for production-related tasks and activities, besides including areas on the batch record itself for documenting such tasks.

Batch production record is prepared for each batch should include information on the production and control of each batch. The batch production record should confirm that it is correct with standard operating procedure.

These records should be numbered with a unique batch or identification number and dated and signed when issued.

The batch number should be immediately recorded in data processing system. The record should include date of allocation, product identity and size of batch.

Documentation of completion of each significant step in the batch production records (batch production and control records) should include :

- Dates and, then appropriate time
- Major equipment used machinery and specific batch numbers of raw materials, reprocessed materials used during manufacturing.

- Critical process parameters records.
- Trial product or sample (if required).
- Signatures of staff for sequence of operation.
- Laboratory test results and line inspection notes.
- Achieved production against target.
- Packaging and label (if any) details.

Batch processing record : (Sample format - 1)

The format 1 used in documentation of batch processing record has the description of the job, necessarily mentioned with part number and name of the part.

A predetermined batch quantity with batch number allotted and identified with batch record number for documentation. The product reference is made with purchase order number.

The product reference is made with purchase order number.

The production process is descriptively written about the sequence of operation to be carried out on the product. The batch processing record is signed with date mentioning name of person responsible and their designation.

The manufacturer organization name, period of

manufacture preferably the year with starting date of manufacture and end date of manufacturer and number of pages of document according to batch quantity processed, and total number of pages of document,

inclusive of inserted pages and manufacturing facilities is provided with.

The remarks if any on the process should be also mentioned then and there.

BATCH PROCESSING RECORD - FORMAT - 1

Batch Processing Record		
Description of job	Batch no. :	
Part no. :	Batch quantity :	
Name of part :	Batch record no. :	
	Purchase order no. :	
Description of process :		
<div style="position: absolute; top: 50%; left: 50%; transform: translate(-50%, -50%); opacity: 0.3; font-size: 2em; pointer-events: none;"> Copyright @ NIMI Not to be Republished </div>		
Manufacturing Organisation :		
Period of manufacture (Year - Qtr):	Start date of manufacture:	End date of manufacture:
Number of pages according to batch:	Inserted pages:	Manufacturing facilities:
Total number of pages		
1. Operator / Technician	Date	Name and signature
2. Production in-charge:	Date	Name and signature
3. Section manager	Date	Name and signature
4. Plant in-charge:	Date	Name and signature
5. Production in-charge:	Date	Name and signature
Remarks (if any)		

Bill of materials (BOM) format - 2

The list of parts involved in manufacturing of an assembly hierarchially is given in this format.

The format shown is as per bureau of Indian Standards IS:11666-1985 as example for Engineering Component drawings.

The BOM in the form of tabular columns has the component marked with item number, and its name is

given under description and number of is mentioned under quantity, with reference drawing ie., sub assembly/ part drawing number.

The material designation as per code of practice or standards is mentioned, and any other specific notes are given under remarks column.

The BOM is placed on the manufacturing drawing containing with assembly and parts in standard sheet sizes of engineering drawing.

BILL OF MATERIAL (BOM) - FORMAT - 2 as per IS: 11666-1985

S.No	Item No.	Description	Quantity	Reference dwg no.	Material as per standard	Remark

Cycle time

Cycle time is the total time from the beginning to the end of the process. Cycle time includes process time, during which a raw material worked with to bring it closer required form output, and delay time, during which the to workpiece waiting for next operation.

The time taken to perform one operation repeatedly measured from "Start to Start" the starting point of one product's processing in a specified machine or operation

until the start of another similar product's processing in the same machine or process. Cycle time is commonly categorized into same machine/process.

Machine cycle time

The processing time of the machine working on a part.

Auto cycle time

The time a machine runs un-aided (automatically) without manual intervention.

Overall cycle time

The complete time it takes to produce a single unit. This term is generally used when speaking of a single machine or process.

Total cycle time

This includes all machines, processes, and classes of cycle time through which a product must pass to become a finished product. This is not lead time, but it does help in determining it.

Production cycle time (Format - 3)

This format 3 should contain mentioning the organization name department / section name. The process which is being observed for analysing the cycle time is mentioned with line in charge name and the date/time of the operations, with operator name is indicated.

The time observation on each operation, sequence noted in the column, and lowest repeatable is also mentioned for each operation. The times observation for machine cycle time is also noted, with any notes be recorded in respective operations in sequence.

PRODUCTION CYCLE TIME - FORMAT - 3

Organisation Name: Department / Section :		Process:		Line Incharge:		Date/Time:	
Operator :						Machine Cycle Time	Notes
Operator Sequence	Observed Times			Lowest Repeatable			

Productivity report

Productivity report to measure and review the efficiency of a person, machine, factory, system, etc., in converting inputs into useful outputs. Productivity report is computed by dividing average output per period by the total costs incurred or resources (capital, energy, material, personnel) consumed in that period.

The base document daily production report which reveals the actual output against the target plan and on investment cost incurred as mentioned above decides the cost efficiency.

Daily production report (Format 4)

The output of production is shown in the format, referring the job order no quantity, material and size, every process involved, to produce a component, quality control, packing should contain the details of planned quantity and produced quantity is recorded in the document. This is the base details for arriving the productivity report. The incurred cost is worked out considering infrastructure, raw materials and facilities.

DAILY PRODUCTION REPORT - FORMAT- 4

		Daily Production Report								Organisation Name:			
Date:		Department:				Section:							
		Process - I		Process-II		Process-III		Process-IV		Quality Control		Packing	
		Planned	Completed	Planned	Completed	Planned	Completed	Planned	Completed	Planned	Completed	Planned	Completed
Job Order No.													
Quantity													
Material & Size													
Job Order No.													
Quantity													
Material & Size													
Job Order No.													
Quantity													
Material & Size													
Job Order No.													
Quantity													
Material & Size													

Signature of section Incharge

Manufacturing stage inspection report (Format 5)

The format 5 is to monitor the production in various stages for which manufacturing stage inspection conducted for documentation to review the productivity. The format gives the details of product being inspected showing the details of customer reference by purchase

order (PO) number and date, job order number and date, process involved in manufacture of product, the quality submitted for inspection. The accepted and rejected quality recorded with inspection record review date and the inspection person signature who conducted the stage inspection is recorded date wise for mentioned /specified period with start and end dates.

MANUFACTURING STAGE INSPECTION REPORT - FORMAT - 5

Status: From Date To Date/.....	Inspection conducted by								
	Inspection Record No.								
Organisation Name :	Rejected								
	Accepted								
	Qty								
	Process								
	J.O Date								
	Job Order No.								
	P.O No. & Date								
	Customer								
	Product ID/ Code								
	Date								

Documentations - 2

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

- state the purpose of job card and its format details
- explain work activity log format details
- state the details of batch production format.

Job card

A job card is a document showing the details of a job to be performed in a production shop. It is used to authorize and instruct the work team to take up the production work.

Job card format - 1

Job card has the details of commencing the job, customer name, work order no, document number, reference number and date.

The details which have to be recorded about the product line description showing the operations each into recording of start time and total time of operation. The location time recorded is to track if any delay/ reasons and necessary actions if taken with remarks.

If the product has to be completed with any of the further operations in sequence, this card will travel along with job for next workstations for further operations if any to complete the requirement of job, and recorded till finishing of the job.

JOB CARD - FORMAT-1

Job Card	Doc No.							
	Rev No.							
	Date							
Order Starting Date								
Customer								
Work Order No.								
Details								
S.No.	Date	Production Line Description	Time (Minutes)			Location Time	Remarks	
			Start Time	End Time	Total Time			

Work activity log format - 2

This document is to record the activity/operations performed by the operator from time to time (format) shows time duration as one hour (For whole day shift). The

operator has to record every hour, activity description, equipment/machinery/instrument used to perform the job.

Any remarks may noted by the operator to complete this record.

WORK ACTIVITY LOG - FORMAT-2

Organisation Name:			
Department:			
Section:			
Employee Name:			
Supervisor Name:			
Date:			
Start / Stop	Operations performed	Equipment / Machinery/ Instruments used	Remarks
8.00 to 9.00 a.m.			
9.00 to 10.00 a.m.			
10.00 to 11.00 a.m.			
11.00 to 12.00 noon			
12.00 to 1.00 p.m.			
1.00 to 2.00 p.m.			
2.00 to 3.00 p.m.			
3.00 to 4.00 p.m.			
4.00 to 5.00 p.m.			
5.00 to 6.00 p.m.			

Batch production record format - 3

This document is for recording the details of production covering the processing steps with documented page number with deviation against each in short description.

This document is to be prepared under heading description of job part number, batch number, name of

the part. The processing steps number serially for each process with sequential operations in logical order with documented page number. The description of deviation are noted against each operations in sequence gives the detail of batch production record for every part.

BATCH PRODUCTION RECORD - FORMAT-3

<u>Batch Production Record in accordance with batch processing record</u> Manufacturing Organisation Name: _____ Description of job: _____ Name of part: _____ Batch No.: _____ The following deviations have appeared (continued)			
No. process step	Name of processing step	Documented page no.	Short description of deviation
1	<u>Raw material preparation:</u> Operation 1: Descaling Operation 2: Degreasing Operation 3: Wire brushing		1. _____ 2. _____ 3. _____ 4. _____
2	<u>Sizing of material:</u> Operation 1: Shearing Operation 2: Deburring		1. _____ 2. _____ 3. _____

Estimation and maintenance records

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

- state the purpose of estimation
- explain the details of formats for estimation sheet
- explain the details of formats for maintenance log, history sheet of machinery and equipment and checklist for preventive maintenance.

Estimation is the method of calculating the various quantities and the expenditure to be incurred on a particular job or process.

In case the funds available are less than the estimated cost the work is done in part or by reducing it or specifications are altered,

The following essential details are required for preparing an estimate.

Drawings like plan, elevation and sections of important parts.

Detailed specifications about workmanship & properties of materials, etc.

Standard schedule of rates of the current year.

Estimating is the process of preparing an approximation of quantities which is a value used as input data and it is derived from the best information available.

An estimate that turns out to be incorrect will be an overestimate if the estimate exceeded the actual result, and an underestimate if the estimate fell short of the actual result.

A cost estimate contains approximate cost of a product process or operation. The cost estimate has a single total value and it is inclusive of identifiable component values.

ESTIMATION SHEET - FORMAT-4

Part Name: Base plate Assembly: Shearing machine Assembly No.: MA2WAOA1		Part No.: 1 Material: Fe310.0 Stock size: 305 x 227 x 20		Insert Part Drawing	
Operation No.	Operation description	Machine	Estimated time	Rate / piece per hr.	Tools
01	Setting and aligning job on table	Milling	10 min		
02	Mount arbor and cutter	Milling	10 min		
03	Set speed and feed	Milling	2 min		
04	Align cutter in position	Milling	2 min		
05	Mill four sides	Milling	50 min		
06	Mark 45° angle corner	-	8 min		vernier bevel protractor vernier height gauge
07	Set and clamp the job	-	10 min		
08	Mill 45° on opposite sides	-	10 min		
09	Set clamp on other sides	-	20 min		
10	Mill 45° on other sides	-	20 min		
11	Deburr and mark drill position	-	10 min		
12	Set and align for drilling	Drilling	10 min		
13	Mount drill chuck and drill	Drilling	03 min		
14	Set drill rpm	Drilling	02 min		
15	Drill pilot and holes	Drilling	30 min		
16	Counter bore holes	Drilling	15 min		
17	Place job on magnetic chuck on surface grinder	Surface grinder	03 min		
18	Grind the surface as per drawing	Surface grinder	10 min		
19	Deburr sharp edges	-	02 min		Abrasive stick

Maintenance log - Format 5

This format is made with details of maintenance activities performed machinewise,

MAINTENANCE LOG - FORMAT - 5

Organisation Name :				
Department:				
Section:				
Name of the machine:				
S.No	Date	Nature of fault	Details of rectification done	Signature of in-charge

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History sheet of machinery equipment - Format 6

The document recorded with historical data about the machinery and equipment, contains all details about supplier address, order no., date of receipt, installed and placed, Date of commissioning and machine

dimensions, weight, cost, particulars of drive motor, spare parts details, belt specification, lubrication details, major repair/ overhauls done with dates recorded then and there for analysing the functional and frequency of breakdown etc.,

MACHINERY AND EQUIPMENT RECORD FORMAT - 6

Organisation Name :	
Department:	
Section:	
History sheet of machinery & Equipement	
Description of equipment	
Manufacturer's address	
Supplier's address	
Order No. and date	
Date on which received	
Date on which installed and place	
Size : Length x Width x Height	
Weight	
Cost	
Motor particular	Watts/ H.P./ r.p.m: phase: Volts:
Bearings/ spares/ record	
Belt specification	
Lubrication details	
Major repairs and overhauls carried out with dates	

Checklist for preventive maintenance inspection - Format 7

The very essential document required to observe, the functional aspects of each parts, defects and the remedial measures taken is recorded.

This format enables to program the frequency of maintenance schedules so as to minimise frequent breakdown of machinery/equipments.

PREVENTIVE MAINTENANCE RECORD - FORMAT 7

Organisation Name :				
Department :				
Section :				
Name of the Machine :				
Machine Number :				
Model No & Make :				
Check list for machine inspection				
Inspect the following items and tick in the appropriate column and list the remedial measures for the defective items.				
Items to be checked	Good working	Satisfactory	Defective	Remedial measures
Level of the machine				
Belt/chain and its tension				
Bearing condition (Look, feel, Listen noise)				
Driving clutch and brake				
Exposed gears				
Working in all the speeds				
Working in all feeds				
Lubrication and its system				
Carriage & its travel				
Cross-slide & its movement				
Compound slide & its travel				
Tailstock's parallel movement				
Electrical controls				
Safety guards				
Inspected by :				
Signature :				
Name :				
Date :				
				Signature of in-charge

Application of Pneumatics

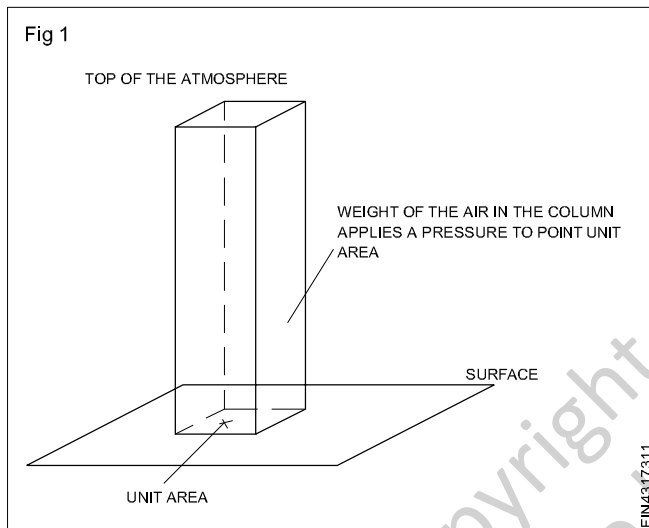
Objectives : At the end of this lesson you shall be able to

- define pneumatics
- state the application of Pneumatics
- list the advantages and limitation of pneumatics

Overview of Pneumatic

original word PNEUMA is taken from Greek language which means breathing.

Pneumatic system gets compressed air as an energy input then converts it into a suitable work and after that exhaust back to the atmosphere. This process of intake and exhaust is compared with breathing.



Definition: It is the science under which you study properties and application of air.

Common terms used in pneumatics

Pressure

Pressure is defined as the load acting upon unit area. (Fig 1)

$$\text{Pressure} = \text{Force}/\text{Area}$$

In pneumatic system three terms related to pressure are commonly used.

Atmospheric Pressure

It is pressure caused by weight of column of atmospheric air acting on the surface

Gauge Pressure

It is pressure value read through an instrument called Pressure Gauge. It indicates pressure value above the atmospheric pressure.

Absolute Pressure

It is the pressure value measured with respect to perfect vacuum.

Absolute pressure = Atmospheric pressure+gauge pressure

$$\text{Abs Pr} = \text{Atm Pr} + \text{Gg Pr}$$

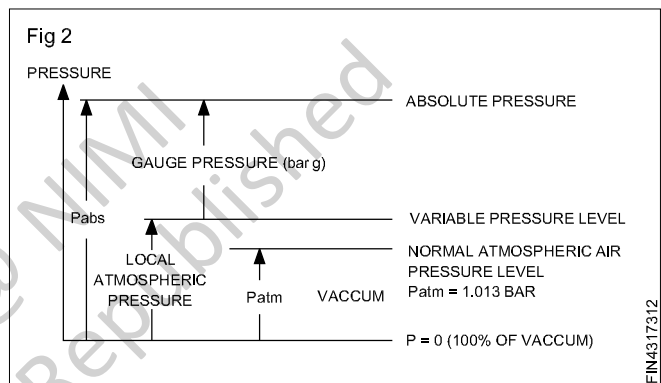


Fig 2 shows the relation between Absolute pressure, Gauge pressure and Atmospheric pressure.

Units of Pressure: Pressure is measured in Pascal (Pa) in SI unit. 1 pascal = 1 newton per meter square. one pascal is the pressure exerted by a force of magnitude one newton perpendicularly upon an area of one square metre...

Example: Pressure = Bar = 1 Kg/Cm² (aprox.)

Bar is a metric unit of pressure equal to 100,000 pa (pascal) standard atmospheric pressure at sea level is 1013.25 milli bar or 101.35 kilo pascal

$$1 \text{ Bar} = 1 \text{ Kg} / \text{Cm}^2$$

Force

Force is the product of pressure and cross section area upon which force is acting.

$$\text{Force} = \text{Pressure} \times \text{Area} \quad (F = P \times A)$$

Unit of Force: Force is measured in Newton in SI unit

$$1 \text{ newton} = 1 \text{ kg m} / \text{s}^2$$

Flow rate

Flow rate is the volume of air flowing per unit time.

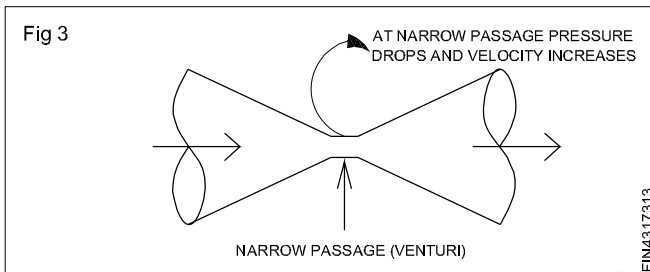
Units of Flow Rate: Flow rate is measured in lpm (Litre/Minute) or M³/ Hour.

Example: Flow Rate = 10 Litre/ Minute

Or Flow Rate = 50 M³/ Hour

Properties of Air

- Atmospheric air possesses certain properties as follows:
- Air is a mixture of gases. (Nitrogen - 78%, Oxygen - 21%, Other gases, Water vapour - 1% by Volume)
- It contains dust particles and water vapour.
- Air is compressible means its volume can be reduced.
- Air does not burn itself.



- Volume of air increases with increase in temperature.
- Moisture or water vapour carrying capacity increases with increase in temperature of air or volume of air.
- Pressure of air increases with reduction of volume.
- Air temperature increases with increase in pressure.
- When air passes through narrow passage pressure drops velocity increases. (Refer Fig 3)

Applications: Pneumatic is widely used in many industrial automation applications where fast movements of lesser loads are required.

Pneumatics is used to move load with less efforts, general applications are:

- Push - Pull
- Lift - Drop
- Clamp - Unclamp
- Tilt

Boyle's Law

Robert Boyle (1627-1691), an English scientist, was among the first to experiment with the pressure volume relationship of gas at constant temperature.

Statement: If a given mass of a gas is compressed or expanded at a constant temperature, then the absolute pressure is inversely proportional to the volume.

Pressure $\propto \frac{1}{\text{Volume}}$, when temperature = constant

$$\text{or } pV = \text{constant}, p_1 v_1 = p_2 V_2$$

Advantages of Pneumatics

Pneumatics is popular in industrial applications as Low Cost Automation because of following advantages:

- Air is available at free of cost.
- Air is available in unlimited quantity every where.
- Air can be compressed, pressurised and can be transported through pipes.
- Air can be exhausted to the environment without any harmful effects.
- Action is fast.
- Speed control is possible.
- System is overload safe.
- Air does not ignite.
- Simple in design and construction.
- Long life and low maintenance
- Components are simple in design and hence cheaper.

Limitations

- Pneumatic system has certain limitations as follows:
- Pneumatic system is economical up to a limit of 3000 kgf force.
- Pneumatics need fine quality equipment to remove dust and moisture. (Air filters & demisture)
- Air exhaust is noisy
- Uniform speed is not possible.
- Special lubrication technique is required to avoid friction between internal components.
- In case of leakage pneumatic system becomes costly.
- Compressing air beyond 7 bar is costlier.

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.

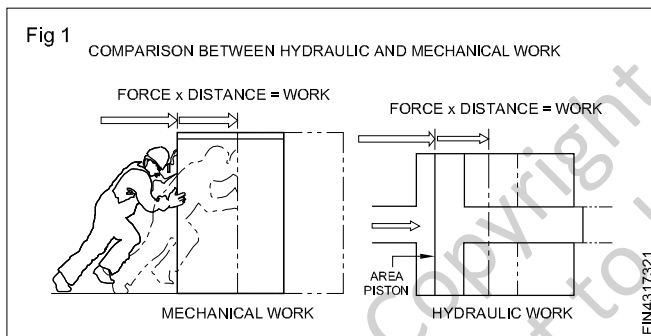
The word hydraulic is derived from Greek words "hydra" meaning water and "aulic" meaning pipe.

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.

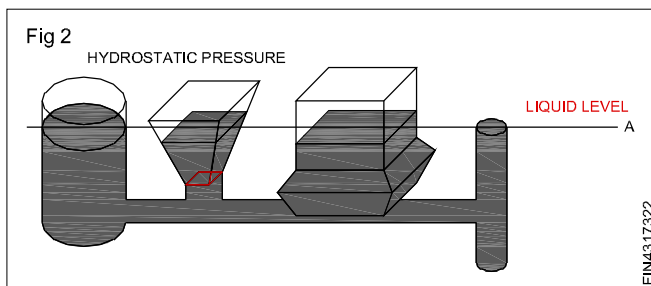
The following paragraphs gives basic physical properties and laws that govern liquids, relevant to hydraulic systems.

"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.



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.



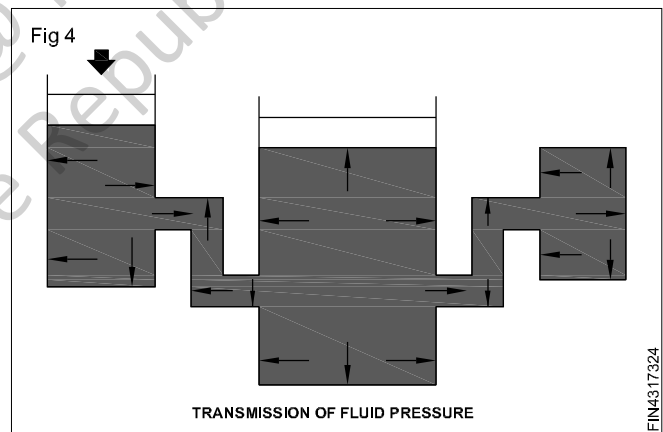
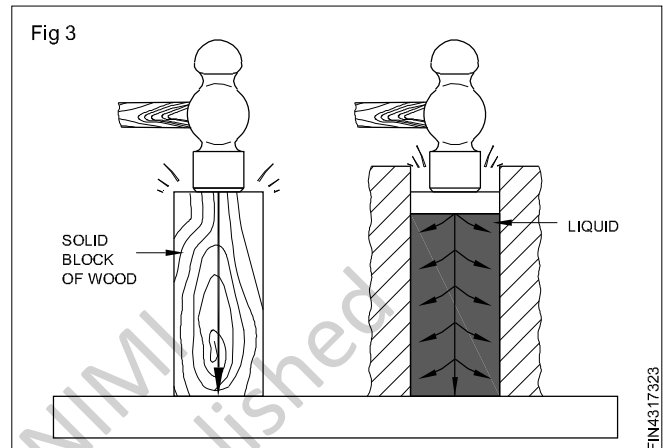
Therefore the higher pressure in any of the container will force the liquid to flow to the next container until the pressure on both the sides are equalised.

Through the line 'A' the pressure in all the open containers

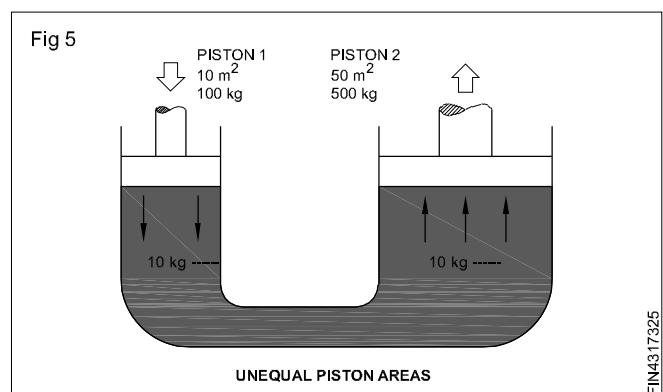
remain the same, since height of liquid columns are same.

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.

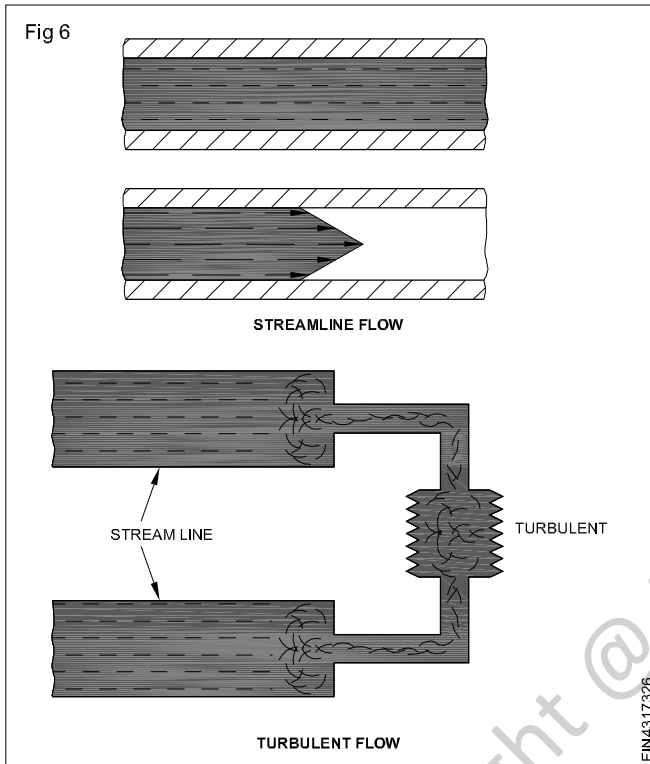


Thus if small amount of pressure is exerted on a smaller piston as shown in Fig 5, the higher force can be attained at the larger piston, since the pressure is equally applied on larger area.



Cavitation

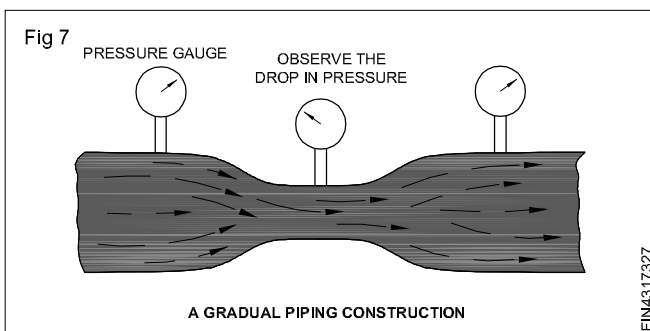
The inter-locked air bubbles and pockets in the hydraulic pipe lines and components is called cavitation. In cavitation the static pressure falls below vapour pressure. The vapour formation condenses resulting in pressure jerks and noise, and heating-up the oil resulting in a turbulent flow. Therefore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



Bernoulli's principle

Kinetic energy is the energy present in oil by virtue of its motion. Potential energy is due to the pressure. The total energy is the sum of these two energies.

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.



Effect of heat

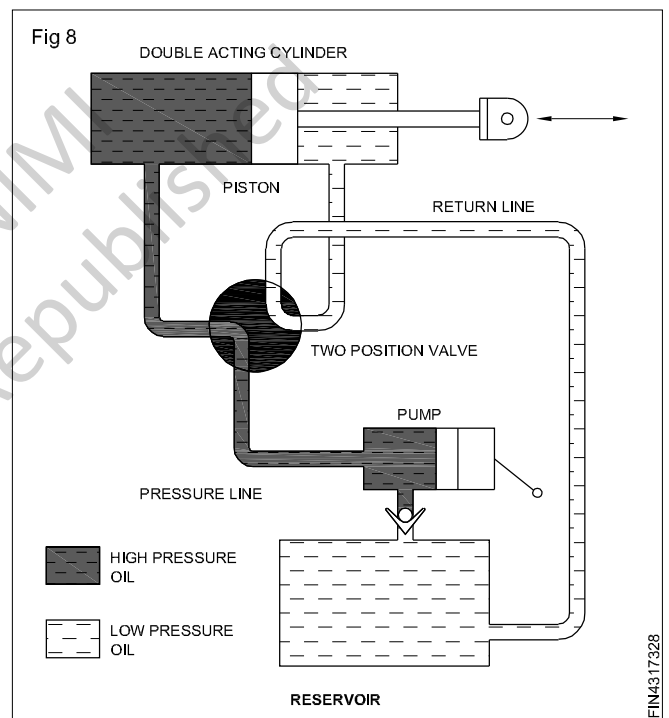
Since the liquids (oil) full in containers cannot expand or be compressed on heat, it exerts pressure on the container thus developing unwanted stresses.

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:

- A reservoir to store the hydraulic fluid
- A pump to provide fluid pressure to the system
- A control valve to direct the flow of fluid
- An actuating unit, such as a cylinder
- A suitable hydraulic fluid
- Piping or tubing to circulate the fluid through the system.

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



- 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

Comparison between Pneumatics and Hydraulics

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

Advantages of Hydraulics

- Liquids are incompressible and capable of moving much higher loads providing much higher force.
- No need to bleed off “ pressurized air to release pressure on the load.
- Highly responsive compared to pneumatics
- Supply more power than pneumatics
- Also provides Lubrication & cooling.

Air compressor parts and function

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

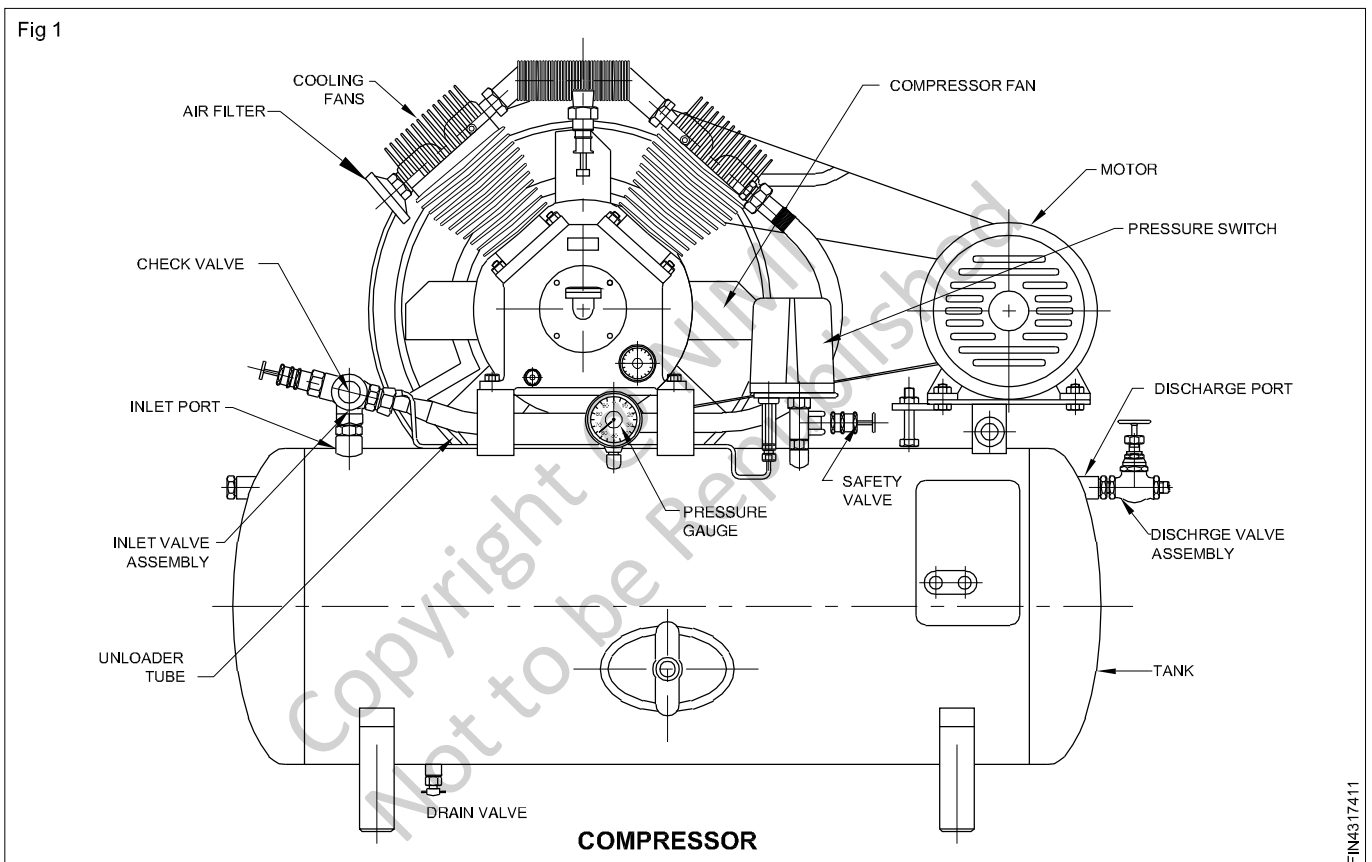
- state construction of compressor
- explain parts of compressor
- describe working principle of compressor.

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)



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 comprises 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 aluminum.

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 to 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 within 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
- 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

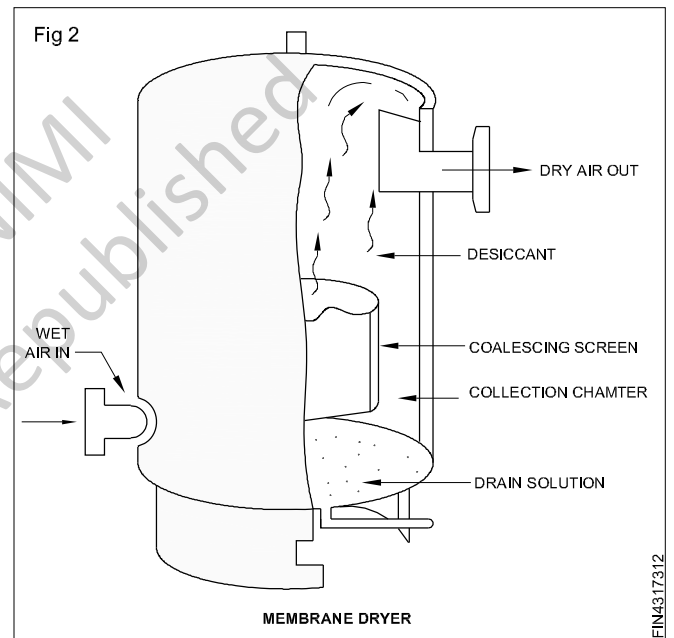
The term “desiccant dryer” refers to a broad class of dryers. Other terms commonly used are regenerative dryer and twin tower dryer, and to a lesser extent absorption dryer.

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)

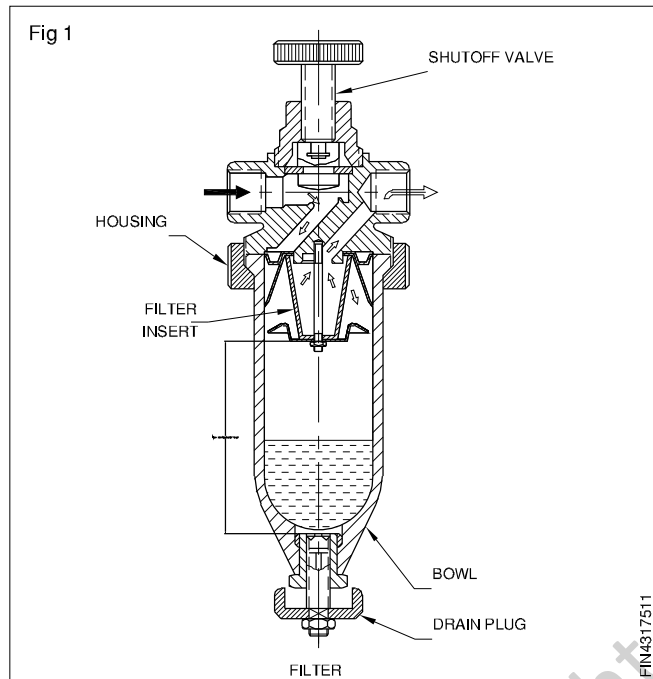
Membrane dryer refers to a dehumidification membrane that removes water vapor from compressed air. Typically, the compressed air is first filtered with a high-quality coalescing filter. This filter removes liquid water, oil and particulate from the the compressed air. The water vapor-laden air then passes 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.



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.

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. Manufacturers offer flow characteristics charts on their products to help choose the correct combination of regulators and lubricators.

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
- Adjustment control
- Connectors or pipe size
- Body material
- Environmental parameters

Applications of pneumatics

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

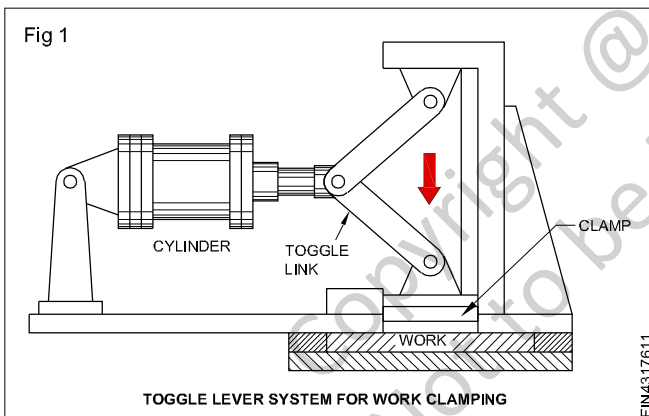
- state the application of pneumatic cylinders
- state various areas of automation
- describe the hazards and safety precautions in pneumatic system

Application

In any control system or automation, pneumatics 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.

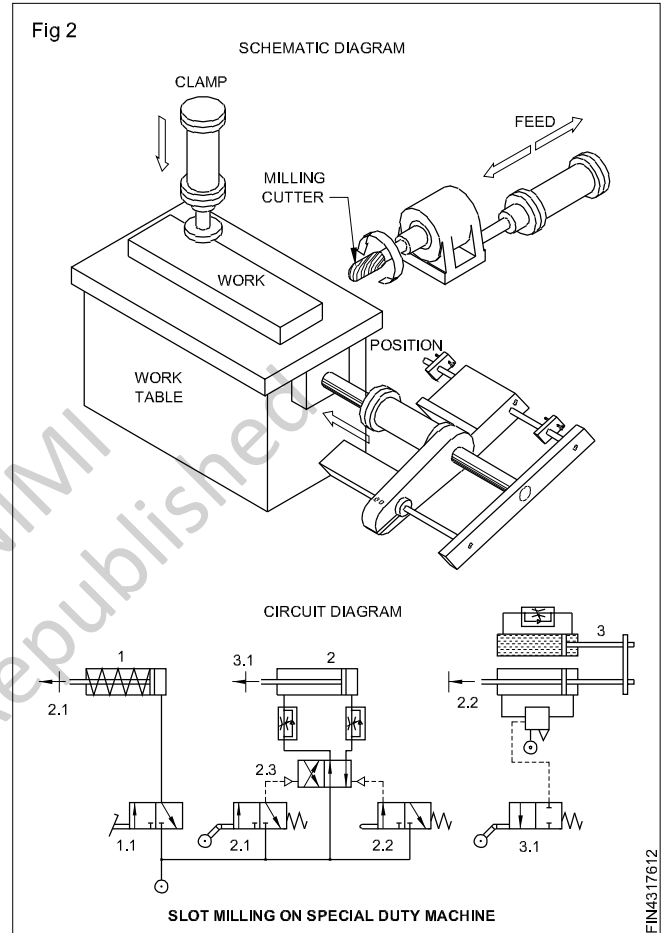
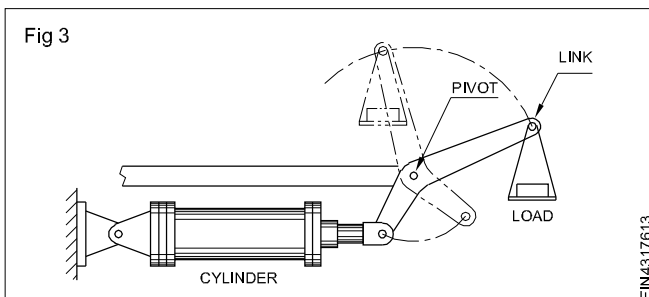
Air cylinders are widely used in pneumatic systems, since the linear motion is the most common requirement of the system. But rotating actuators (motors) find their application in hand tools like portable drilling machine. As a general practice, pneumatics is efficiently used in speed control rather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

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

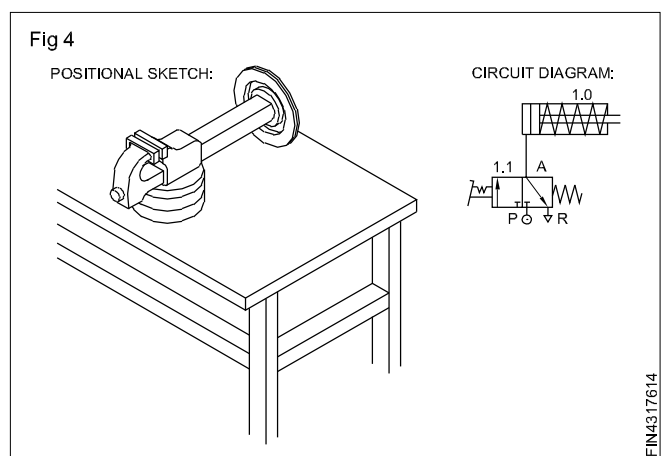


The Fig 2 Shows feed unit. For a slot milling machine. The pedal operates valve 1. 1 clamps the jobs on the table. The piston rod at the end of its travel operated the valve 2. 1 and make the cylinder to move forward, in turn operating the valve 3.1. The valve operates the cylinder 3 to enact the feed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

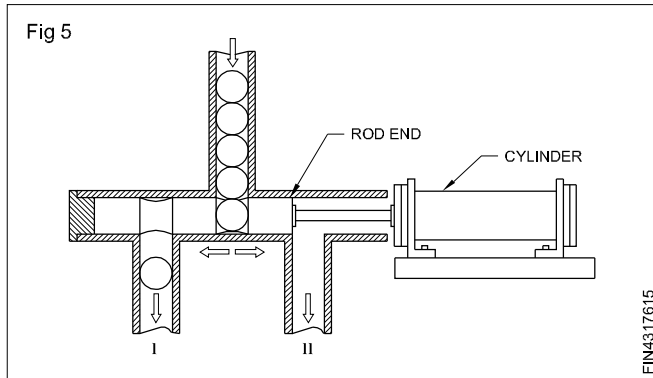
In Fig 3, the movement of the piston rod to the right tilts the pivoted link to the left. By this movement the load is swing to the left hand side.



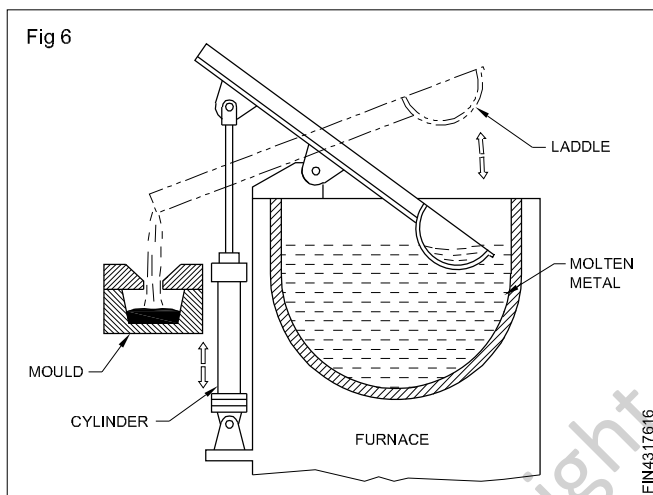
The operation of vice is shown in Fig 4. The 3/2 way valve extends and retreats the single acting cylinder attached to the movable vice.



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



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



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 ignite 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 pneumatic actuators**
- **to calculate cylinder forces**
- **define stroke length**

Pneumatics 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 be achieved by a large size of the cylinders.

1.2. 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, properly size 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.

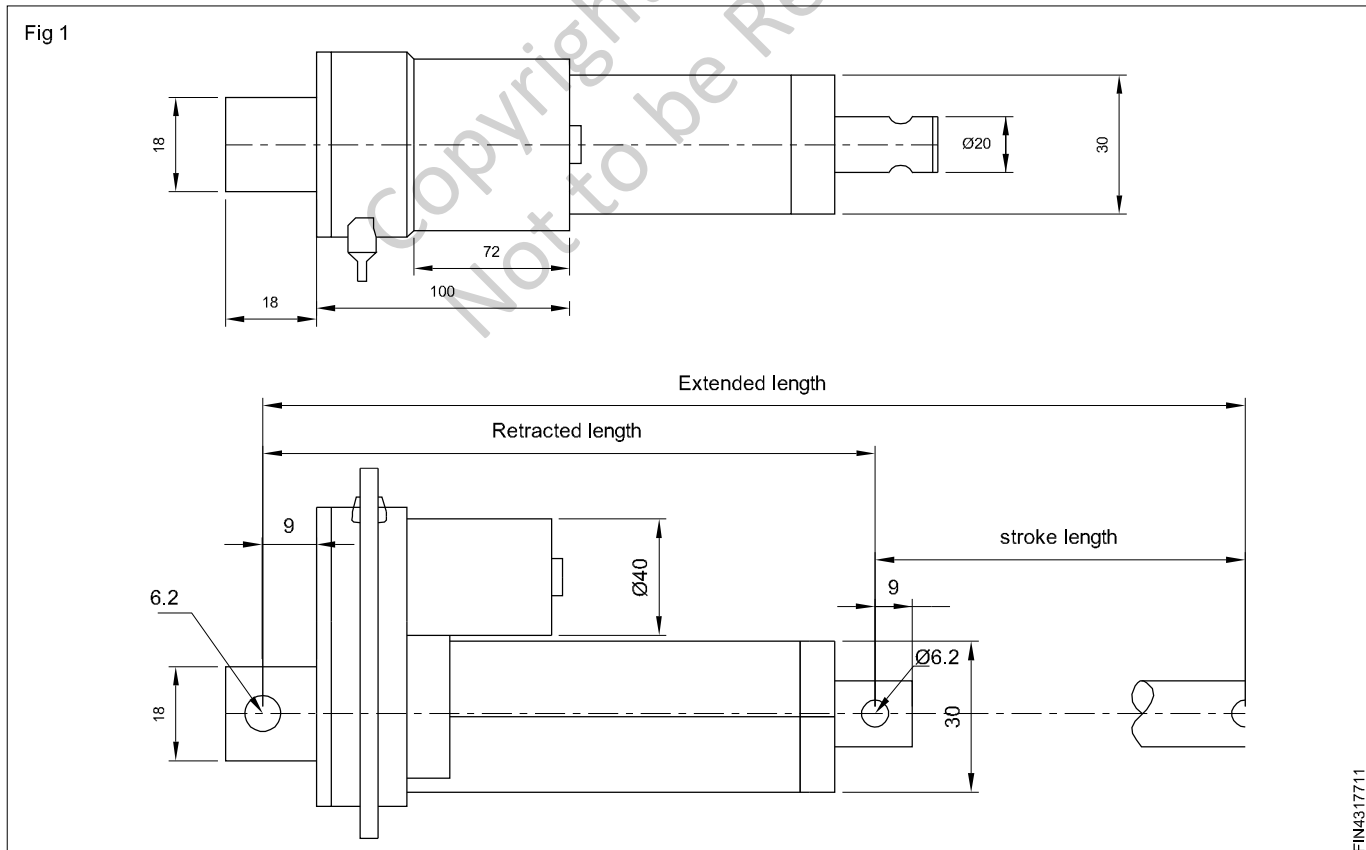
Deduction for pull force

Piston rod size (mm)	Piston rod Area (mm ²)	Reduction in Force (N) at various Pressures in Bar			
		1	5	7	10
4	13	1	6	9	13
6	28	3	14	20	28
8	50	5	25	35	50
10	79	8	39	55	79
12	113	11	57	79	113
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

Push Force

Cylinder Bore size (mm)	Piston 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

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.



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Single acting cylinder and its application

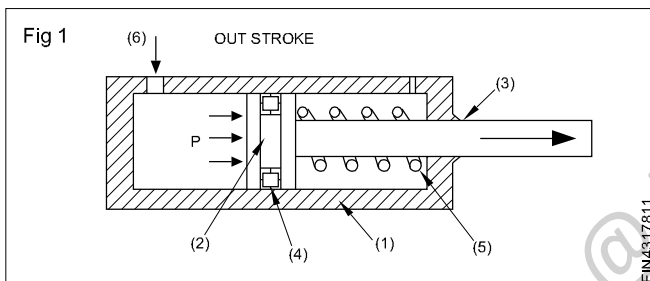
Objectives : At the end of this lesson you shall be able to

- 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.



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

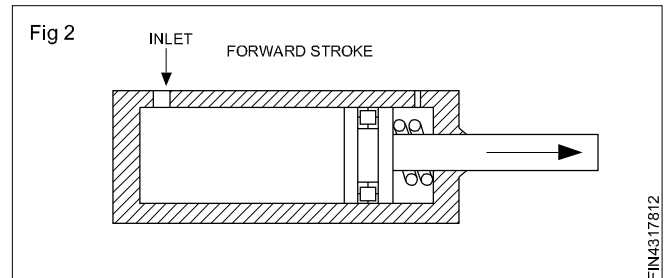
Initially piston remains at the innermost position in the cylinder due to spring force (Fig 1)

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.

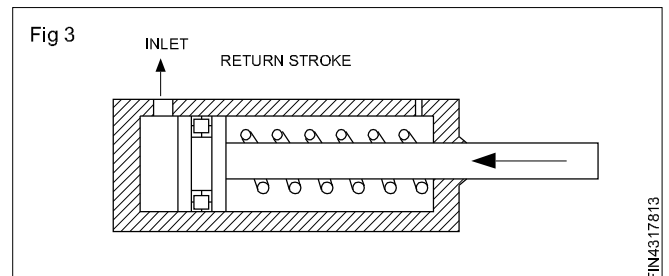


Piston and load move till piston reaches to other end. At the end there is no further space for piston to move, hence piston and load movement stops. (Fig 2)

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

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

It consists of following parts:

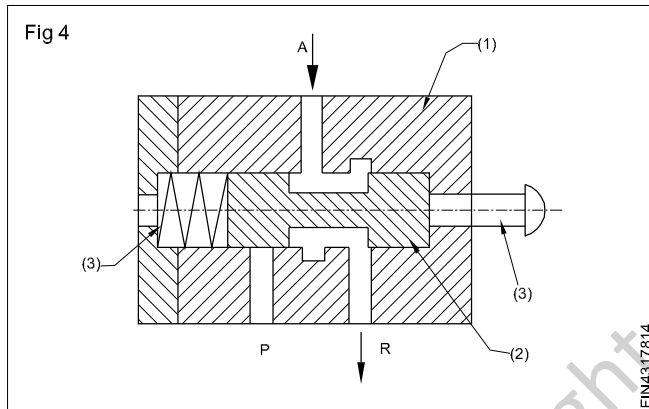
- 1 Valve body
- 2 Spool
- 3 Actuation mechanism: Push button & Spring
- 4 Air flow path
- 5 Ports (P,A,R)

Valve body provides cavity which 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.

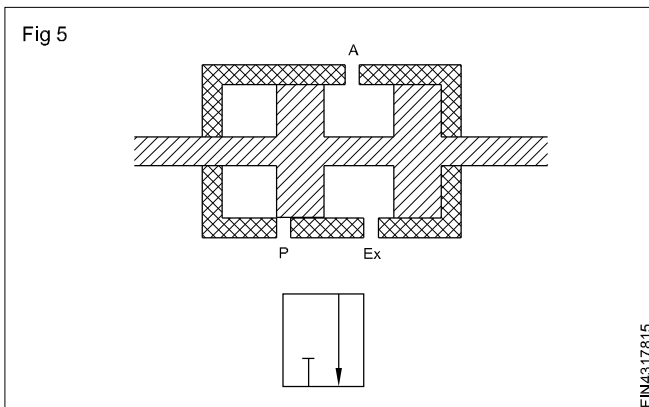
Port is a point where you can connect air pipe with the help of connector.



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)



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)

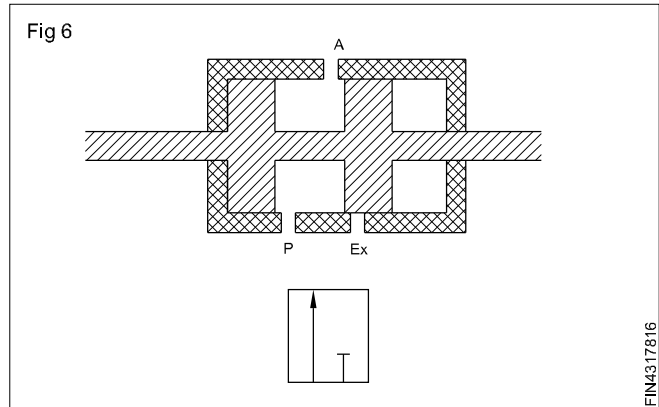
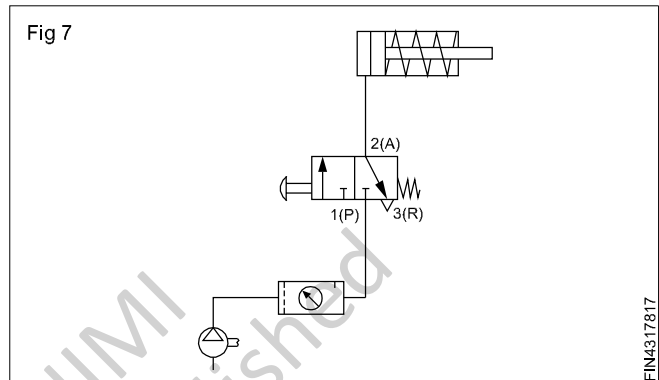
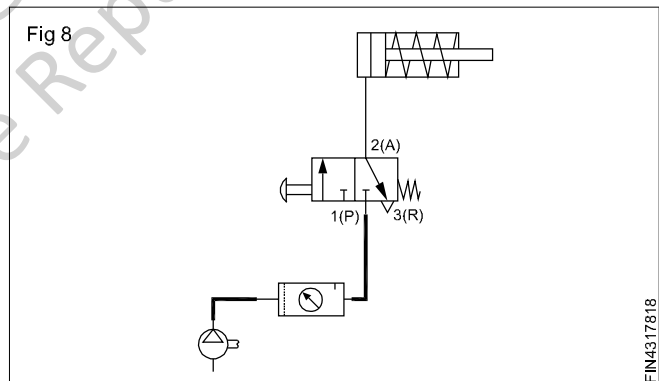


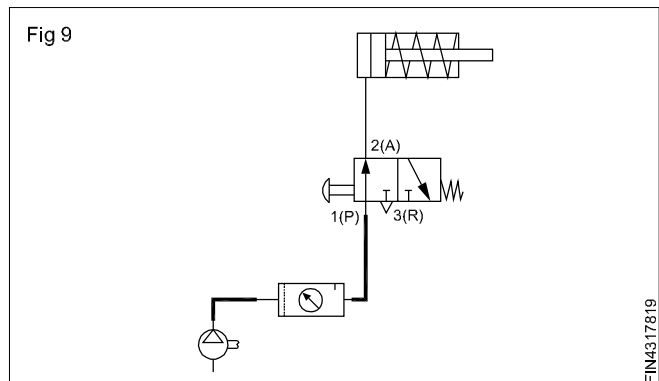
Fig 7 shows the circuit to operate single acting cylinder.



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)



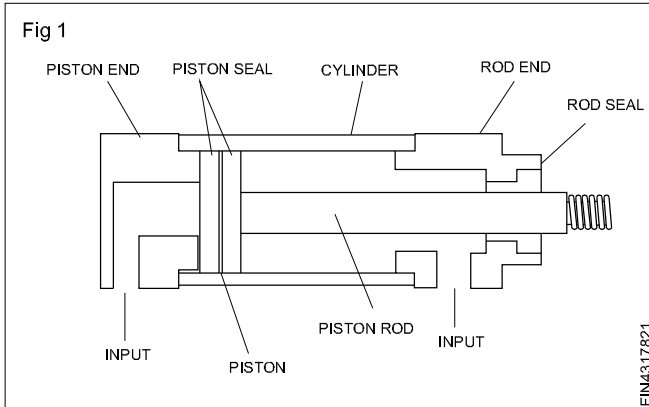
Push button is when released piston returns back. (Fig 8)

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.

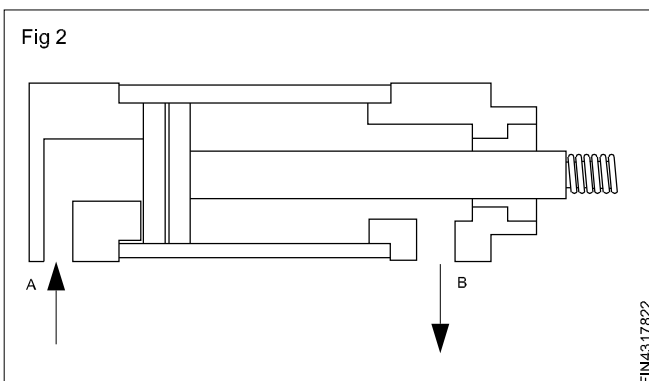
Double acting cylinder is an actuator which can push and pull the load using compressed air. It has two ports for air supply. Fig 1 shows the construction of double acting cylinder.



Input Ports: For air supply

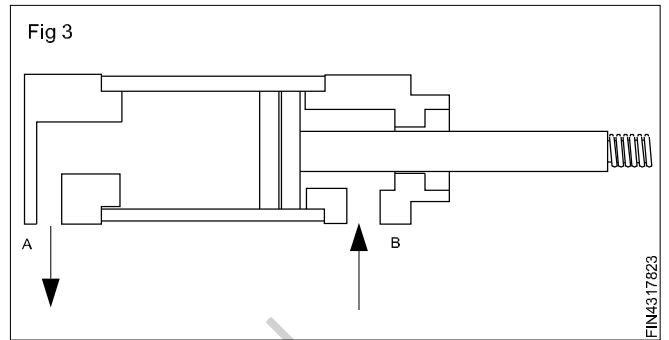
- Piston: Element which moves to and fro inside the cylinder.
- Cylinder: It confines air for the piston movement.
- Piston rod: A rod which connects piston and a load.
- Piston Seal: Seal which prevent leakage across the piston.
- Rod Seal: Seal which prevents air leakage from cylinder to the atmosphere.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

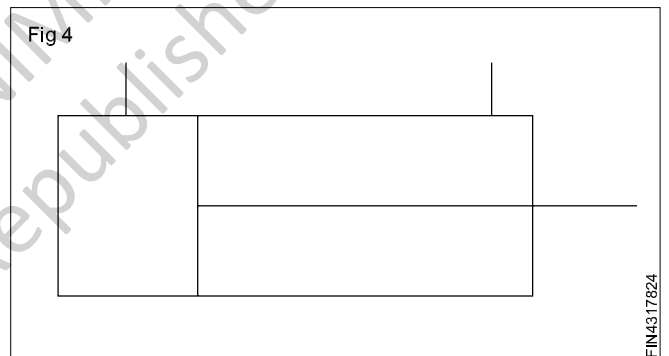


Piston movement will stop if air does not exhaust.

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

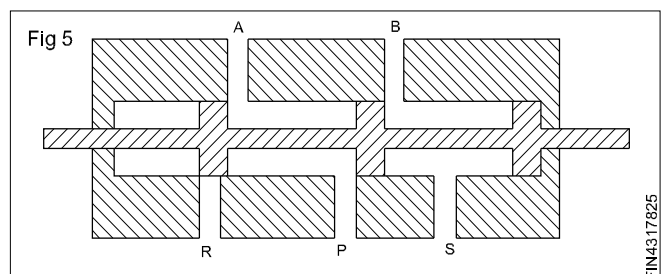


Symbol of double acting cylinder is shown in fig 4



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 which has two output ports. 5 port 2 position valve has two output ports. Construction is shown in fig 5.

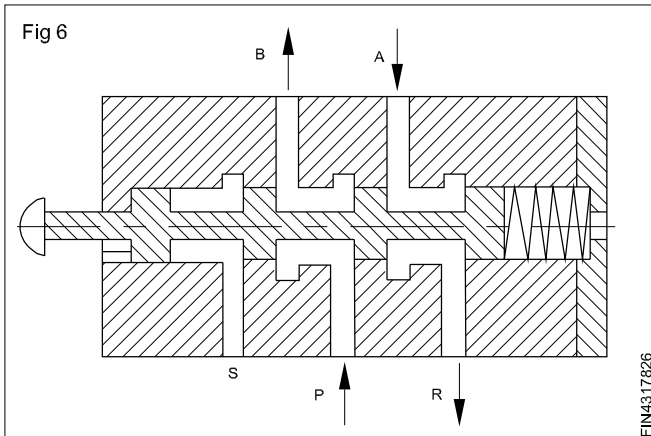


- Valve body: It provide cavity to move spool and ports.
- Spool: It is an element which change flow path when moves inside the valve body.
- Input port: Connection point where air enters into valve. It is denoted by 'P' or number '1'.

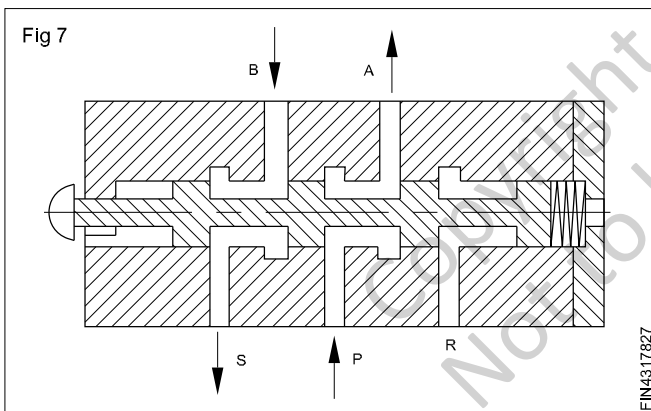
- Output port: Connection points from where air comes out of valve. Output ports are denoted by 'A' & 'B' or number '2' & '4' respectively.
- Exhaust port: Connection points from where air exhausts. Exhaust ports are denoted by 'R' & 'S' or number '3' & '5' respectively.

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

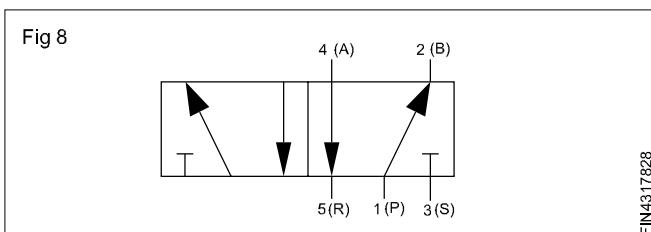
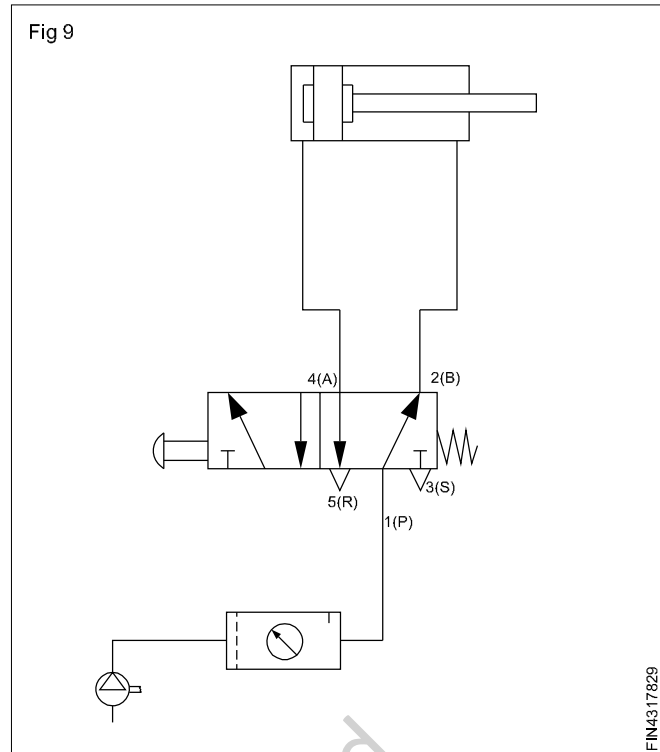
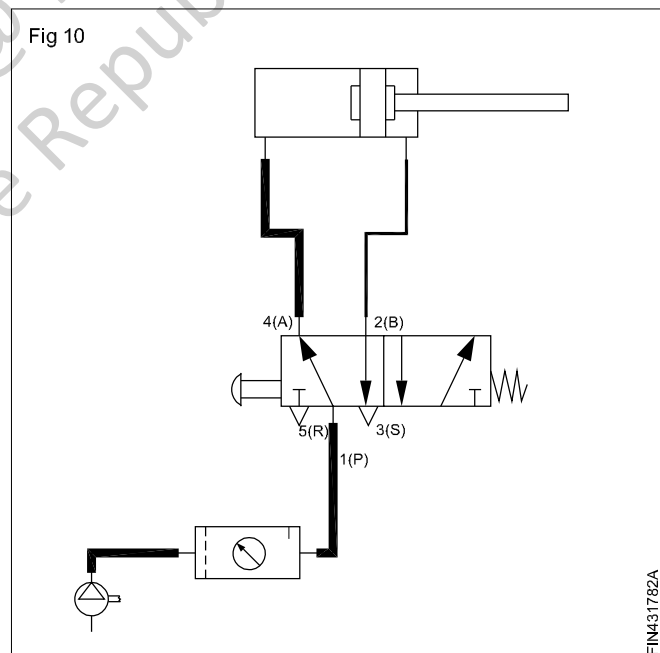


Fig 9 Shows circuit to operate double acting cylinder. initially in normal position (Spring operated position), supply direction is from 1 (p) to 2 (B) and 4 (A) to (R) so that piston is always in retracted position unless actuated. (Fig 9)



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 gauges piston moves forward. (Fig 10)



When push button is deactuated piston retracts. Fig 9

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.

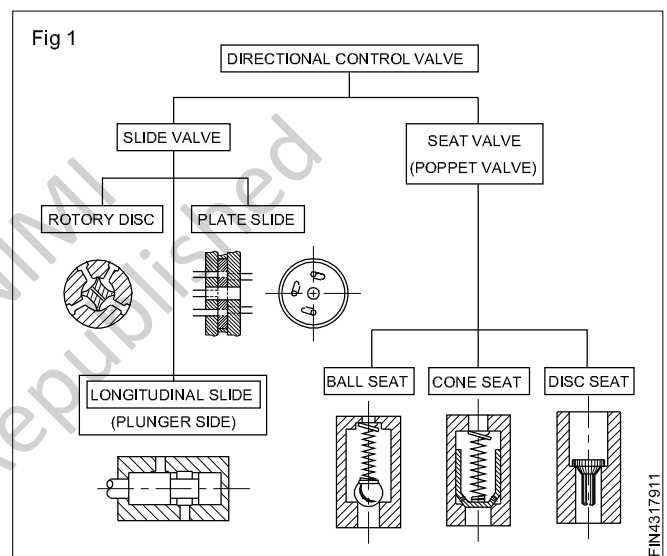
Directional control valves are classified in two major group as shown in Fig 1

Slide valves

Slide valves are called so, because the opening and

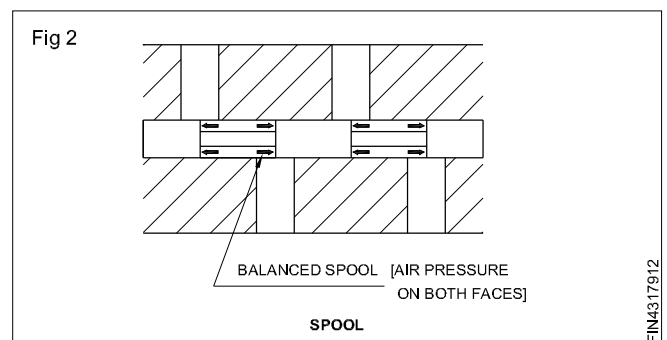
closing takes place by sliding of one of its member. Further in slide valve we have

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



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

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



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

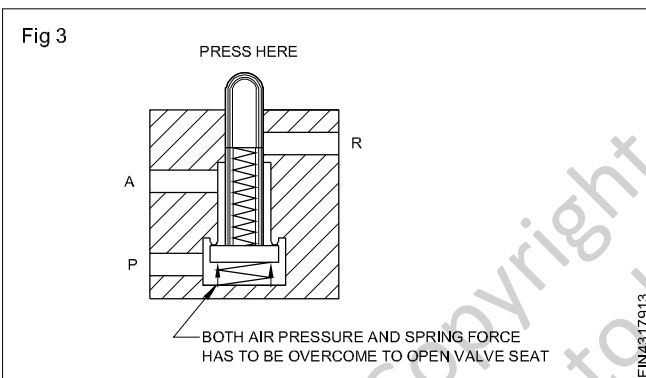
- Ball seat valve
- Cone or taper seat valve
- Disc seat valve.

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)



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)

It also has two positions.

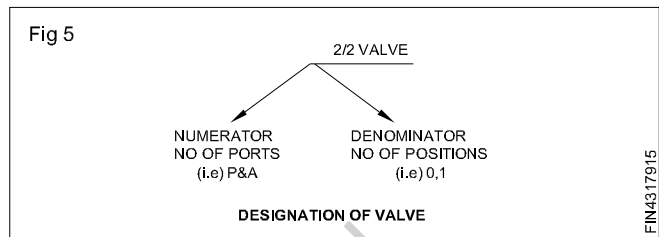
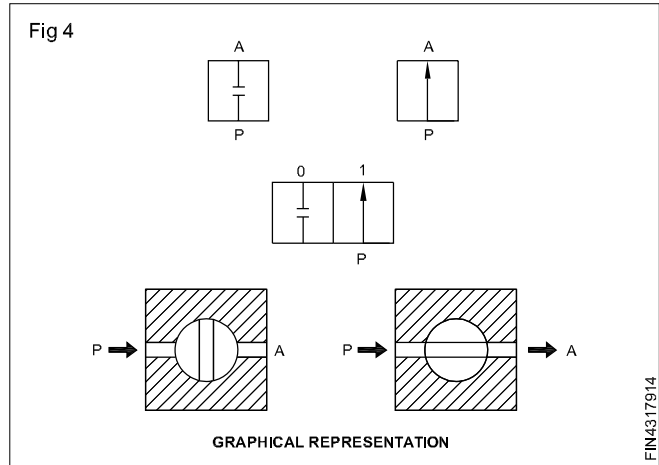
Initial position - No flow. Final position - Full flow. This is graphically represented as one square for each operating position.

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.

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 parts

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

R,S,T = Exhaust parts

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.

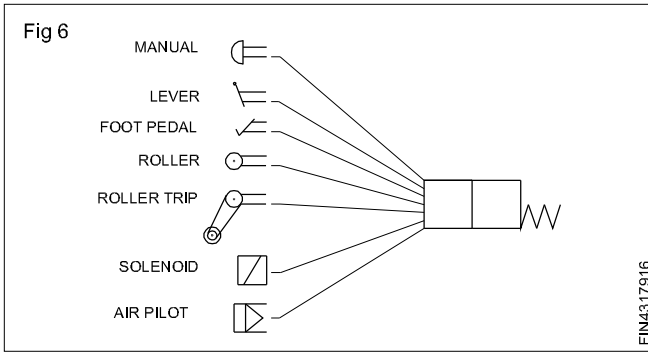
Valve classification according to the type of actuation

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

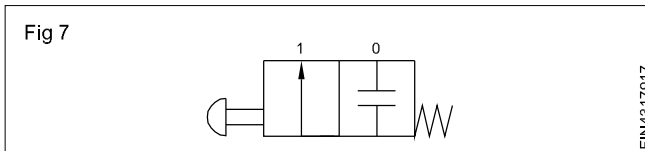
Spring return

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)



- Manual type
- Lever type
- Pedal type
- Roller type
- Roller trip type
- Solenoid
- Pilot operated

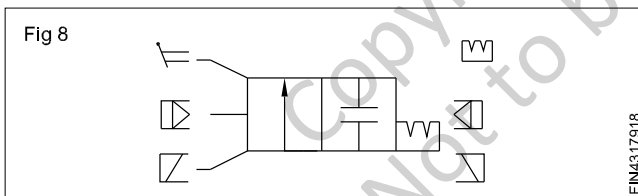
Initial position of a spring return valve is always named as '0' and other position as 1. (Fig 7)



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.

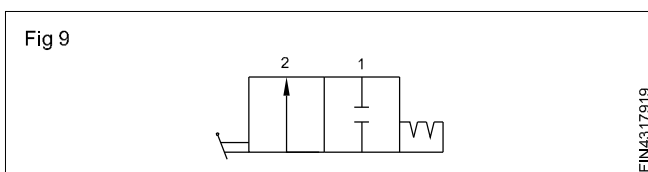
Under this category we have (Fig 8)



- Lever operated
- Impulse operated
- Solenoid operated

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

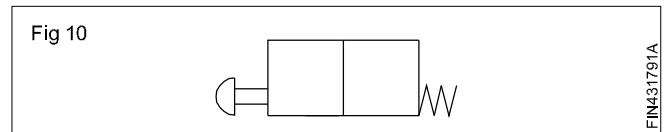
The positions of these detent valves are indicated as 1 and 2 since it does not have a normal position, that is generally denoted by '0'. (Fig 9)



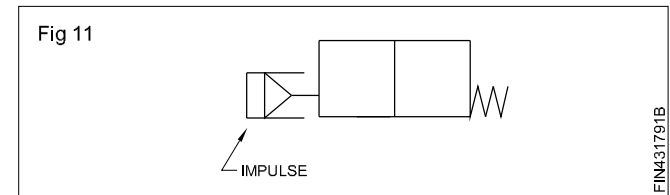
According to the proximity of actuation mechanism from control again actuations can be

- Direct or
- Remote

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



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



Various types of directional control valve

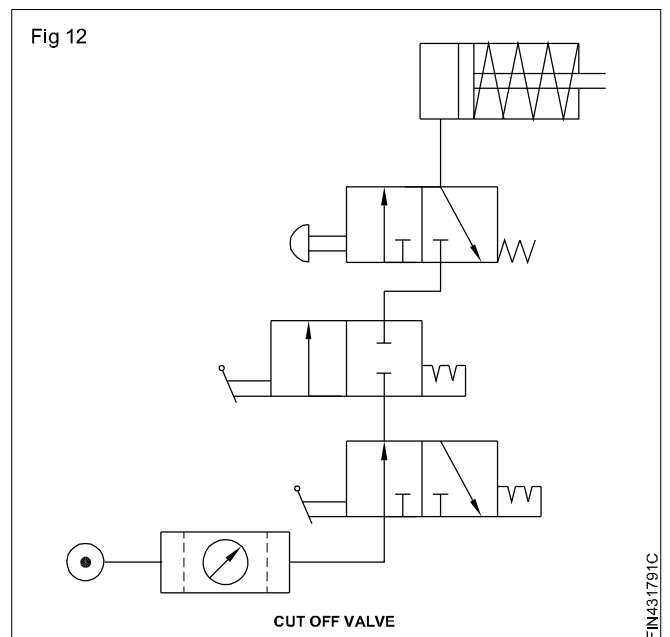
Here we discuss various types of valves according to their function. The type of actuation and constructions are not considered.

2/2 directional control valve

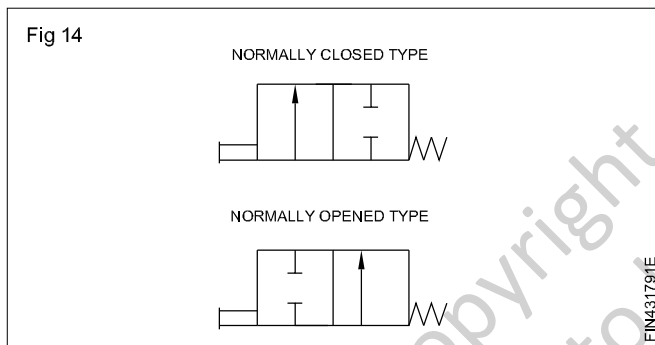
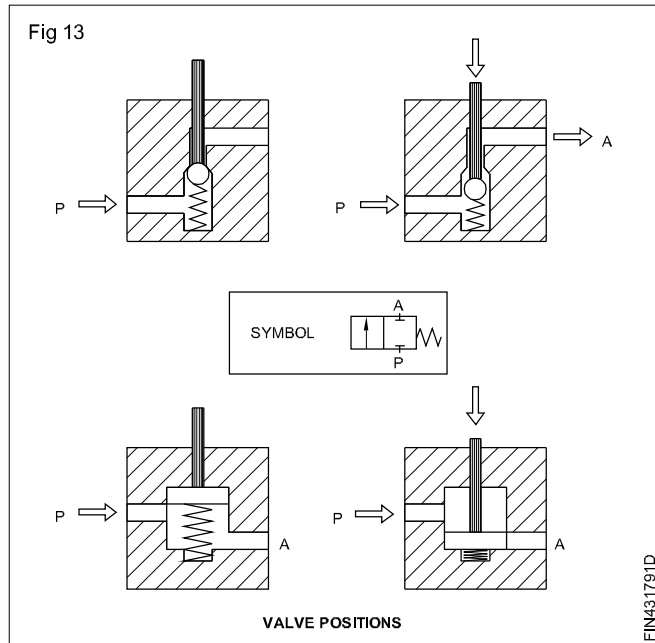
This has 2 ports and 2 positions

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)

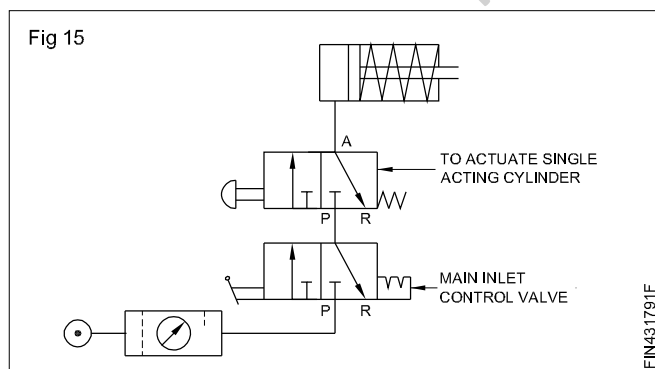
3/2 directional control valve



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.

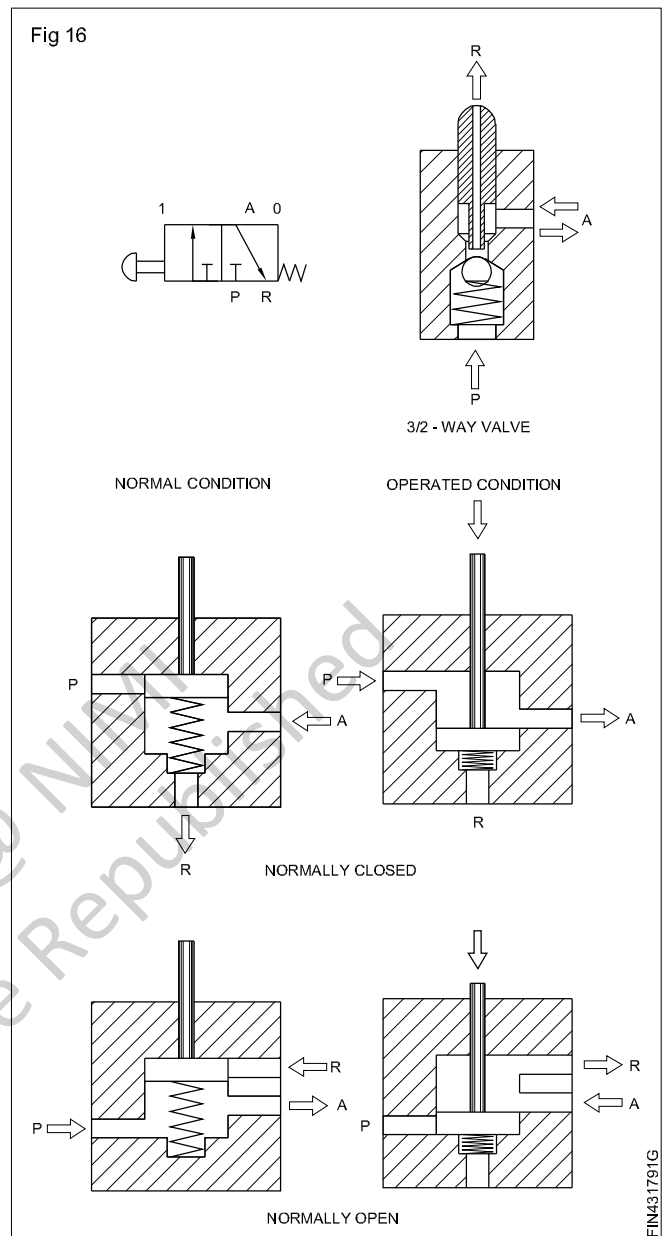


A 3/2 valve is ideally suited for an application of inlet valve, and also for actuating a single acting cylinder (Fig 15).



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.

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)



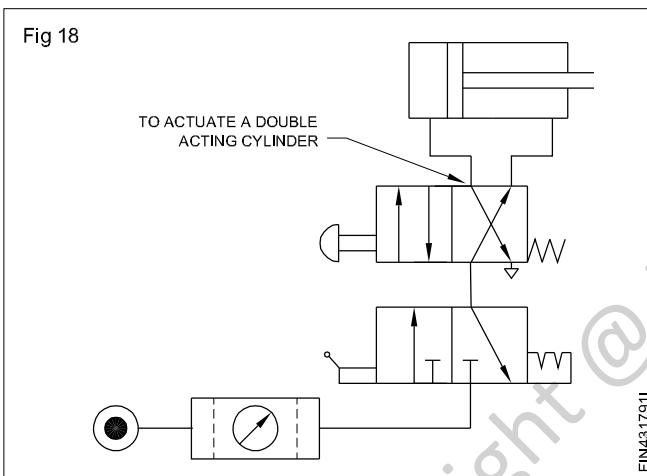
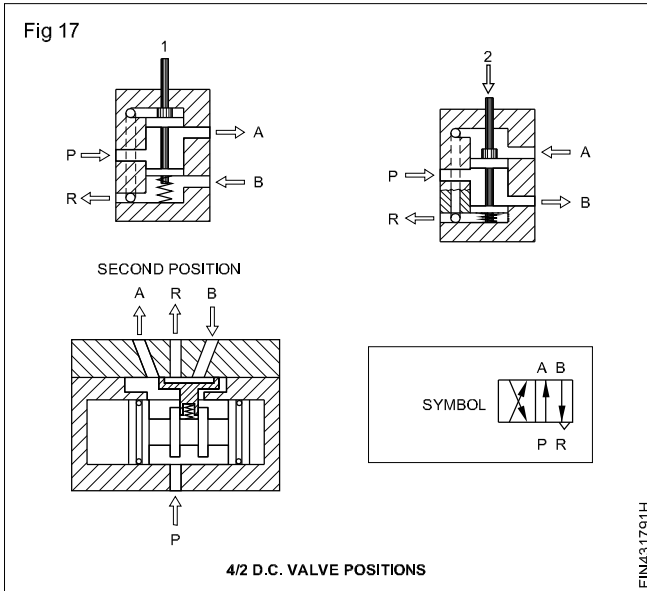
4/2 directional valve

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

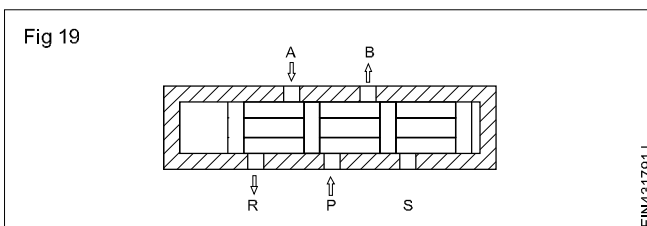
A 5/2 directional control valve functions similar to that of a 4/2 valve, to actuate a double acting cylinder. 5/2 valve has the advantage of having separate exhaust paths for forward and retraction motion, thereby the motion can be controlled independently. 5/2 valve also has advantage in its simple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

P - Pressure port

A & B - Working ports

R & S - Exhaust ports.

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



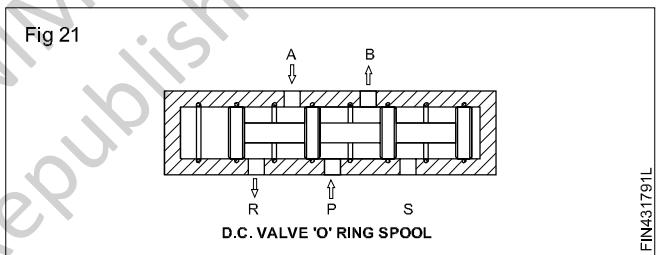
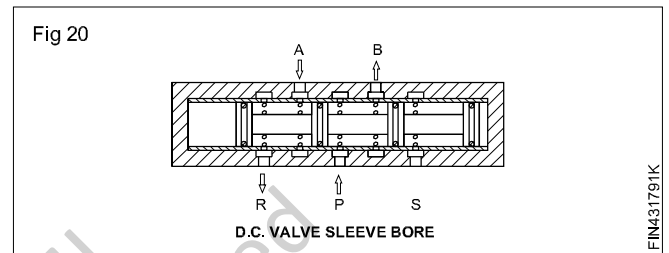
Sealing action in valves

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.

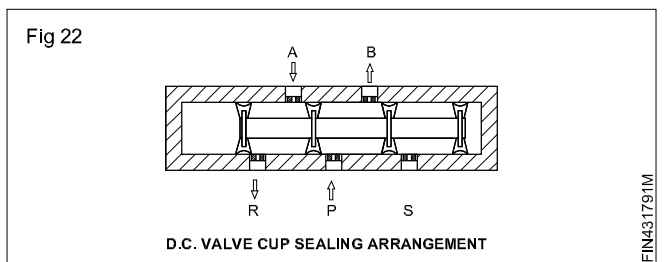
The sealing is done by the following methods.

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.

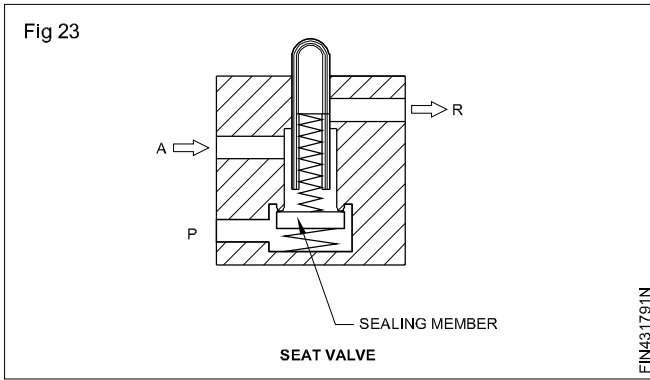


- 'O' ring mounted on the bore of the body (Fig 21) also helps in sealing.
- Cup seats mounted on the spool also helps in having a leak proof (Fig 22) spool movement.



Sealing in seat valve

In seat valves the seat or the disc is usually made of non-metallic substance like 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)



Pneumatic symbols

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

- identify components using ISO 1219 symbol
- interpret symbol of direction control valve symbol.

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

Symbol does not indicate size of the Component.

It does not indicate orientation or arrangement of inner components.

Symbols use common geometrical shapes which categorize the type of component. The shapes used in general are:

Square: It represents a valve.

Circle: It represents compressor, pneumatic motor and gauge.

Line: it represents piping.

Diamond: It represents filter, dryer, lubricator.

Cylinder: It represents receiver.

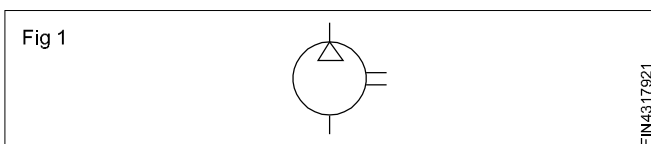
Rectangle: It represents cylinders.

Dotted box: It represents an assembly of various components.

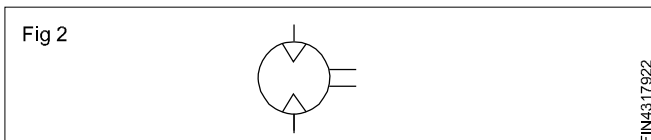
Triangle: It represents pneumatic energy i.e. service air.

Symbol with circle:

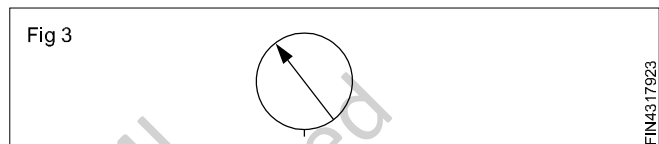
Unidirectional (Fig 1)



pneumatic Motor (Fig 2) Bidirectional

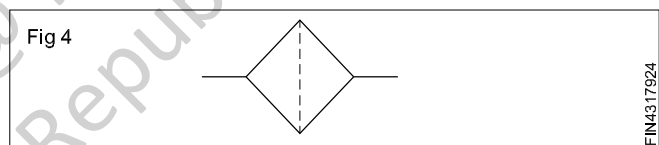


Pressure Gauge (Fig 3)

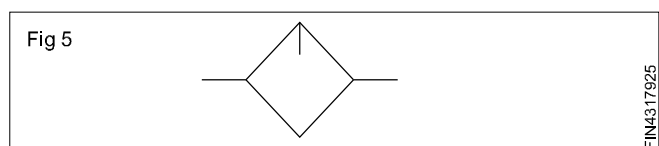


Symbol with diamond shape

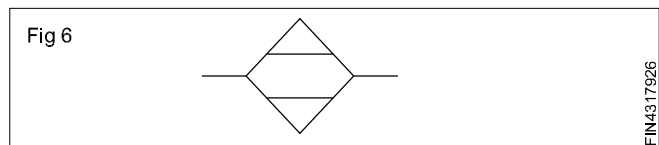
Filter (Fig 4)



Lubricator (Fig 5)

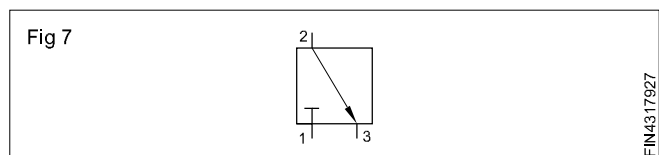


Dryer (Fig 6)

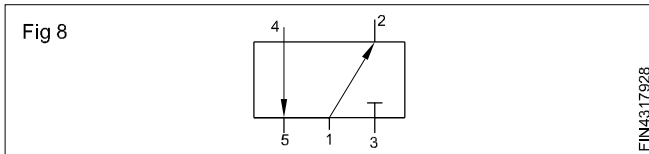


Symbol with square

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



In this figure three extended lines 1, 2, & 3 are shown which show 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.

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 represented by port "R" & "S".

Types of Valves

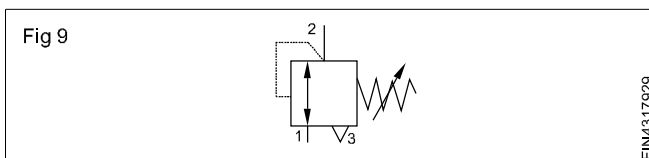
There are three types of valves used in pneumatic system.

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

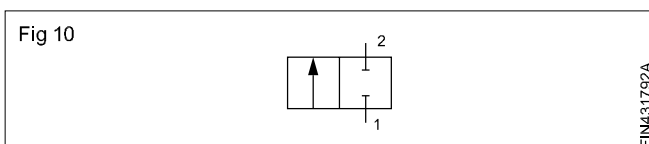
Direction control valve: Used to control the direction of movement of load connected to piston rod; like forward or reverse, clockwise or counter clockwise. It is always represented by combination of minimum two squares.

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



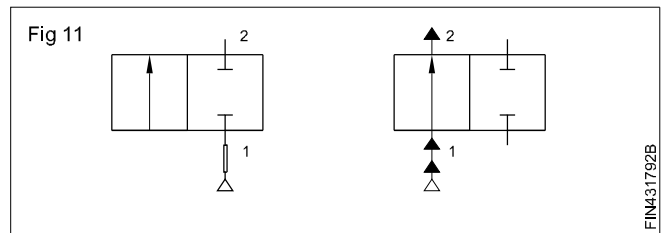
Direction control valves: Look at the symbol shown in fig 10



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.

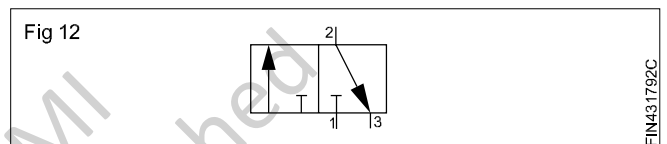
Position refers to status. In the right position port 1&2 are closed, but in the left position both ports are connected.

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

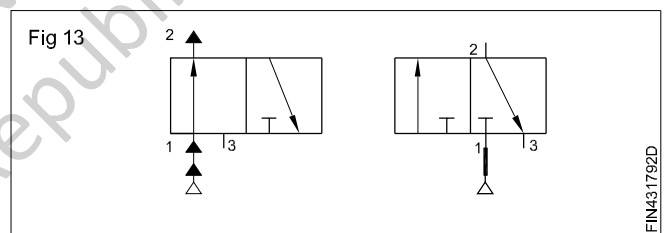


In this valve there are 2 ports and 2 positions, hence called two port two position valve or simply 2/2 way valve.

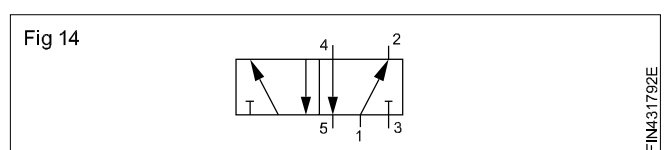
3/2 Way valve: By name it is clear this valve is having 3 ports and 2 position. Symbol is shown Fig 12



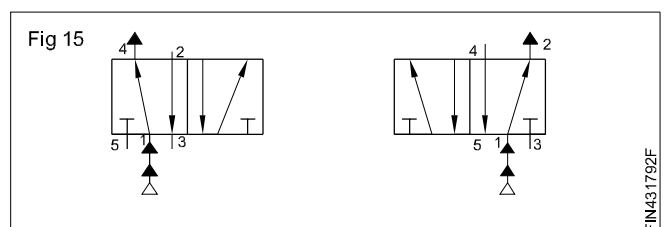
Compare the two positions as shown in fig 13



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



Compare the two positions as shown in 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.

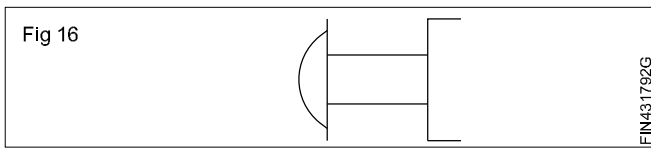
- Manual Type
- Mechanical Type
- Pilot Type
- Solenoid Type

Manual Type

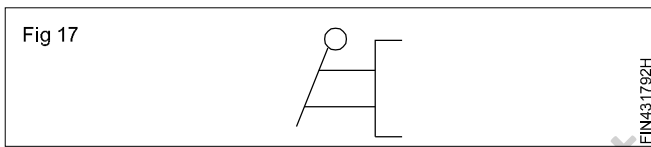
This mechanism is operated by a person, like

- Push Button
- Lever
- Foot pedal

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

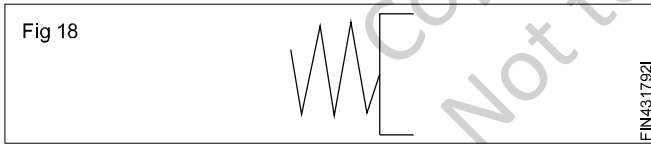


Lever: It is a handle type device when pressed by operator valve actuates (Fig 17)

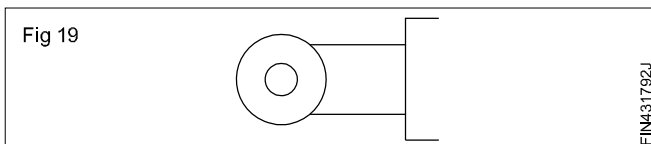


Mechanical Type: Valve is operated by some mechanical force.

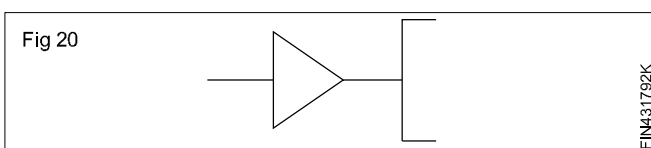
Spring: Common compression spring which actuates valve on de-compression (Fig 18)



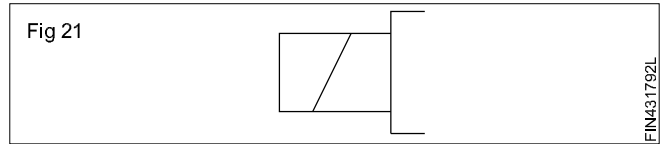
Roller: It is like a lever with small wheel type device when pressed by some object valve actuates (Fig 19)



Pilot: It is air operated type (Fig 20)



Solenoid: IT is electrical operated type (Fig 21)

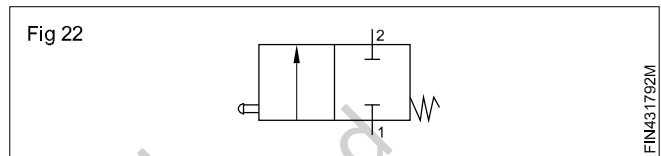


Identifying the direction control valve

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

- 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.

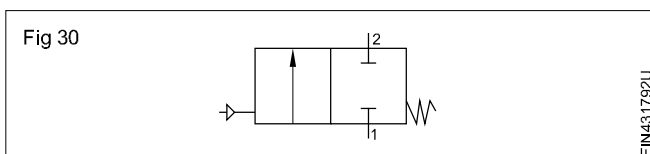
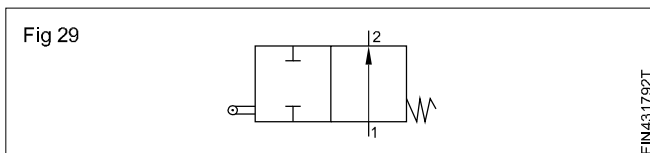
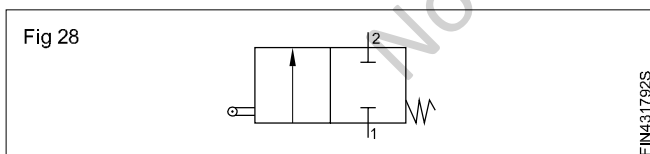
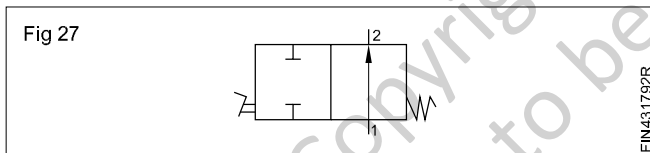
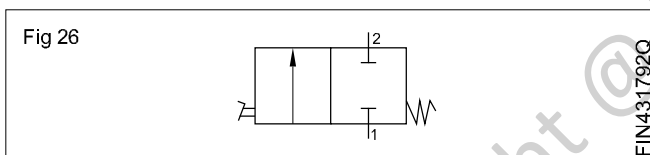
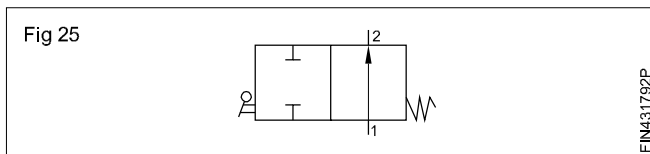
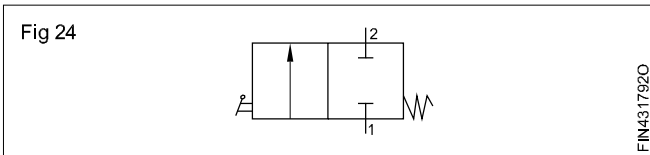
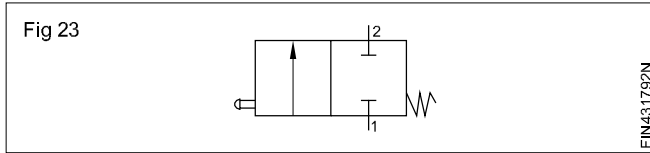
If input port is closed, we say normally closed valve.

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:

Symbol



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)

Designation

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

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

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

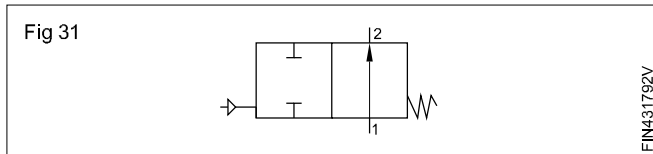
2 port 2 position foot pedal operated spring return normally closed Direction Control Valve.

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

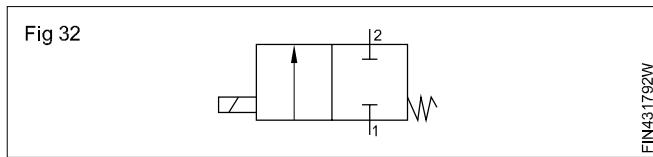
2 port 2 position roller operated spring return normally closed Direction Control Valve.

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

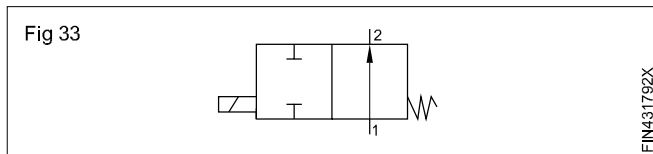
2 port 2 position pilot operated spring return normally close Direction Control Valve.



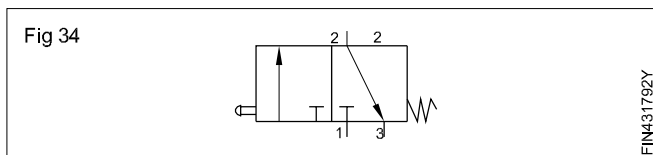
2 port 2 position pilot operated spring return normally closed Direction control Valve.



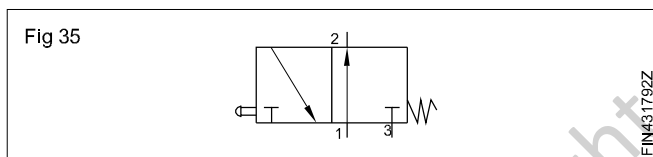
2 port 2 position Solenoid operated spring return normally closed Direction Control Valve.



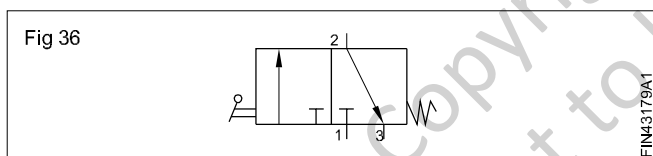
2 port 2 position Solenoid operated spring return normally open Direction Control Valve.



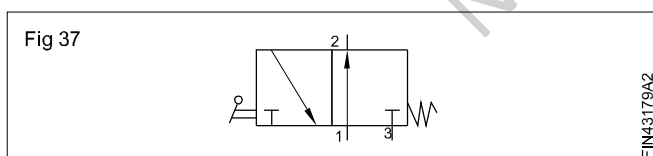
3 port 2 position push button operated spring return normally closed Direction Control Valve.



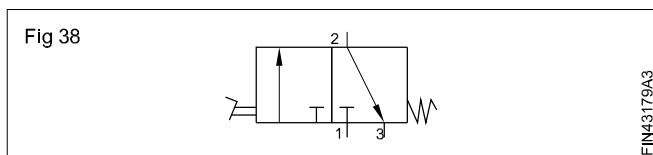
3 port 2 position push button operated spring return normally open Direction Control Valve.



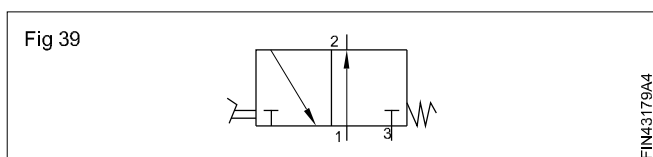
3 port 2 position lever operated spring return normally closed Direction Control Valve.



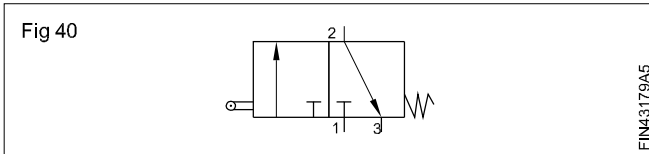
3 port 2 position lever operated spring return normally open Direction Control Valve.



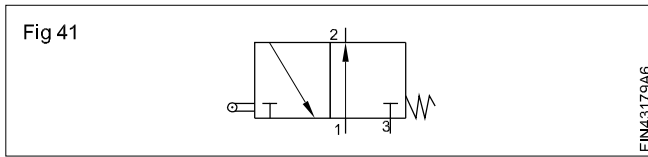
3 port 2 position foot pedal operated spring return normally close Direction Control Valve.



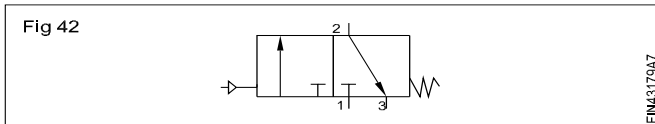
3 port 2 position foot pedal operated spring return normally open Direction Control Valve.



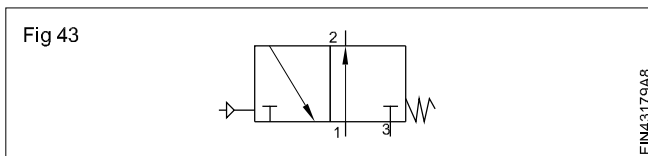
3 port 2 position roller operated spring return normally close Direction Control Valve.



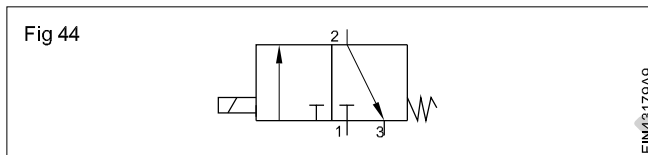
3 port 2 position roller operated spring return normally open Direction control Valve.



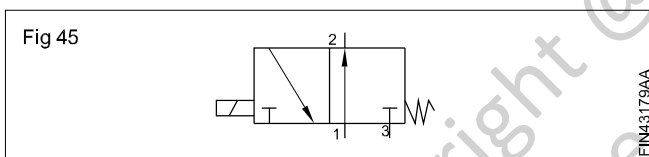
3 port 2 position pilot operated spring return normally close Direction Control Valve.



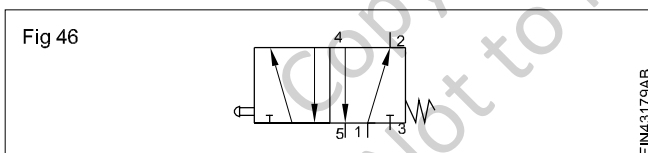
3 port 2 position pilot operated spring return normally open Direction Control Valve.



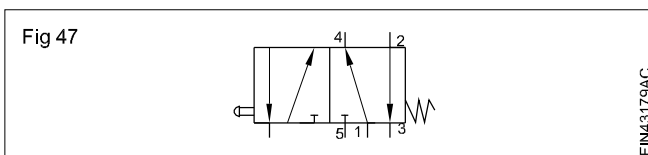
3 port 2 position solenoid operated spring return normally close Direction Control Valve.



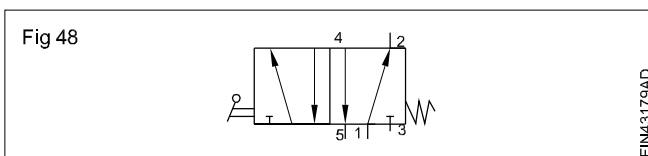
3 port 2 position solenoid operated spring return normally open Direction Control Valve.



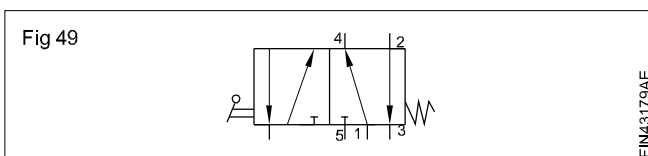
5 port 2 position push button operated spring return Direction Control Valve, normally 1 is connected to 2.



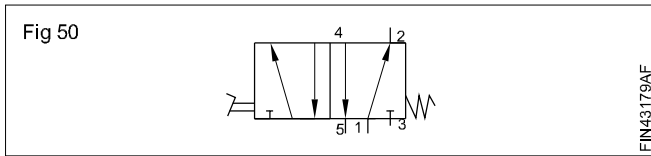
5 port 2 position push button operated spring return Direction Control Valve, normally 1 is connected to 4.



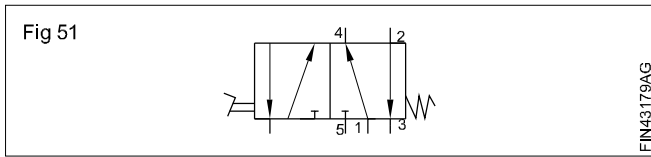
5 port 2 position lever operated spring return Direction control valve, normally 1 is connected to 2.



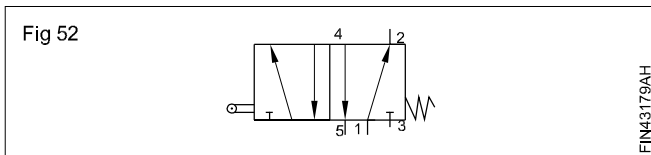
5 port 2 position lever operated spring return Direction Control Valve normally 1 is connected to 4.



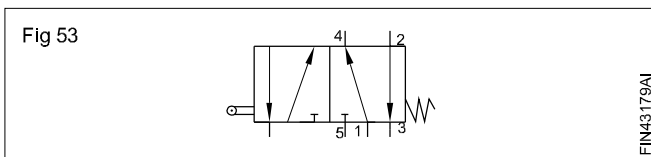
5 port 2 position foot pedal operated spring return Direction Control Valve normally 1 is connected to 2.



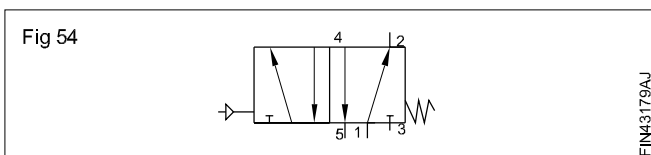
5 port 2 position foot pedal operated spring return Direction Control Valve normally 1 is connected to 4.



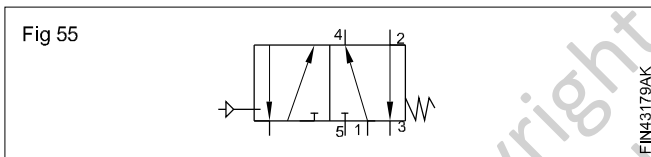
5 port 2 position roller operated spring return Direction Control Valve normally 1 is connected to 2.



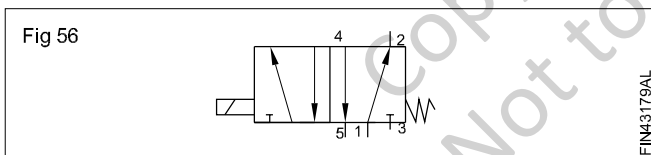
5 port 2 position roller operated spring return Direction Control Valve normally 1 is connected to 4.



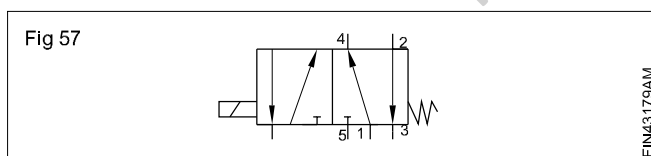
5 port 2 position pilot operated spring return Direction Control Valve normally 1 is connected to 2.



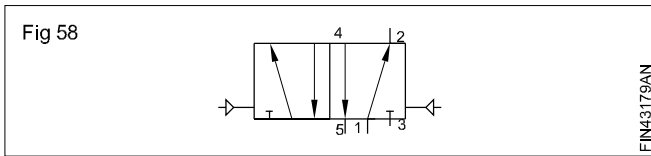
5 port 2 position pilot operated spring return Direction Control Valve normally 1 is connected to 4.



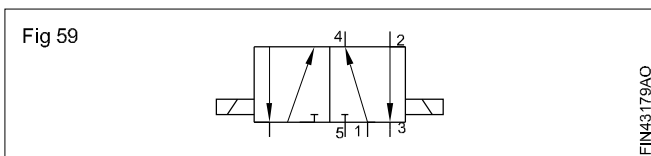
5 port 2 position solenoid operated spring return Direction Control Valve, normally 1 is connected to 2.



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



5 port 2 position double pilot operated Direction Control Valve.

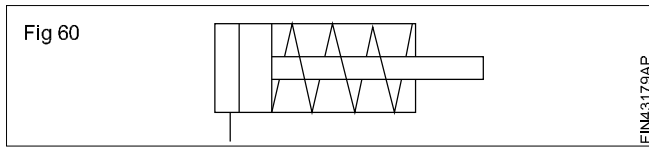


5 port 2 position double solenoid operated Direction Control Valve.

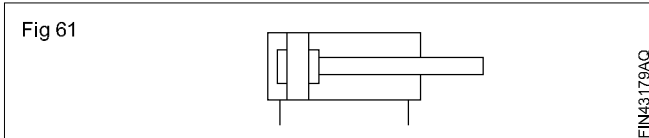
Symbol with Rectangle

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

Single acting cylinder (Fig 60)

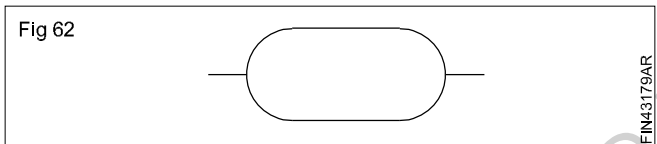


Double acting cylinder (Fig 61)



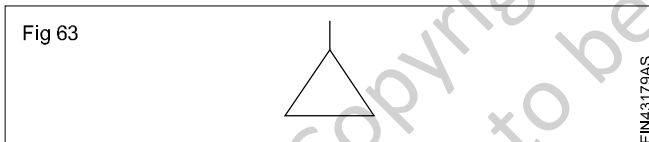
Symbol with cylinder:

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



Symbol with triangle:

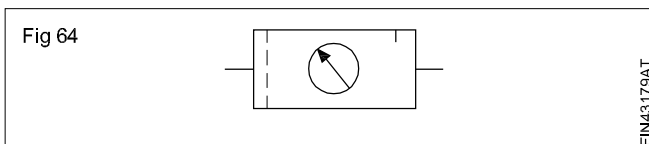
In general triangular shape is used to represent air source (Fig 63).



Symbol with dotted box:

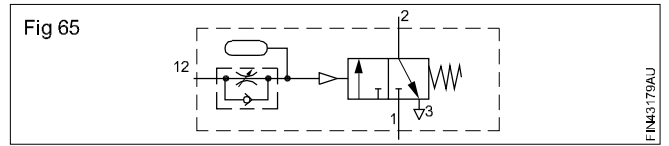
Symbol shown in dotted box represents assembly of components like FRL, Time delay valve.

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



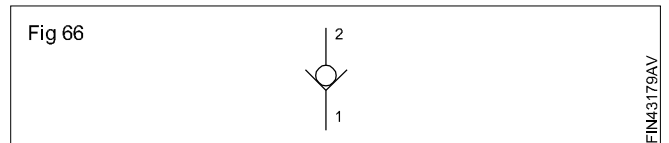
Time delay valve

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

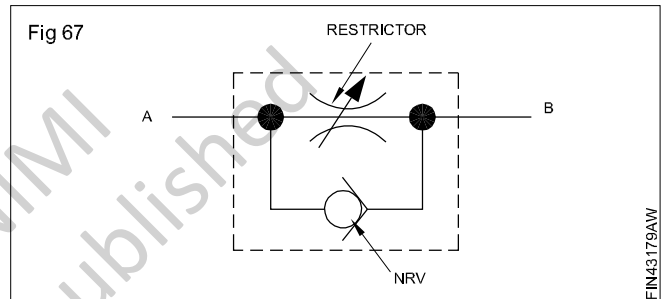


Other Symbols

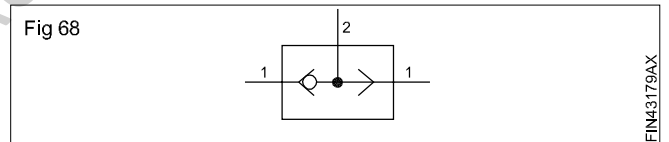
Non return valve (Fig 66)



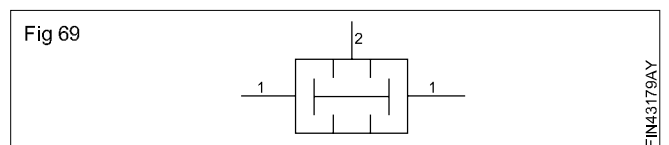
Flow control valve (Fig 67)



Shuttle valve (Fig 68)



AND valve (Twin pressure valve) (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.

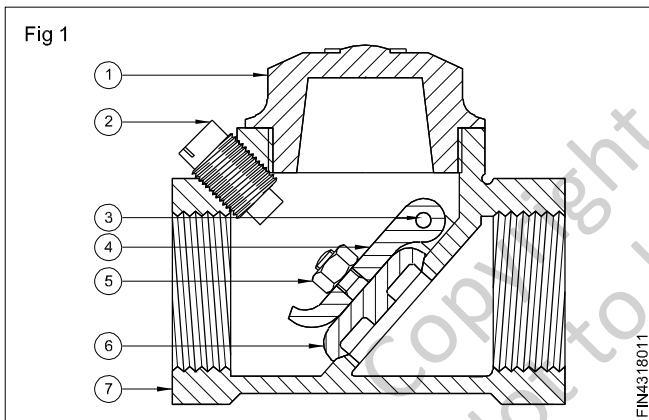
Non-return valve

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.

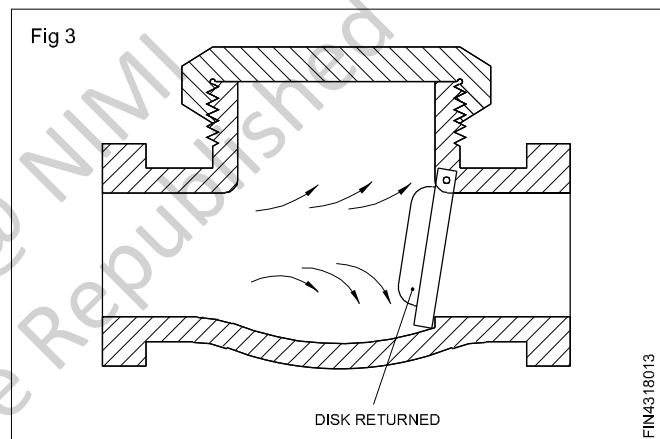
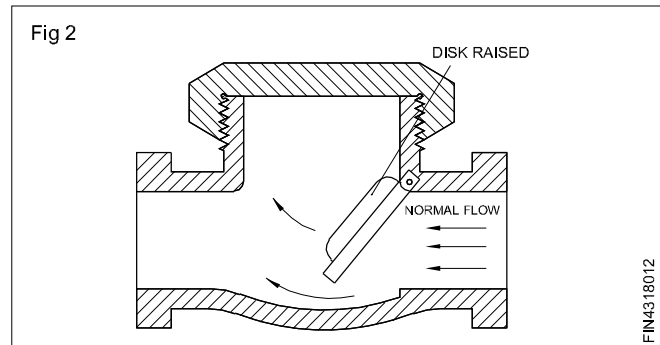
Sometimes two or more different kinds of material are used on a single valve. There are many types of check valves available in the market.

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

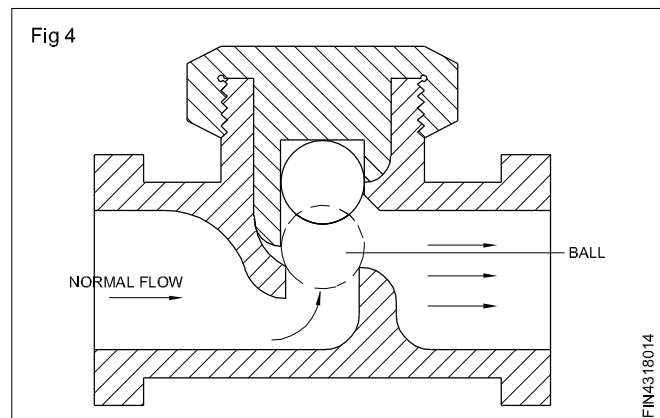


- 1 Cap
- 2 Stop plug
- 3 Hinge pin
- 4 Hinge
- 5 Disc hinge nut
- 6 Disc
- 7 Body

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)



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)



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.

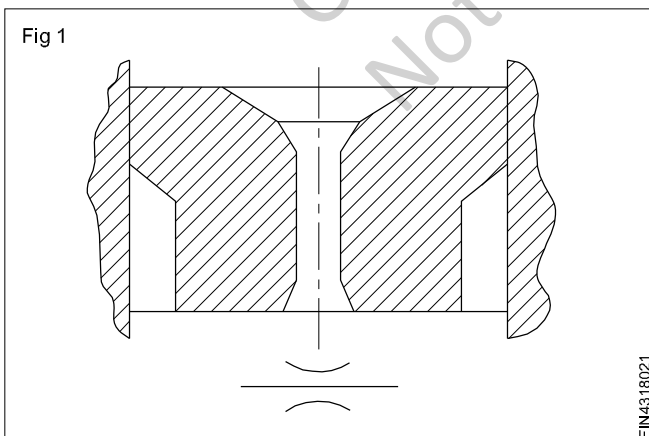
Flow control valve is a orifice or restrictor in hydraulic system.

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)

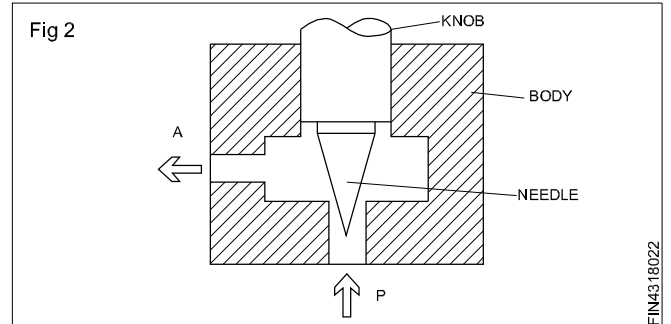
Fixed orifice is a simple small opening in line which is not variable. (Fig 1)



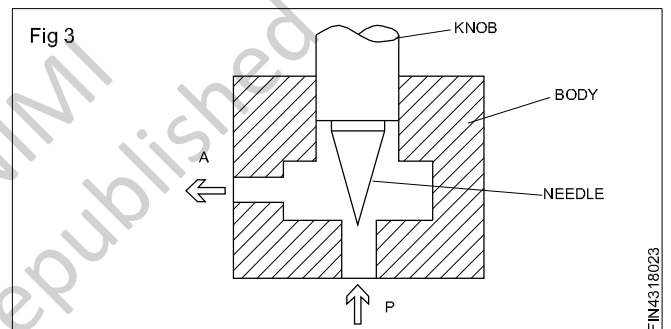
Variable flow control valve

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

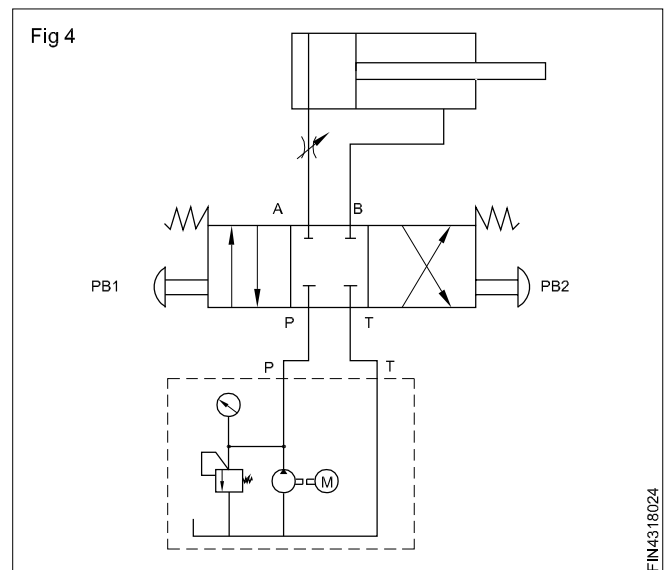
If needle of flow control valve moves closer to the seat then opening is less and flow also reduced. (Fig2)



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



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

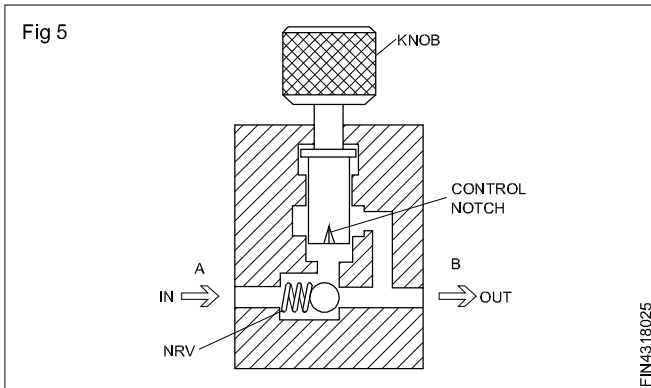


One - way flow control valve

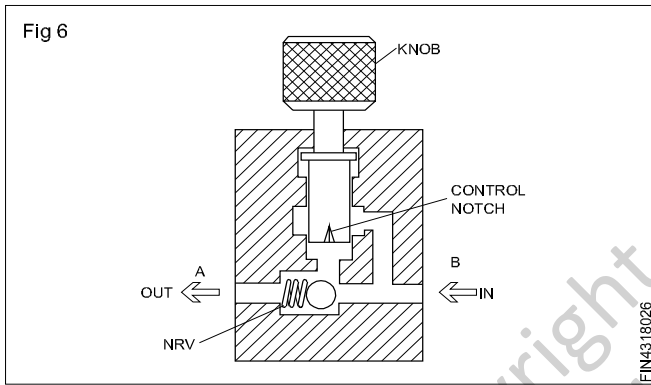
The one - way flow control valve is a combination of an orifice or throttle valve and a non - return valve. The restrictor controls the flow rate in a single direction

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)



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)



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

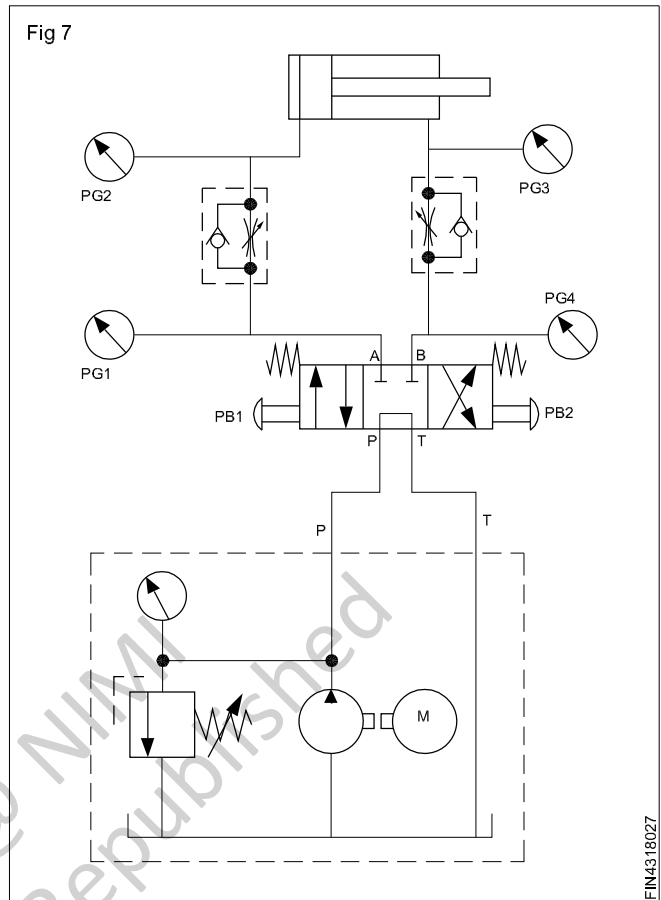
- Meter - in speed control
- Meter - out speed control
- Bleed off speed control

Meter - in speed control

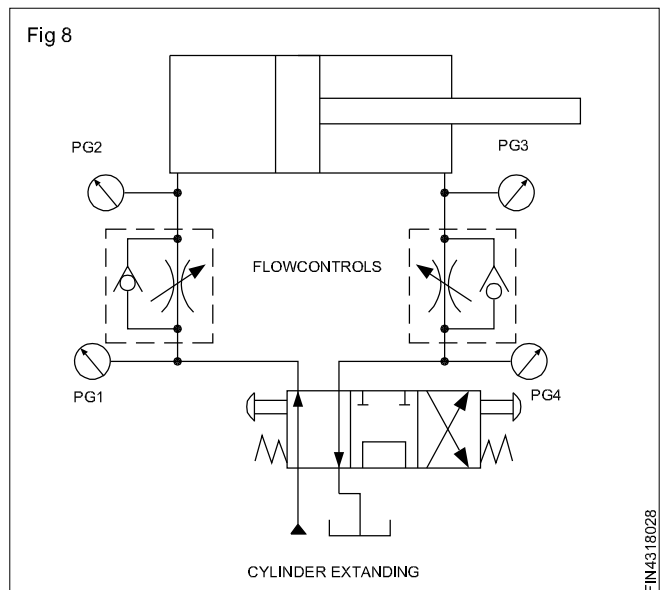
Fig 8 provides a schematic drawing of a meter - in flow control circuit restriction fluid as it enters an actuator port. Meter -in circuits work well with hydraulic fluids, but can give erratic action with air. Meter - in flow controls only work on resistive loads because a running - away load can move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



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

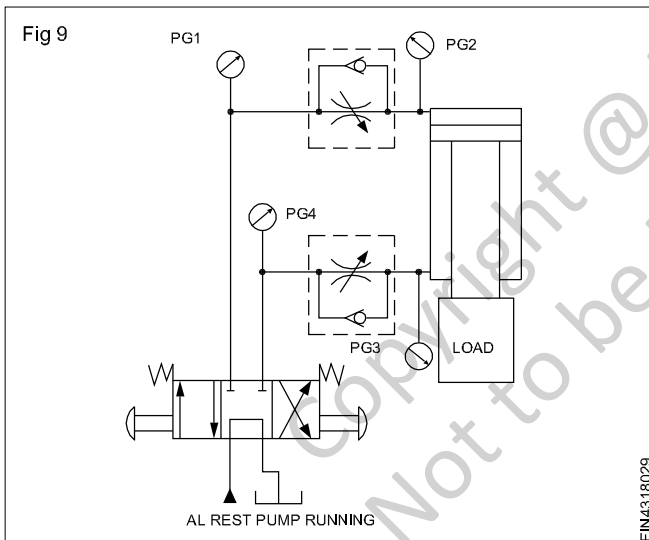
Meter - out speed control

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.

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 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.



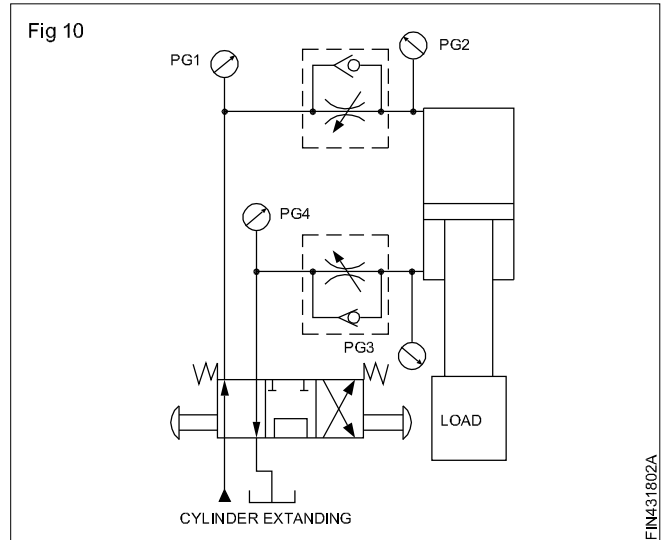
The below circuit shows conditions when the cylinder is extending. The directional control valve shifts to straight arrows and pump flow by passes the upper flow control to go to the cylinder cap end. Fluid leaving the cylinder rod end is held back before it goes to tank even with an external load trying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

Bleed - off speed control

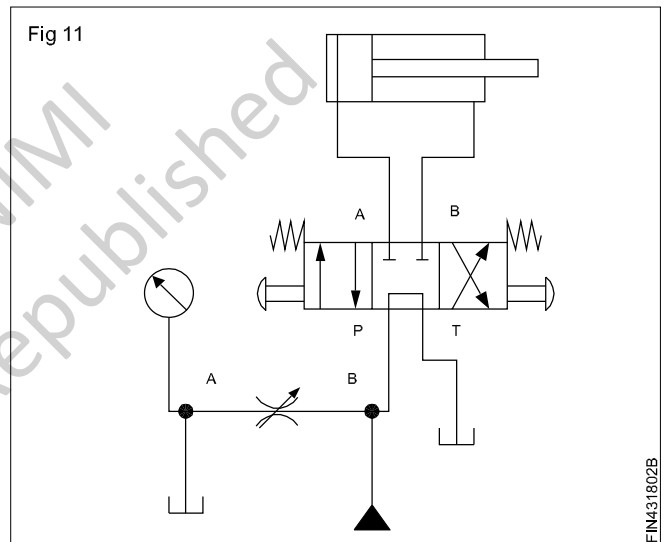
Bleed - off flow control circuits are found only in hydraulic systems and normally only in those with fixed - volume pumps.

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

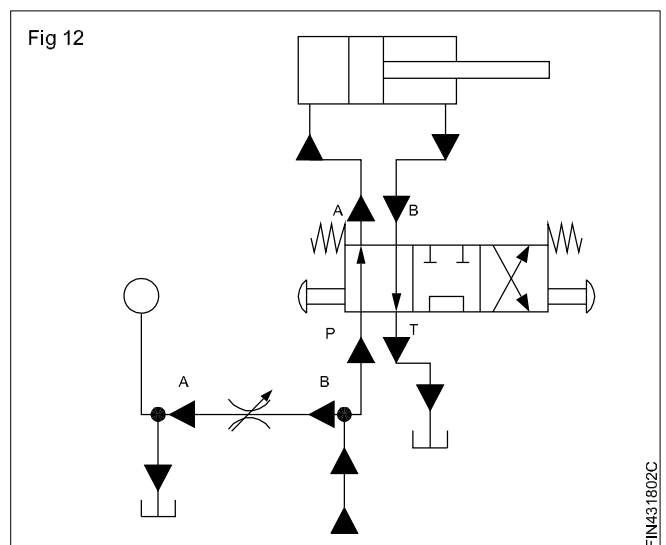
Fig 11 shows a bleed - off circuit at rest with the pump



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.



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

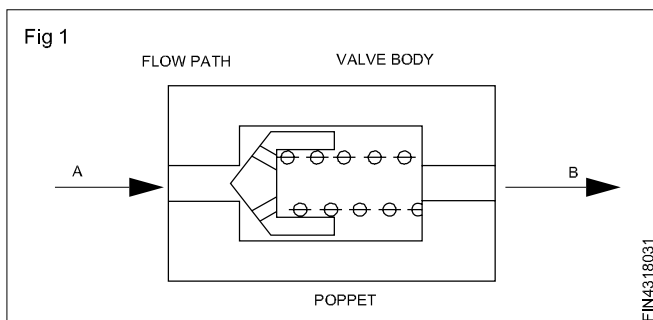
Objectives : At the end of this lesson you shall be able to

- 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:

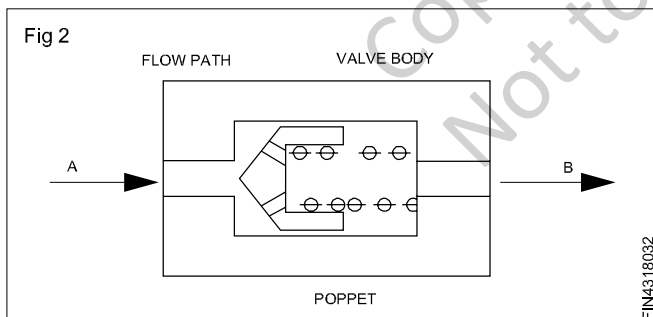
This valve allow air flow in one direction but does not allow air to flow in opposite direction. Non return valve is also known as check valve.

Fig 1 shows the construction of non return valve.

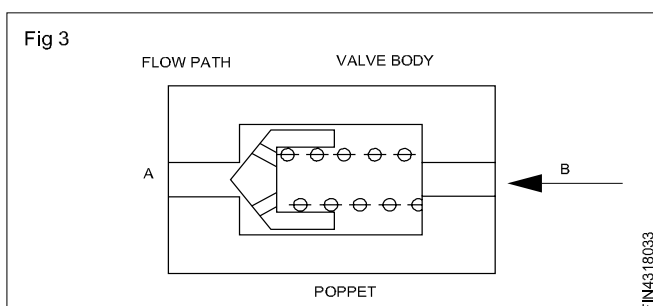


It consists of a valve body having flow path and accommodates poppet and spring. Spring exerts very small force on poppet so that it is closing the path and poppet does not dislocate even if NRV is connected vertically or at an angular position.

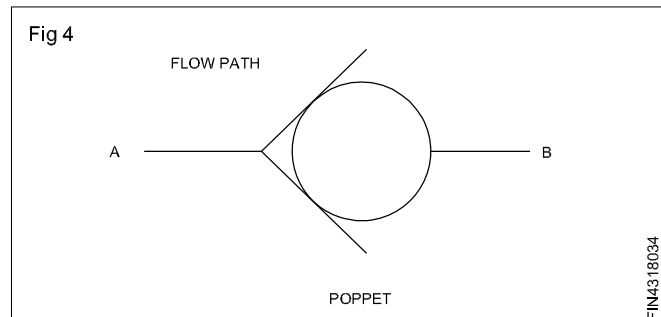
When air flows from port A to B, pneumatic force acts on poppet and spring gets compressed. It causes poppet to shift right side and air flow freely in A to B direction (Fig 2)



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.



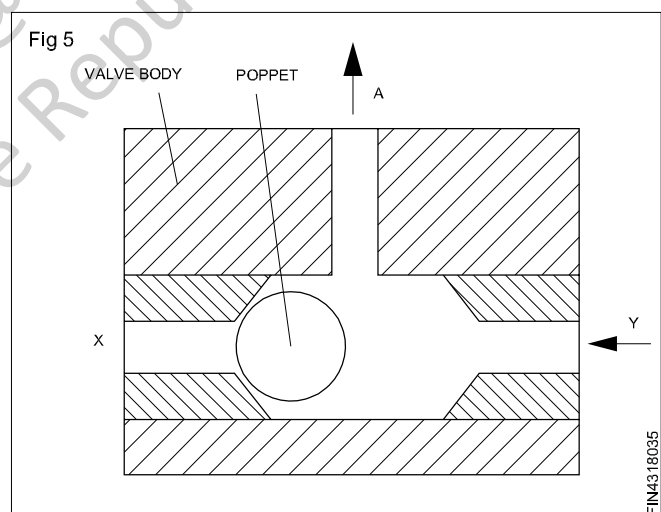
Symbol of NRV is shown in fig 4



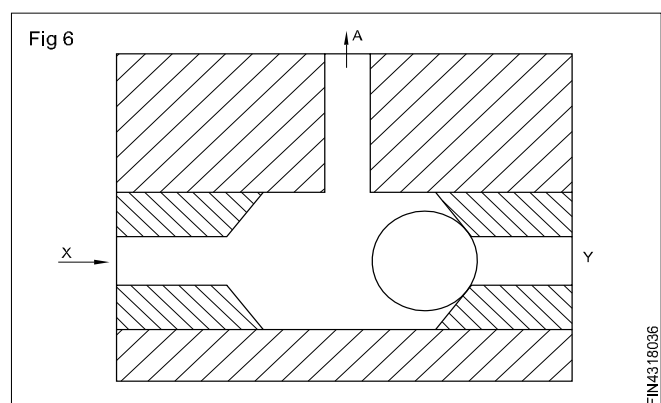
Working principle of Shuttle Valve

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

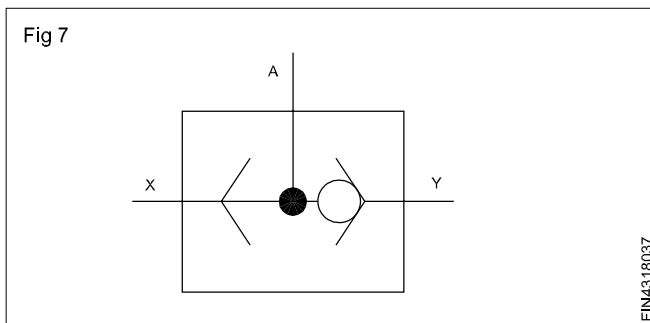
If air is supplied through port Y as shown in fig 5, poppet shifts and block port X, thus air flow from Y to A.



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



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.



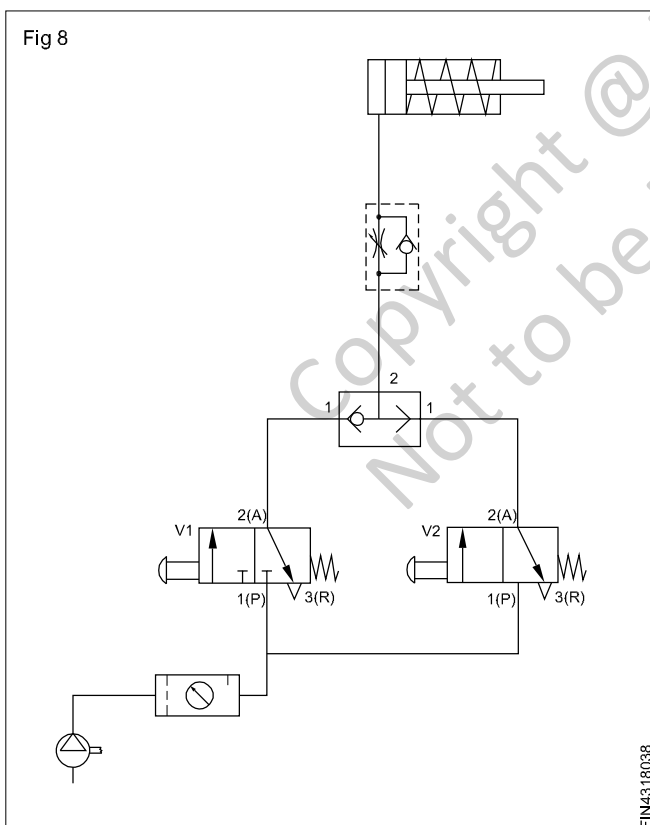
Application

If we use two 3/2 way valves and connect their outputs to 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.

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

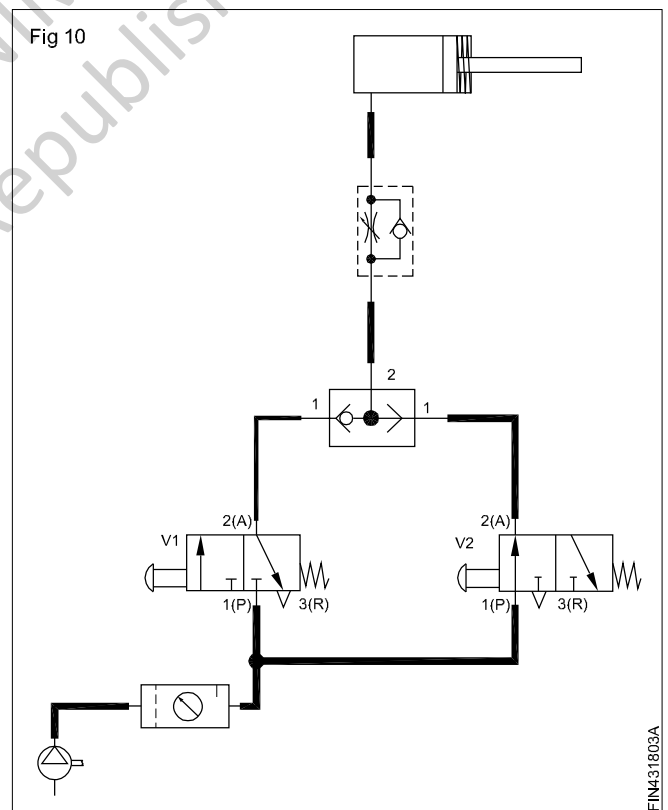
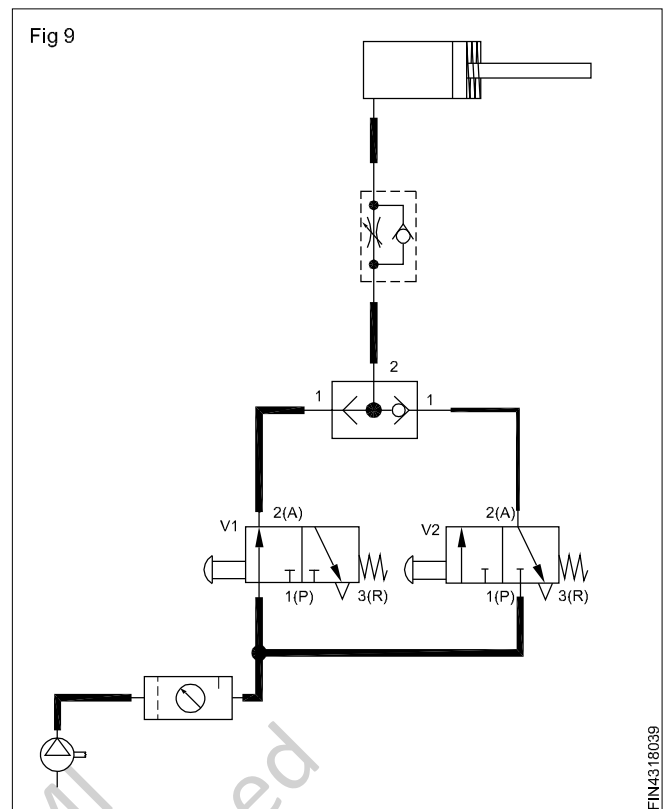
As soon as valve is released cylinder side air exhausts through valve V1 and piston retracts.



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

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)

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

Fig 11

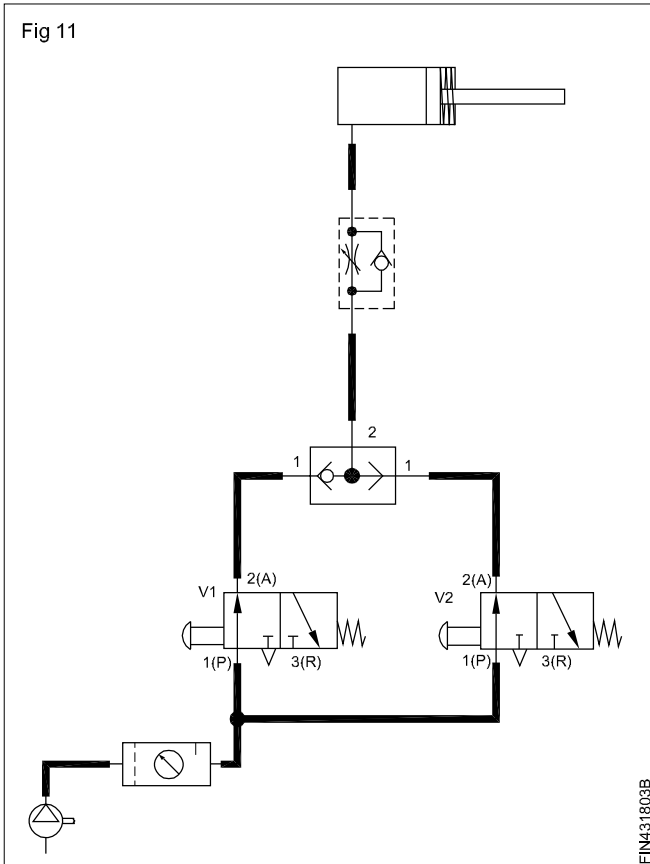
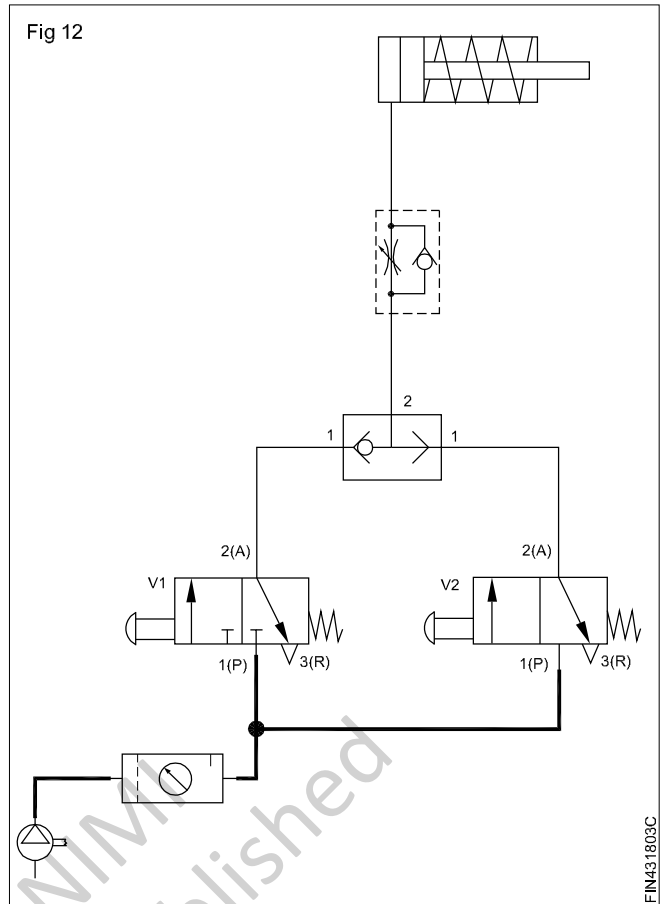


Fig 12



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.

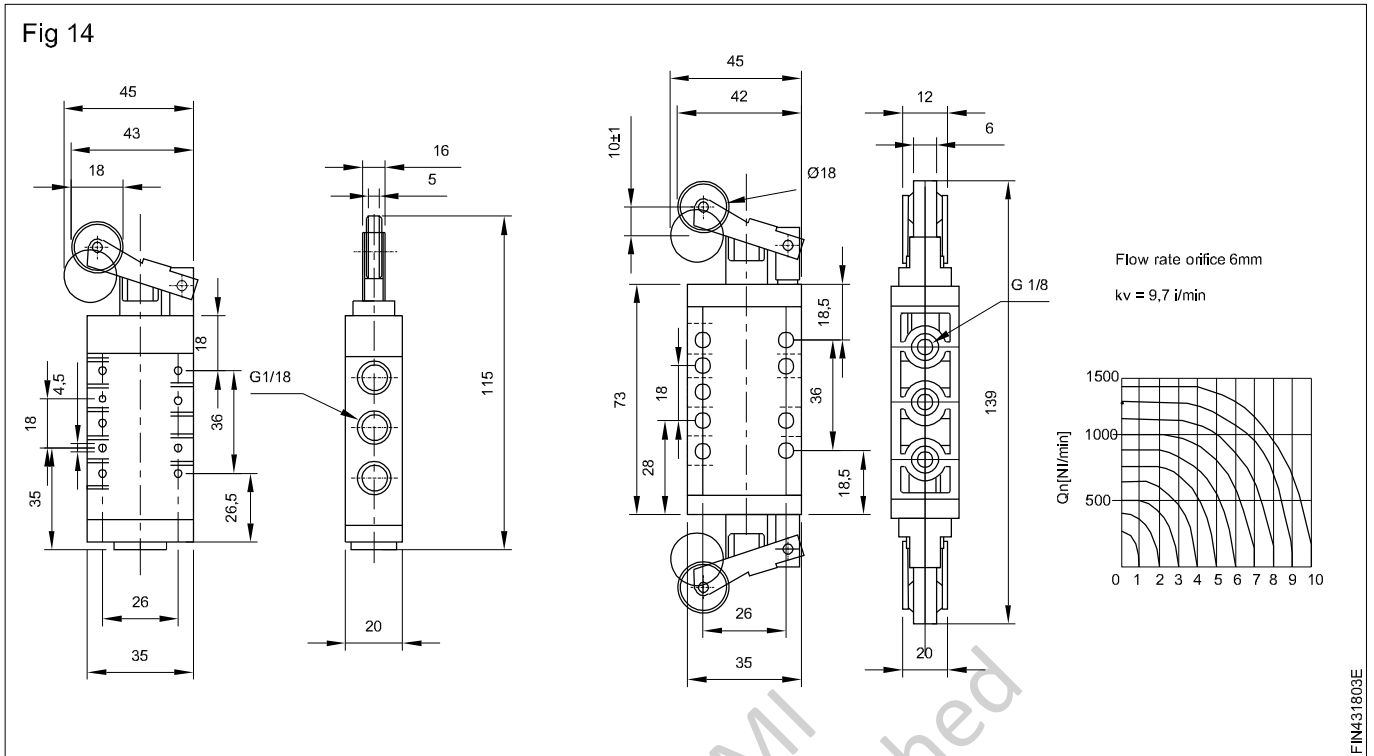
Pneumatic roller lever valves, constructed from a die - cast zinc aluminium alloy that is machined and lacquered offering strength and reliability, an overall excellent quality product. We offer 2 or 3- way normally closed, or a 5 way roller lever valve in either poppet or spool designs. Choose from 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



Dimensional drawings



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 regulate the pressure various pressure control valves are used in hydraulic systems, like:

Classification of Pressure control valve

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

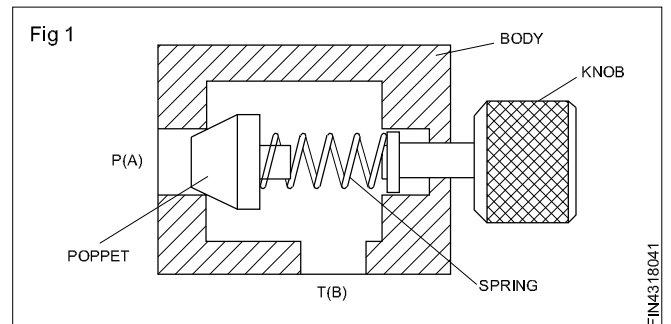
Pressure relief valve

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

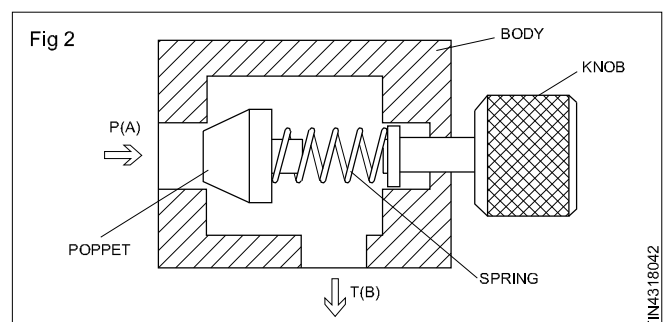
In this design incorporating a poppet valve, a seal is pressed against the inlet port P by a spring when the valve is in its normal position. The input pressure (P) acts on the surface of the sealing element generates the force.

$$F = p_1 A_1$$

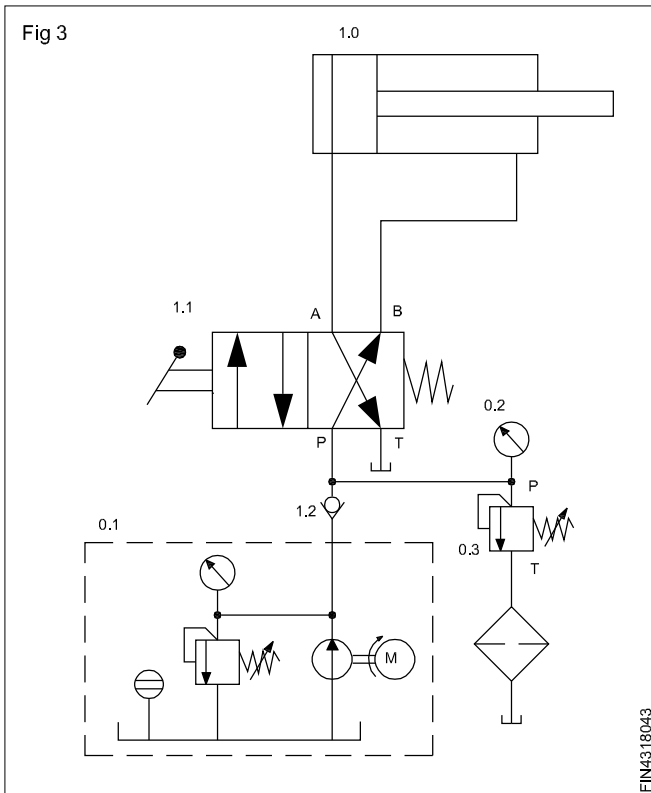
The Spring force by which the sealing element is pressed onto the seat is adjustable



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.



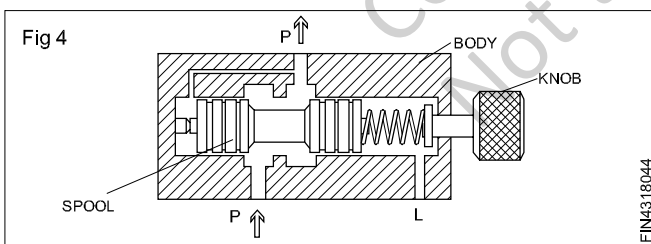
The resistances at the outlet (tank line, filter) must be added to the force of the spring in the pressure relief valve. Application of PRV is shown in the Fig 3



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.

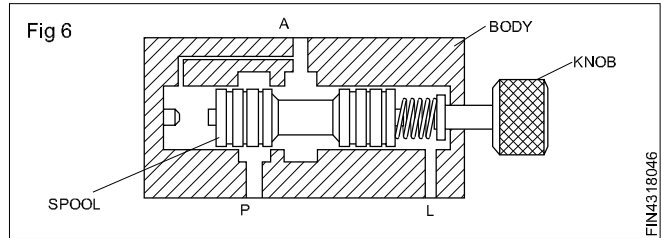
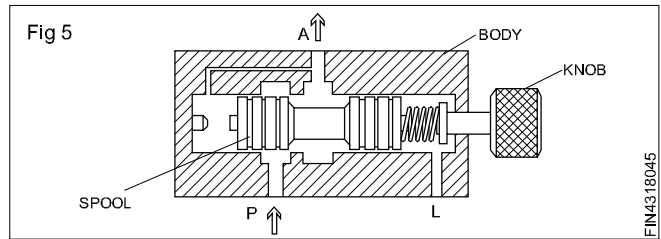
This valve is normally open. The outlet pressure (A) acts via a pilot on the left - hand surface of the pilot piston against an adjustable spring force. (Fig 4)



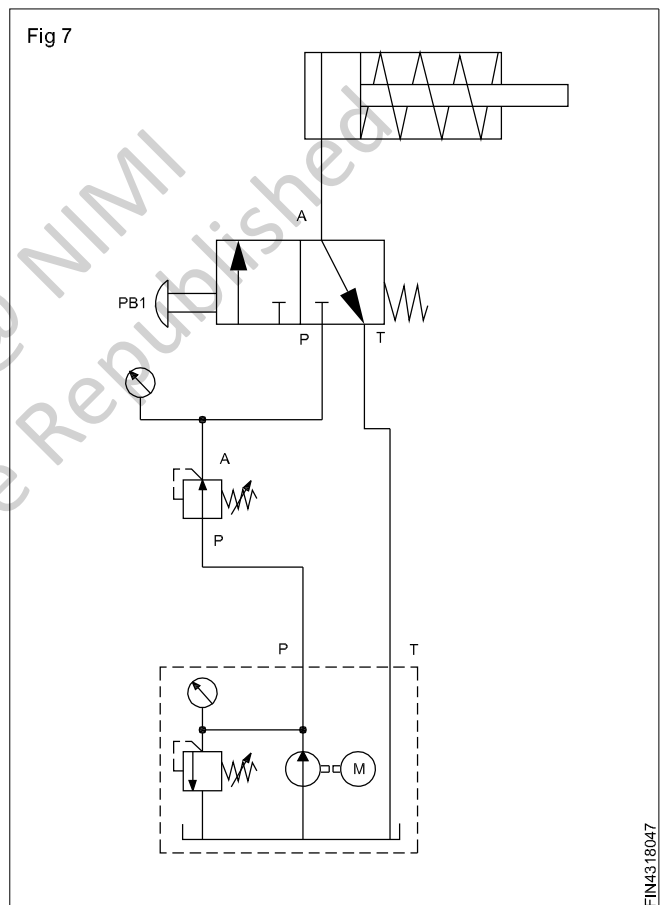
When the pressure rises at outlet A, the force at the left hand surface of the pilot piston becomes increases, the piston is displaced to the right and the throttle gap becomes narrower. This causes a pressure drop. In the case of slide valves, it is also possible to design the control edges in such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

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



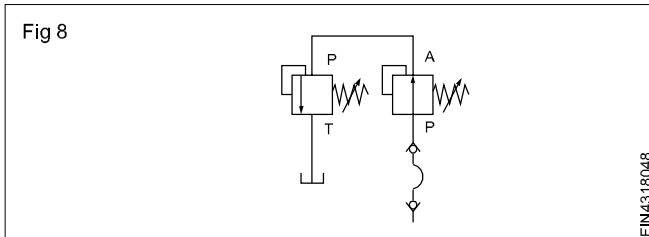
position. Application of pressure reducing valve is shown in the Fig 7



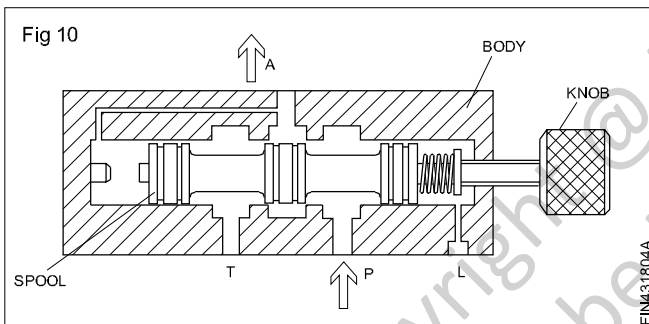
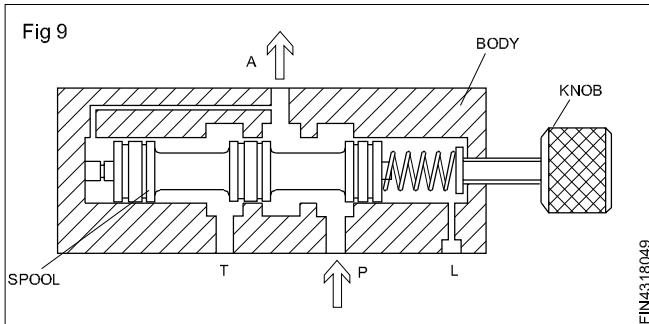
Pressure regulator (3- way Valve)

When the 2 - way pressure regulator close fully, then any impact vibration in cylinder will responsible to increase the output pressure above the set value which is not desirable. One method of rectifying this would be to install a pressure relief valve at the output.

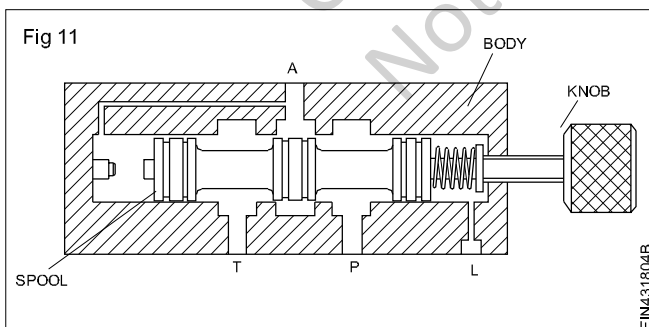
The 3-way pressure regulator can be regarded as a combination of a 2- way pressure regulator (PR) and a pressure relief valve (PRV) (Fig 8)



When the pressure at A raises the result of external conditions, this pressure acts via a pilot line on the left hand piston surface of the pilot piston against an adjustable spring force. Every pressure increase causes the throttle gap to become narrower, resulting in a pressure drop. (Figs 9 & 10)



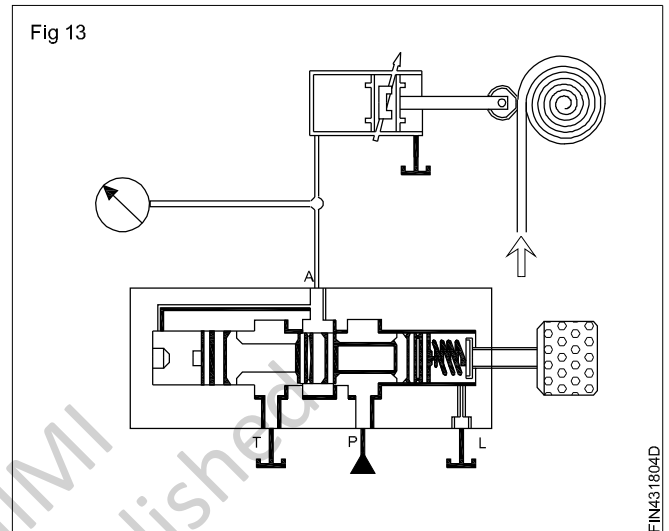
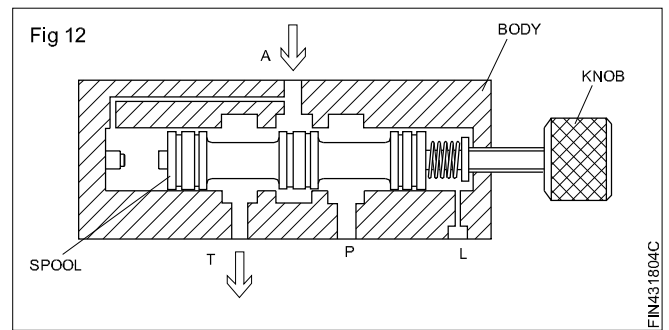
When the maximum preset pressure is reached, the throttle point closes completely. (Fig 11)



If the pressure rises above the preset value as the result of an external load at outlet A, the valve opens to allow from A to the tank port T (pressure - limiter - function). (Fig 12)

Example of pressure regulator is shown in the fig 13

Pressure regulator help to maintain constant pressure in line and also safe the sytem from excess pressure, so you able to get approximate constant pressure in line.



Counter Balancing

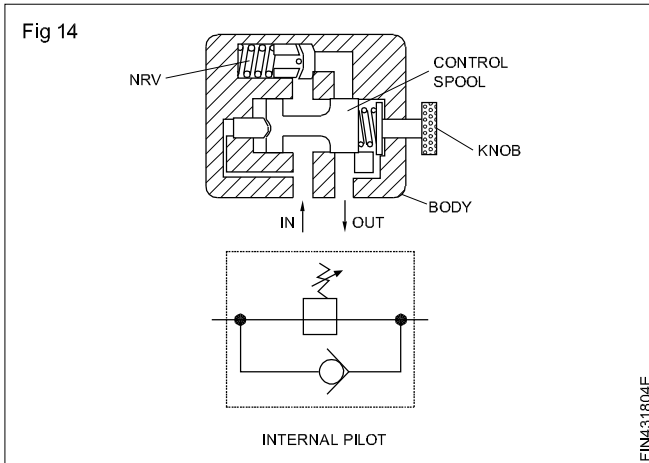
Cylinders with external forces such as weight from a platen, machine members, or tooling acting against them will over run when oil flowing out of them is not restricted. A meter - out flow control circuit is one way to control over running loads but it has one main drawback. A flow control's speed is fixed except for manual adjustment. Because flow is fixed, the actuator will continue at the same speed, even when working flow to it increases or decreases.

The valve which is used to create a back pressure against pushing or pulling types of load to maintain normal speed of cylinder is known as counterbalance valve.

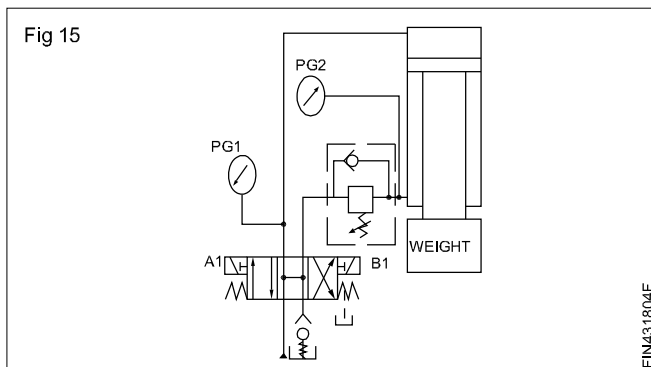
A counterbalance valve keeps an actuator from running away regardless of flow changes because it responds to pressure signals, not flow. A counter balance valve is almost the same as a sequence valve. The figure of counter balance valve and symbols are shown in Fig 14

A counterbalance valve usually has a bypass check valve for reverse flow because its most common use is in controlling actuators with running away or overrunning loads.

Fig 15 shows a vertically oriented cylinder with rod facing down and a load trying to extend it . To keep the cylinder from running away, the counterbalance valve must resist the load - induced pressure from the weight.



The load - induced pressure can be calculated and the counterbalance valve could be preset at 100 to 150 psi higher on a test stand.



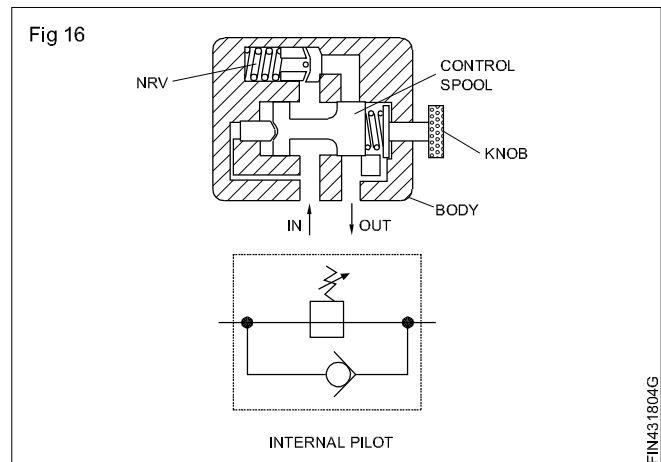
In the centre position of directional control valve ports A and B are connected to tank in the center condition. There is no chance of extra pressure buildup in the pilot line while the circuit is at rest. If ports A or B were blocked, pressure could not build and counterbalance valve will not open, not allowing the cylinder to drift.

Press PB1 oil flows to the cylinder cap end. As pressure builds there, pressure also increases in the rod end. When pressure at the cylinder rod end reaches 100 to 150 psi above the load- induced pressure, the cylinder starts to extend as fast as the pump fills the cap end. When flow increases, cylinder speed increases and when flow decreases, cylinder speed decreases. Back pressure at the cylinder rod end is present during the entire extend stroke.

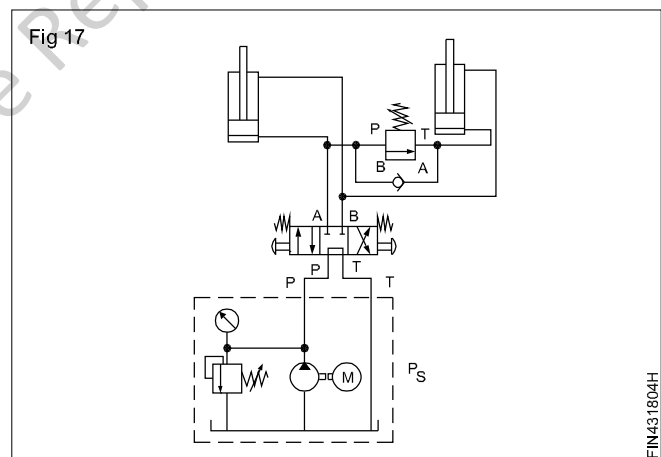
When PB2 is operated oil flows to rod end via check valve thus by passing the counterbalance hence piston retracts.

Sequencing

To operation of number of hydraulic actuators in desired steps sequencing is done. A sequence valve is the simplest mechanism to achieve desired steps. Fig 16 shows the sectional view and symbol of sequencing valve.

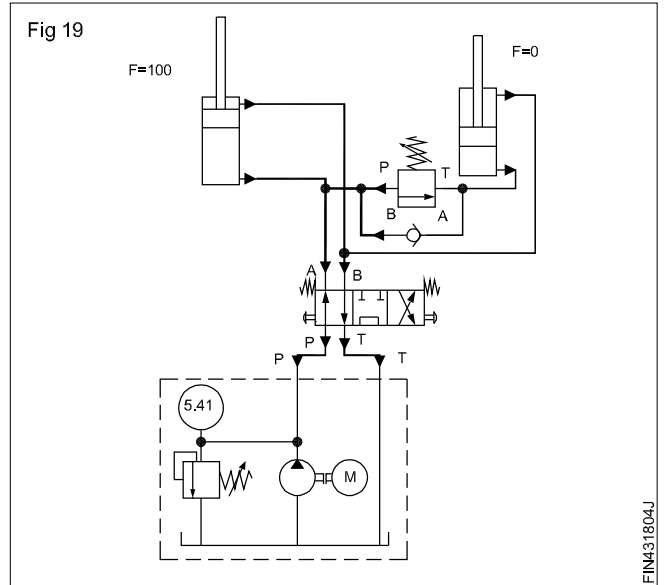
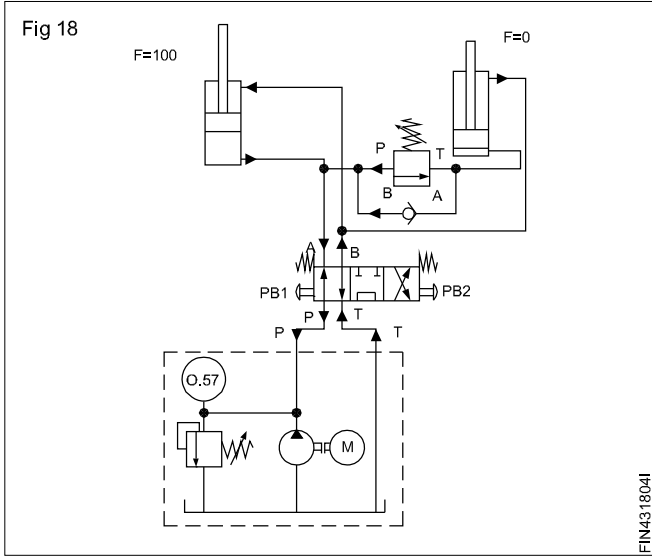


A balanced spool held in place by an adjustable - force spring blocks fluid at the hydraulic sequence valve's inlet. When pressure at the inlet reaches the spring setting, pressure in the internal pilot line pushes the spool up to allow enough flow to the outlet. A by pass check valve allows reverse flow without pressure sequencing. In this circuit 4/3 way valve is in neutral position Fig 17 so the pump flow is flowing into tank without any resistance.



In the actuated condition (Fig 18) the loaded cylinder will complete it's stroke first then after no load cylinder start moving. This is the sequencing of actuation for cylinder with the help of pressure sequence valve.

In other actuated condition (Fig 19) cross connection of port in direction control valve, loaded piston will return back at faster speed as compare to the no load piston.



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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 12v 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.

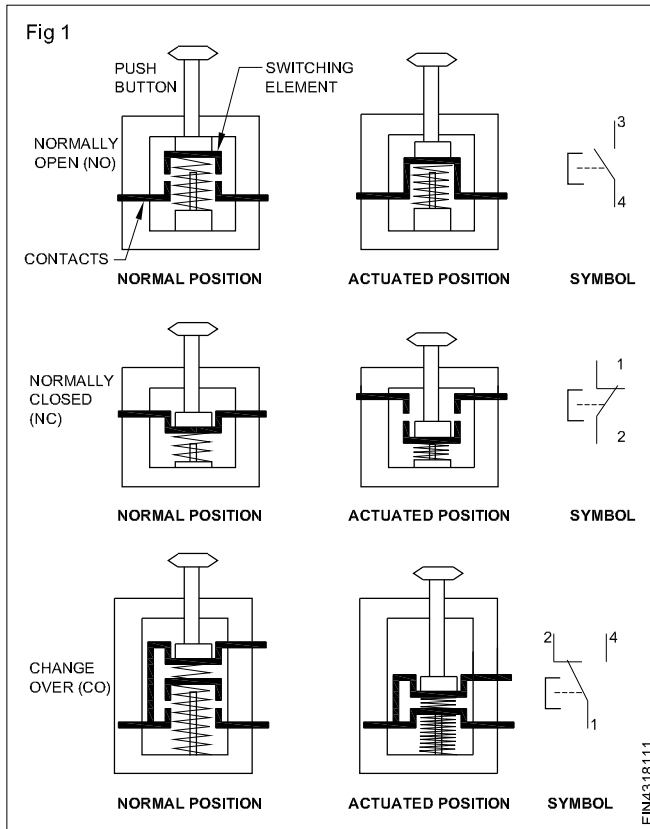
- Normally open (NO) type
- Normally closed (NC) type
- Change over (CO) type.

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.



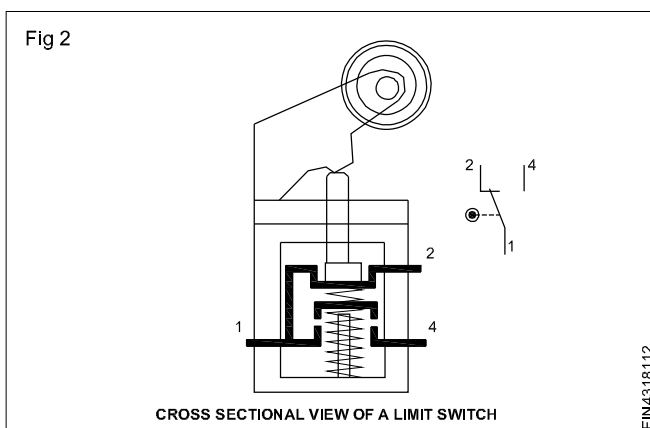
Limit switches perform the same function as push button switches. Push buttons are manually actuated whereas limit switches are mechanically actuated.

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

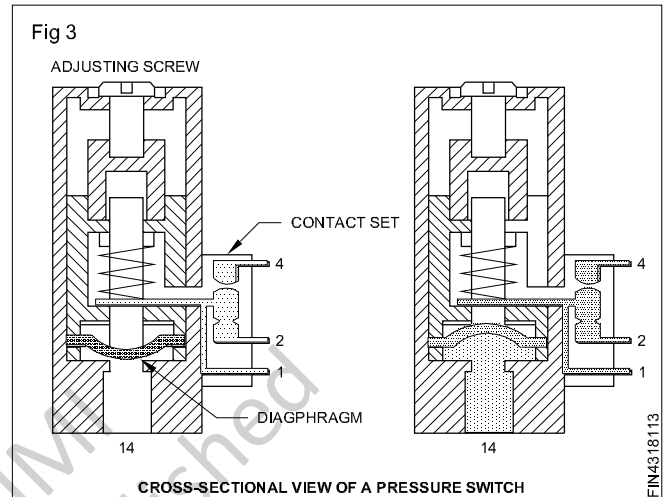
Lever actuated contacts

Spring loaded contacts

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



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. Bellows or diaphragm is used to sense the change of pressure. Bellows or diaphragm is used to expand or contract 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.



Temperature switch

Temperature switches automatically sense 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

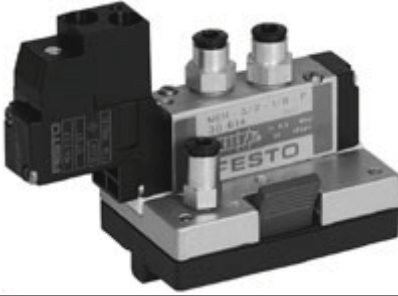
Extension and retraction of cylinder drives.

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



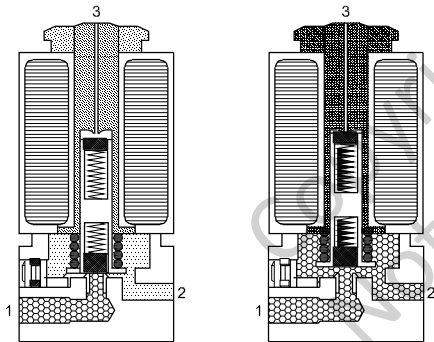
- Double solenoid valves (double solenoid valve) retain the last switched position even when no current flows through the solenoid (fig 5)

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

Fig 6

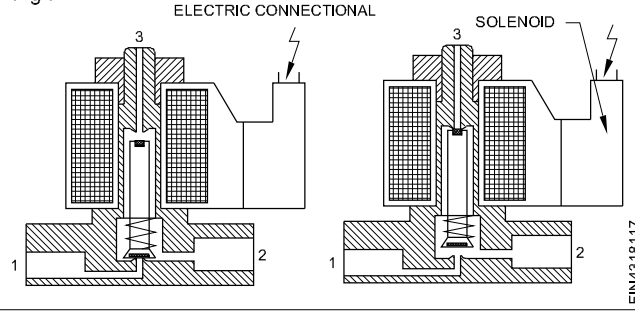


CROSS SECTIONAL VIEW OF A 3/2 SINGLE SOLENOID VALVE

FIN4318116

3/2 way single solenoid valve, spring returners : 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 port 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 7

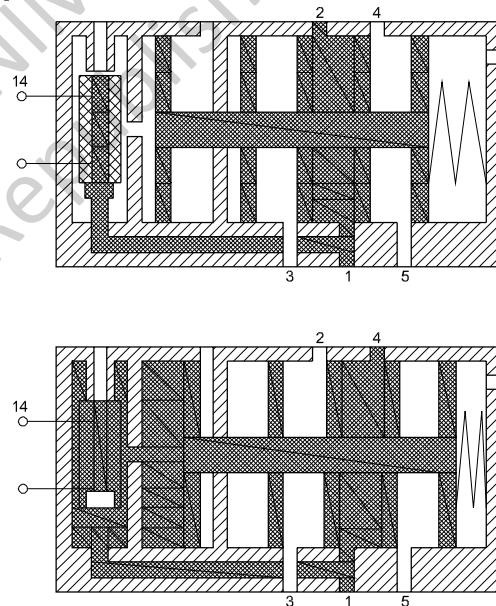


FIN4318117

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 figure 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

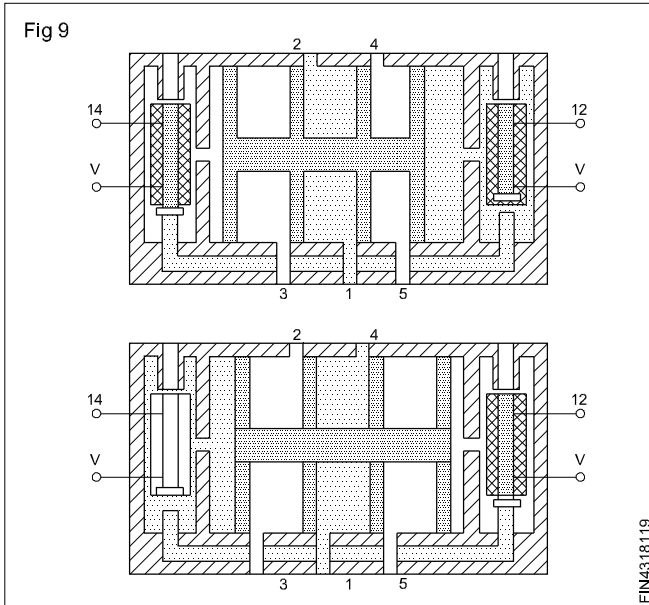


CROSS SECTIONAL VIEW OF A 5/2 WAY SOLENOID OPERATED VALVE

FIN4318118

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.



The symbols for the various solenoid/pilot actuated valves are given in table 1

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)

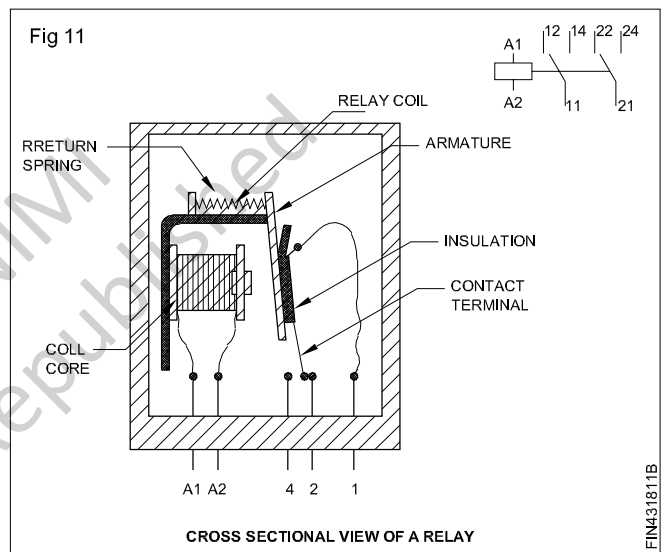
VARIOUS SYMBOLS FOR DCVs

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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.

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.



Symbols for hydraulic components

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

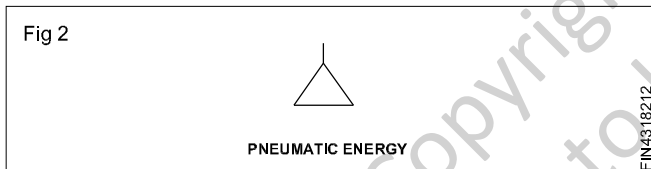
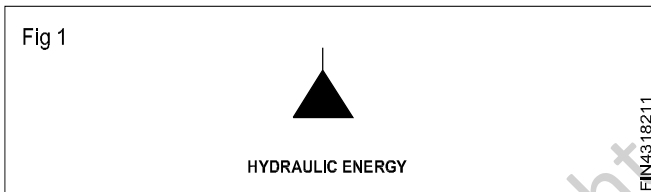
- read and interpret the circuit symbol
- state the uses of symbol in hydraulic components

In a hydraulic circuit symbols are used to represent 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.

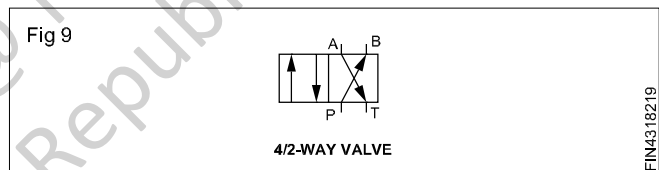
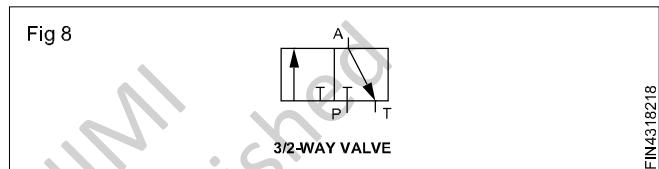
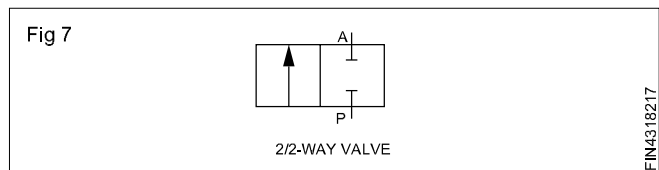
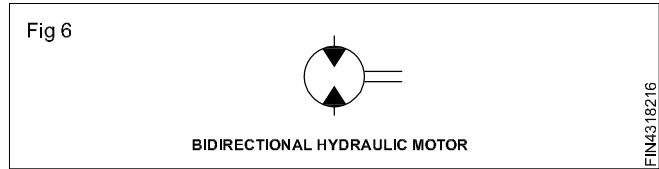
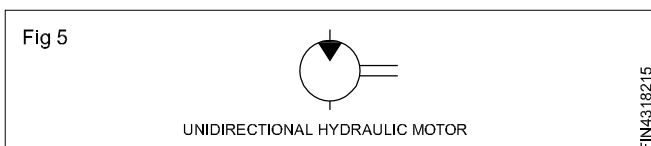
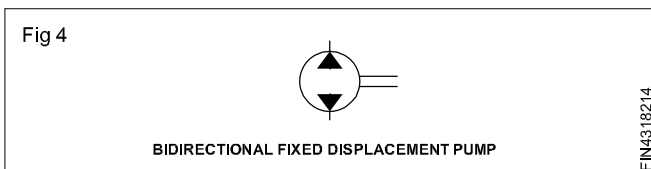
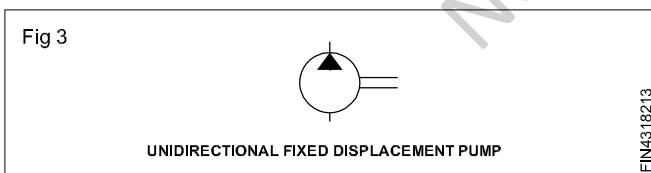
Pump and motor

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)



Symbols of pump and motor (Figs 3 to 9)



Direction control valve

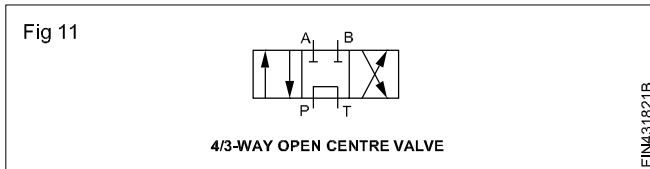
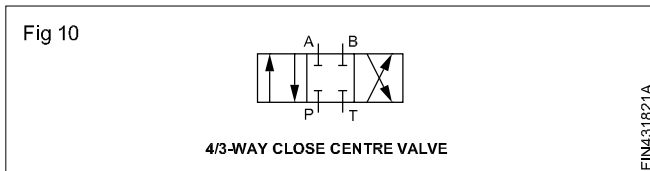
Direction control valves are represented by several connected squares.

- 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)



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

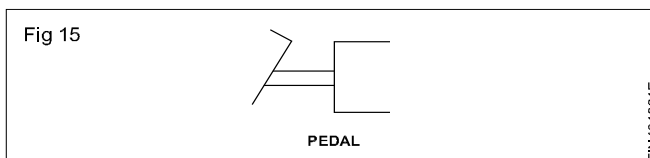
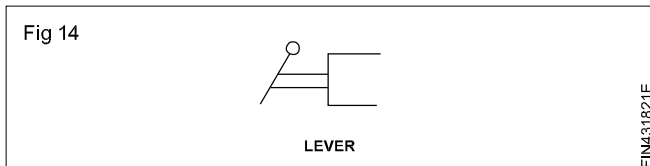
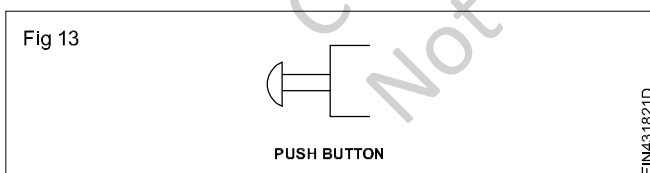
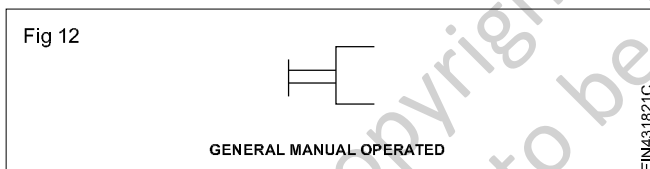
The neutral position is a position which automatically come in valve due to spring force when no any command is available in valve, it is also the initial position unless otherwise actuated.

Actuating mechanism of Valve

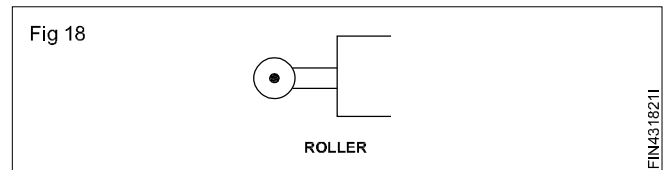
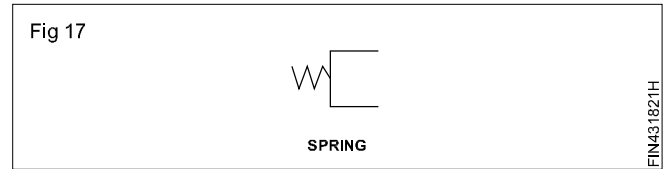
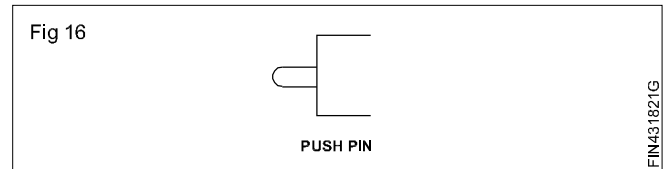
The switching position of direction control valve can be changed by various actuation methods.

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

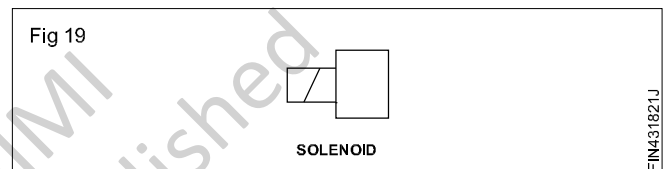
Mechanical actuation



Manual actuation



Electrical actuation

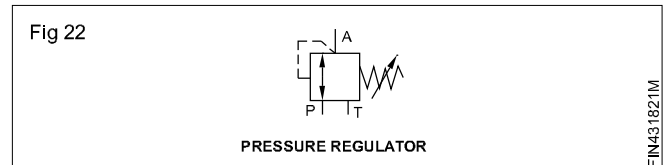
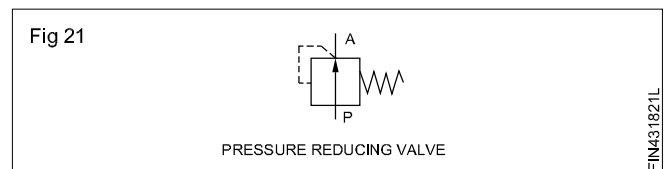
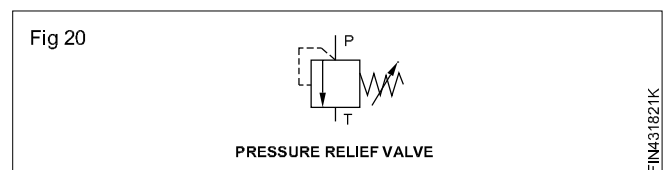


Pressure control valve

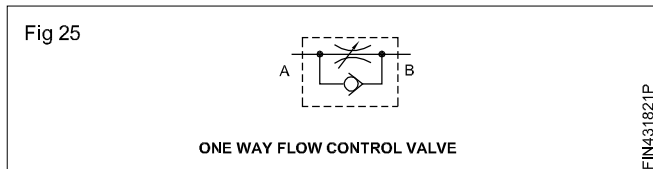
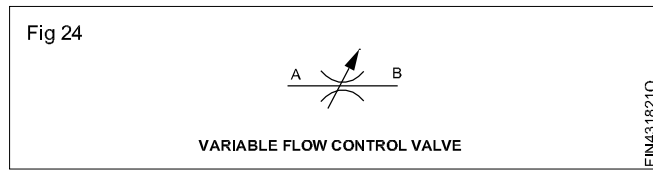
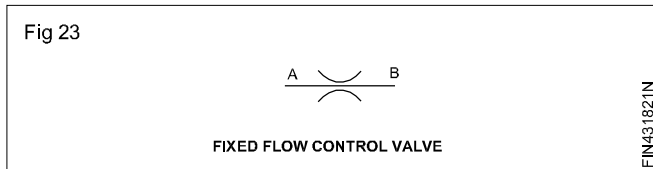
Pressure control valve are represented by a single squares. Arrow within the square indicate the direction of fluid flow.

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)

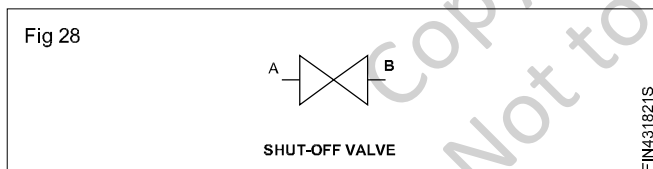
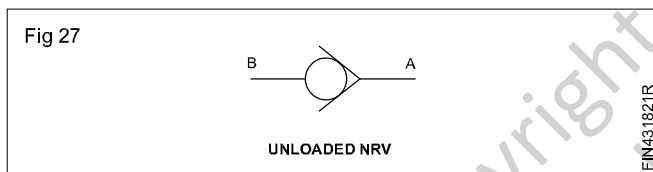
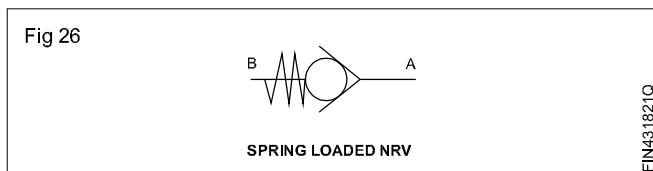


Flow control valve(Fig.23 to Fig.25)



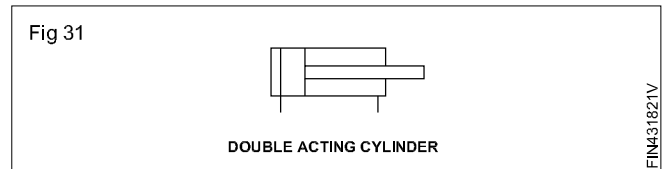
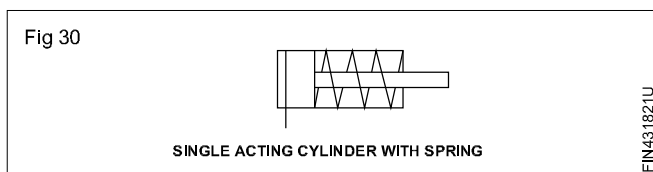
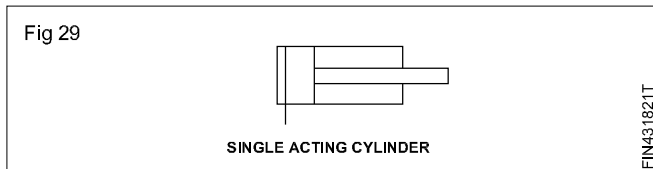
Non-return valves

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



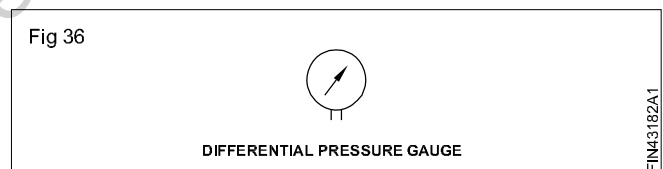
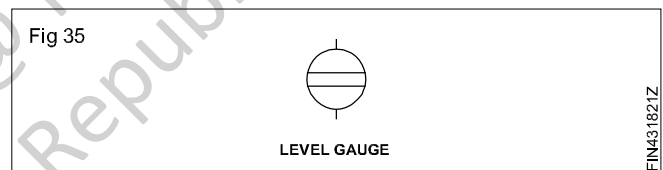
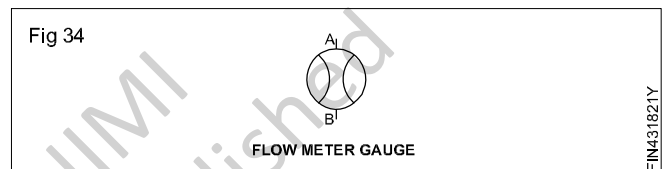
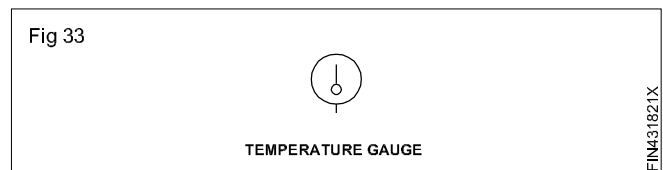
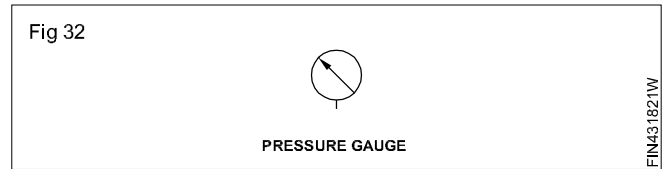
Cylinder

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

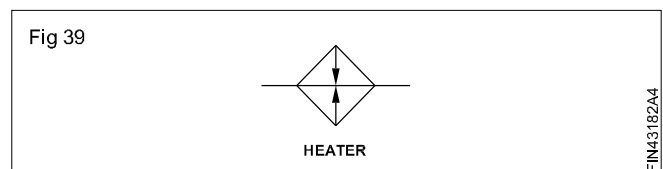
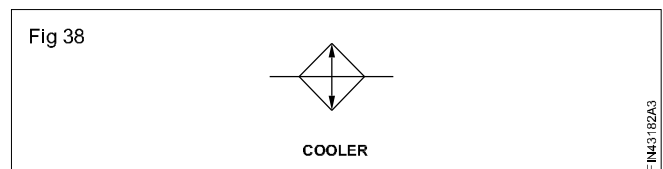
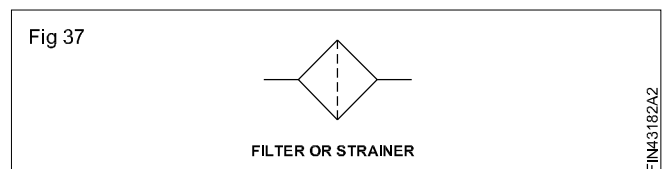


Measuring devices

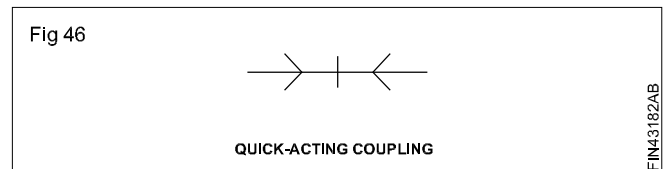
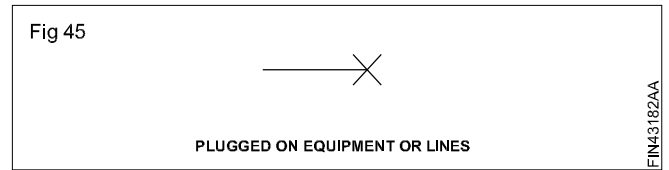
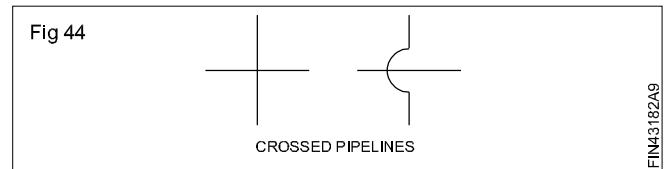
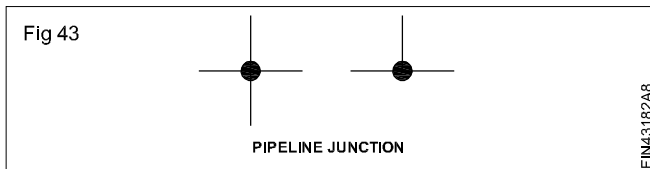
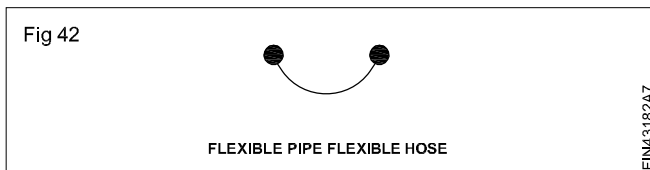
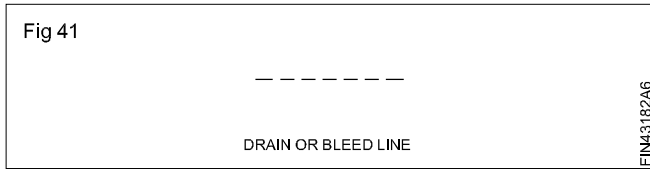
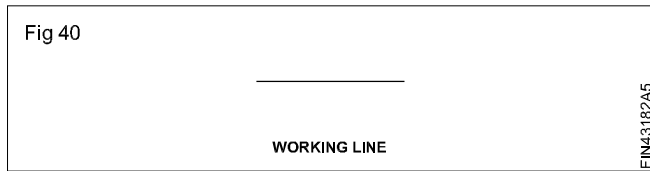
Measuring devices are shown in the Fig.32 to Fig.36.



Other symbols(Fig.37 to Fig.39)



Symbols using Line (Fig 40 to Fig 46)



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 for film 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 Frction modifications Radiation resistance
Environmenal 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.

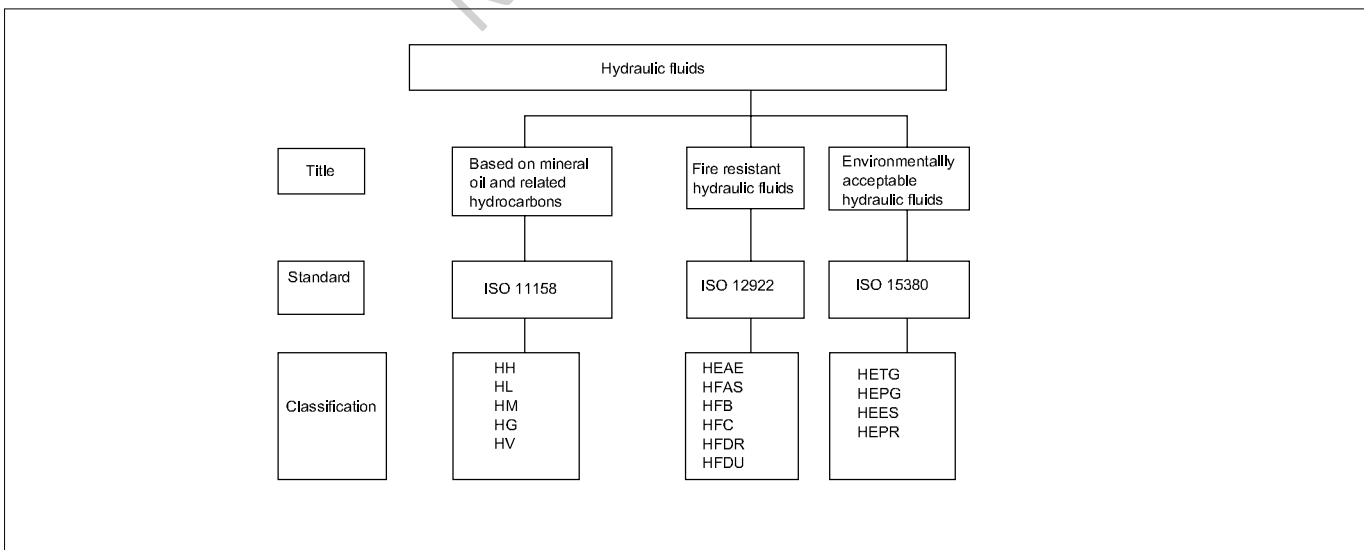
HM is a version of HL- type fluids which have improved anti- wear additives. These fluids use phosphorus, zinc and sulphur components to get their anti-wear properties. These are the fluids mainly used in the high pressure hydraulic system.

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 (Brithish Thermal Unit) compared to those of mineral oil based fluids, such as water-glycol, phosphate ester and polyol esters. 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 (polyol esters).

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 between 2,000 and 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 ingress) 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 micrometers or 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 μm 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, adsorbent, 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

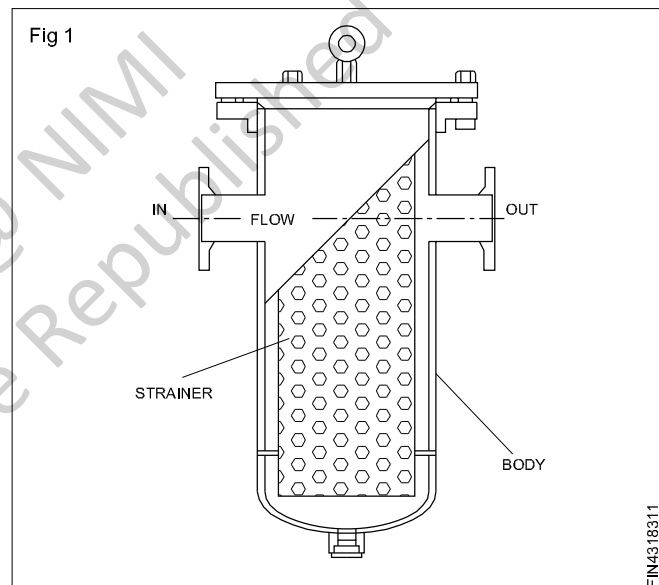
There are four types of filters generally used in hydraulic system.

- 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)



Grade of Mechanical filter: 60-100 μ m

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

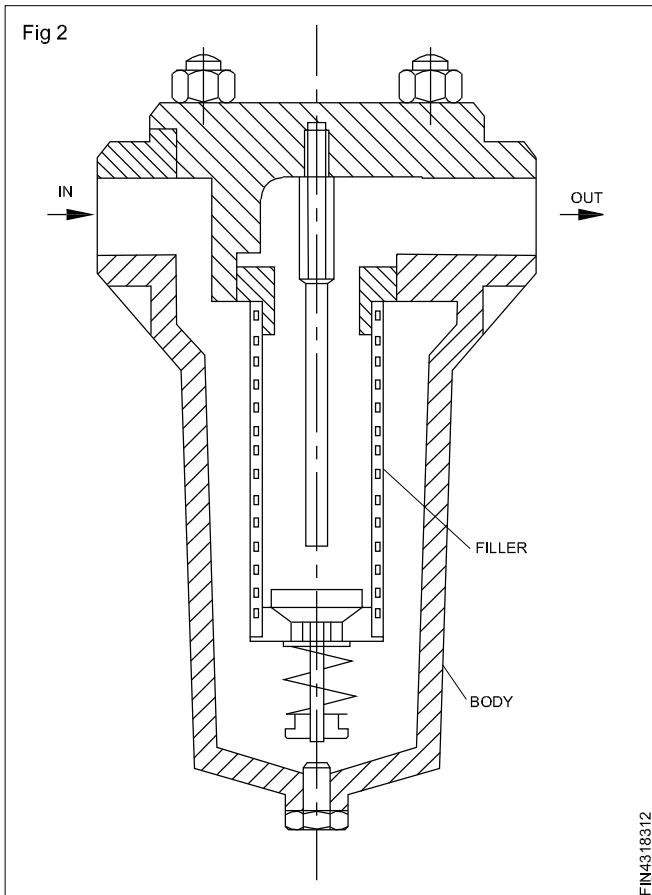
$$1\mu\text{m} = .001 \text{ mm}$$

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.

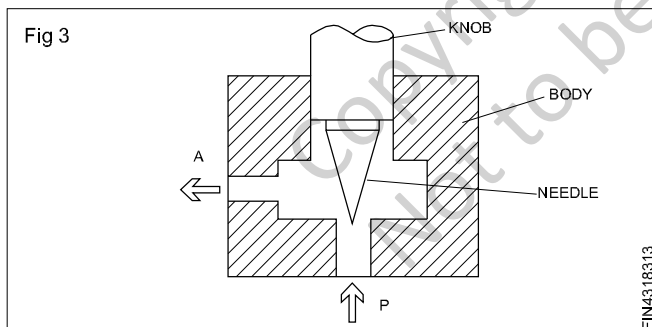
These filters are installed in the pressure line of a hydraulics system at the pressure port of the pump.

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.

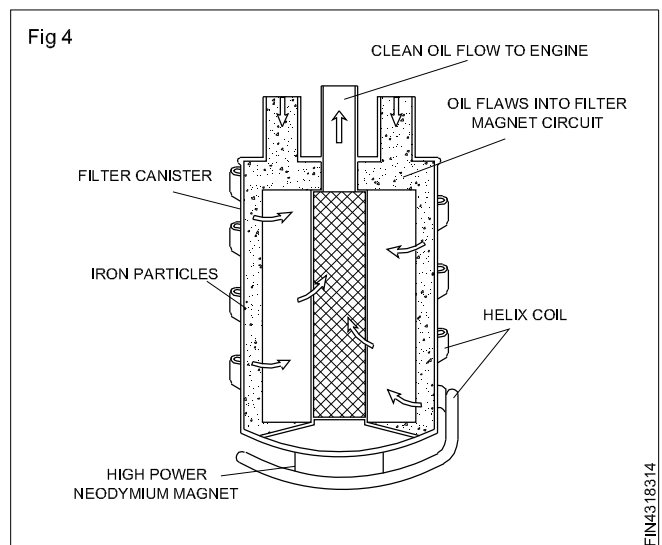
Magnets are geometrically arranged outside or inside the filter which produce a strong magnetic field that help to arrest the ferrous particles from oil.

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

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)



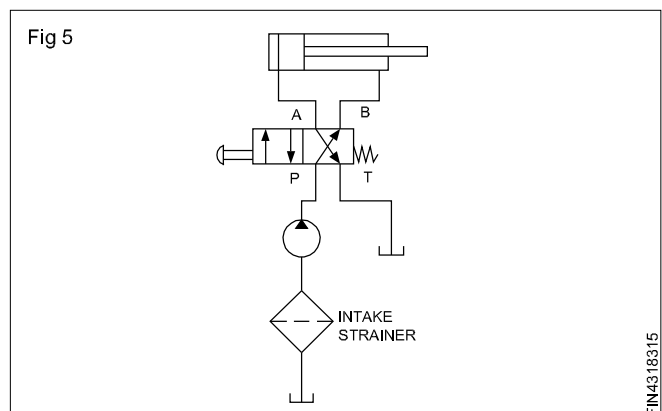
Generally filter can be classified on the basis of their location in hydraulic system:

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

Filter types on the basis of location

Suction stainer

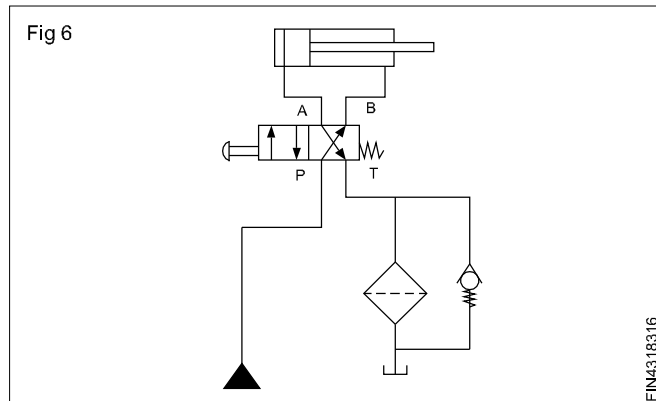
Suction filters serve to protect the pump from fluid contamination. They are located in the upstream of pump's inlet port. Inlet strainers are submersed in fluid in the tank. Suction filters have relatively coarse elements, due to cavitations limitations of pumps.(Fig.5)



Return line filter

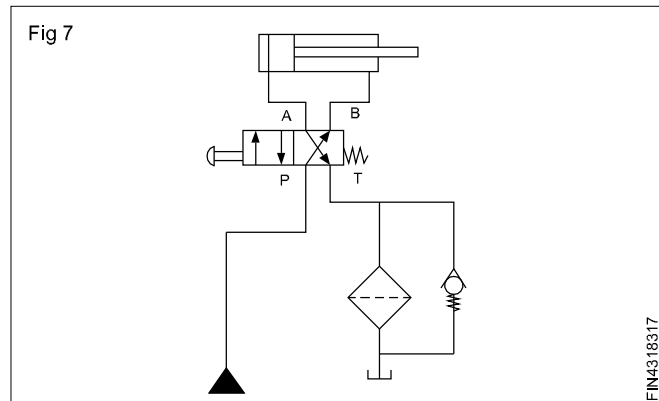
Return line filters may be the best choice if the pump is particularly sensitive to contamination. In most systems, the return filter is the last component through which fluid passes before entering the reservoir. Therefore, it captures wear debris from all of the system's working components and any 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)



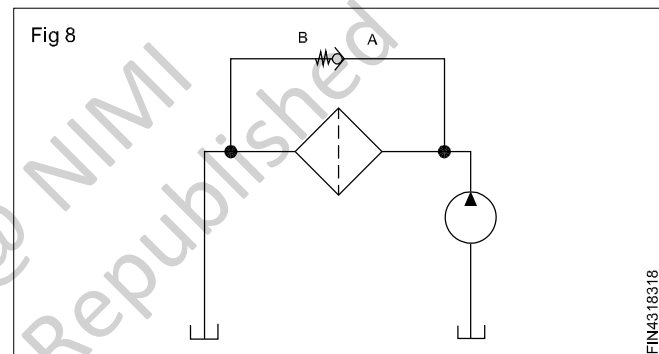
Pressure line filter

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)



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).



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

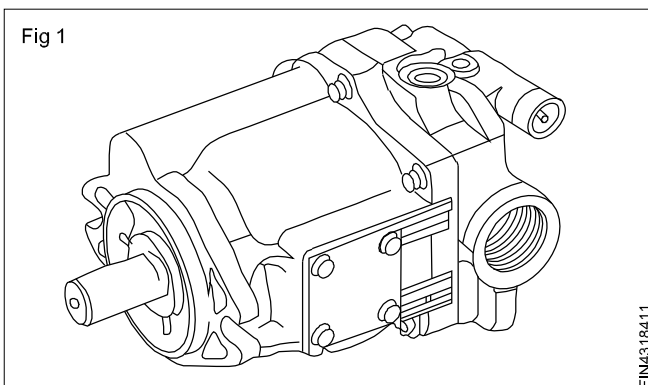
Due to high pressure with in a hydraulic system, the impact force of a disconnected and flailing hydraulic hose can cause abrasions, temporary unconsciousness, bruise, fractures and lacerations. Proper maintenance and good pre - shift equipment inspections can minimise these hazards

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.**

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.



Classification of pumps

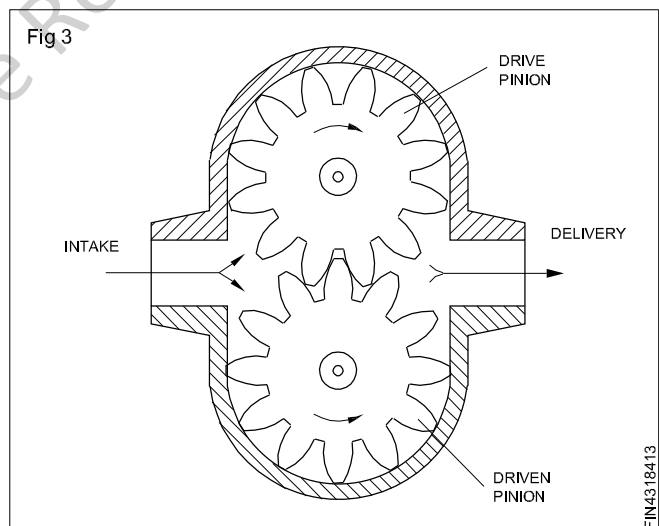
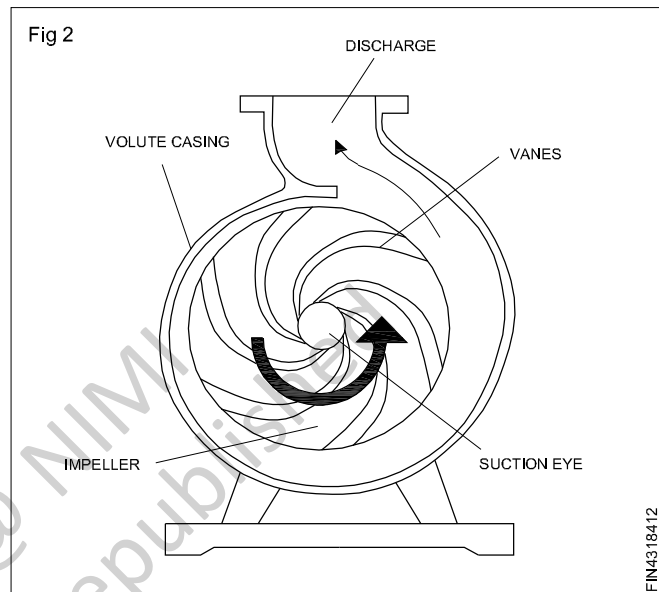
Pumps are classified as either non-positive or positive displacement. This describes the fundamental division of pumps.

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)

Positive displacement pumps (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.

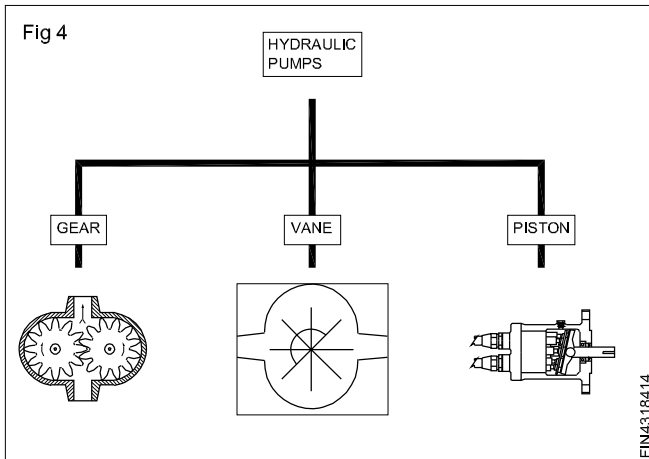


Types of Hydraulic pumps(Fig. 4)

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)

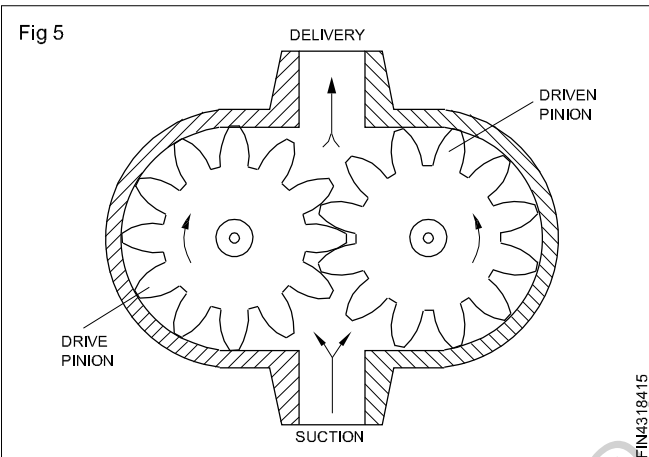
As gears rotate the volume of area on the inlet increases, thereby decreasing the pressure and making it possible for the atmospheric pressure exerted on the surface of



- Displacements volume 0.2 to 200 Cm³/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.



Internal gear pump

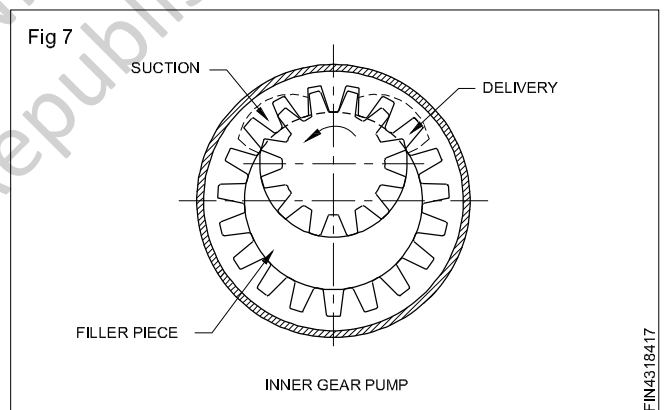
Two gears are available in internal gear pump. The spur gear is mounted inside a large ring gear (outer gear). The smaller spur gear is in mesh with one side of the larger gear and kept apart by a crescent-shaped separator on the other side. The crescent-shaped separator isolates the inlet port from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

As the gear teeth un-mesh, a partial vacuum is created

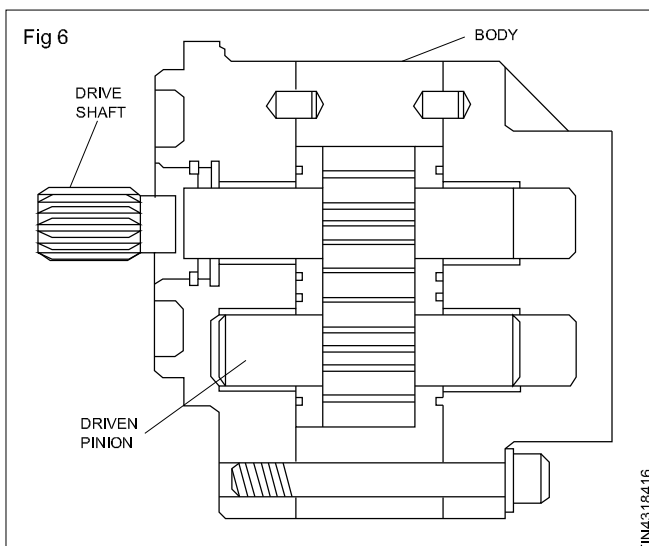
the liquid in the reservoir to push the liquid into the inlet port. This causes liquid to be trapped in the gear space as the gears rotate and to be carried from the inlet port to the discharge port.

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



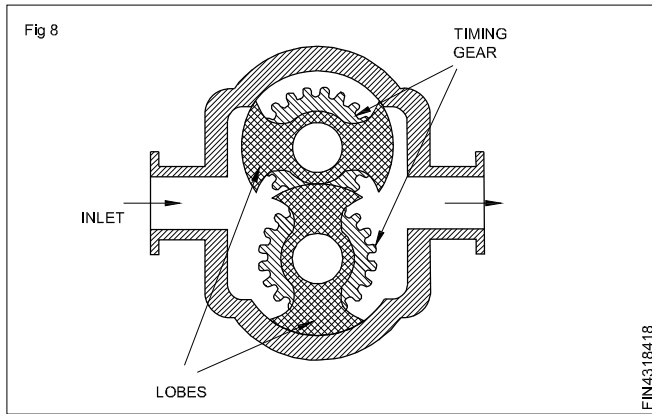
on the inlet side. Atmospheric pressure forces liquid into the space created, and with the rotation of the gears, liquid is carried around the periphery of the gears and the crescent-shaped separator until it reaches the outlet port. A continuous flow of liquid is pushed out through the outlet port.

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.

Lobe pump

Lobe pump is a multiple rotor type of pump and the rotor utilizes a lobe shaped design. The working is similar to the external gear pump except that unlike gears, the lobes do not directly make contact with each other. The relative motion is synchronized by means of timing gear and therefore the internal contact between the lobes is a sealing contact and not a driving contact. (Fig. 8)



The suction and discharge of the pump is primarily decided by the direction of rotation of the lobes. Let us look into the internal of the pump and its operation.

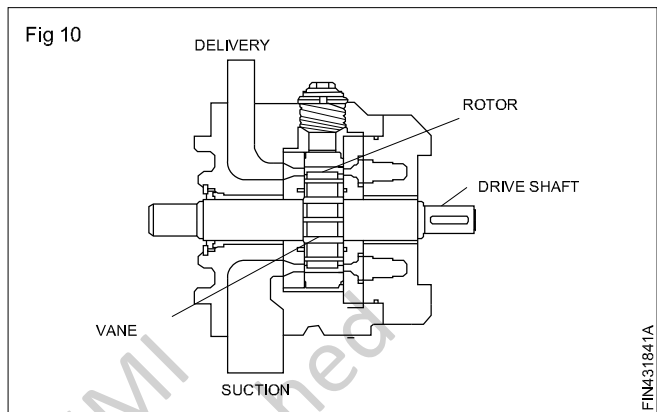
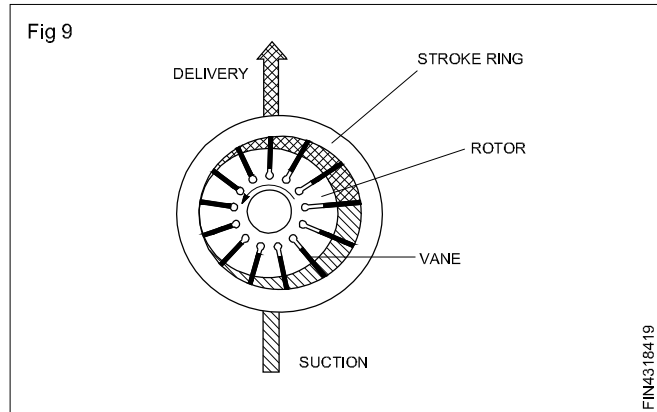
At the suction side, as the lobes come out of mesh, liquid flows into the pump. The liquid is further carried in the space between the lobe and the casing to the discharge side of the pump. Towards the discharge side the lobes come back into mesh and the liquid is forced out the discharge port.

Since the lobes do not directly mate, lobe pumps are suitable for handling liquid with suspended solids. However this feature reduces its performance especially while handling low viscosity fluids. As the pump has a clean internal surface with few crevices the pump can be used for hygiene related application.

Vane Pump

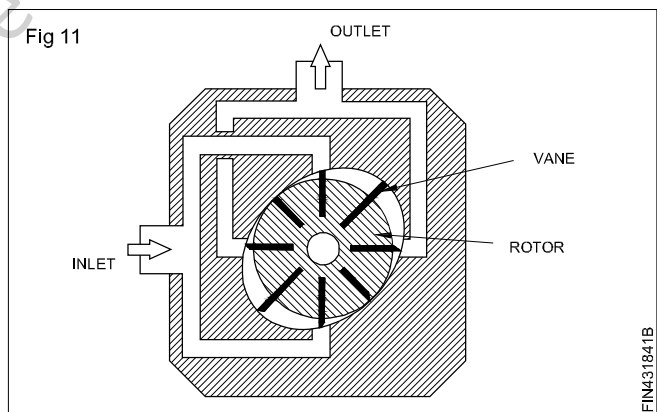
Vane pump is very common type of pump. The vane pump having slots in the rotor. When the rotor spins, centrifugal force pushes the vanes out to touch the casing, where they trap and propel fluid. Springs are used to push the vanes outward. When the vanes reach the delivery side they are pushed back into 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.9)

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.10)



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.11)



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.

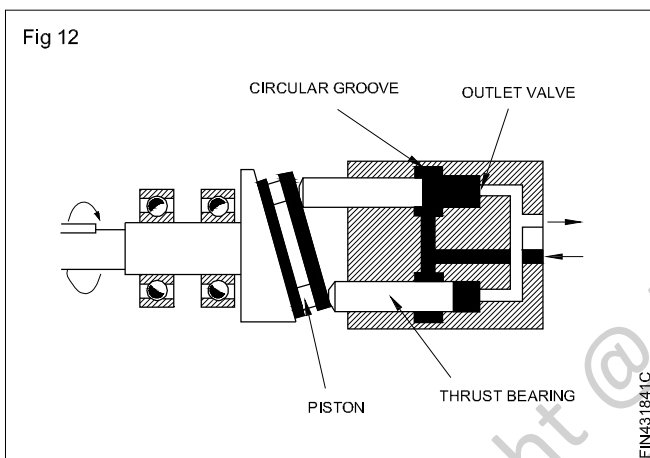
Piston pump

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

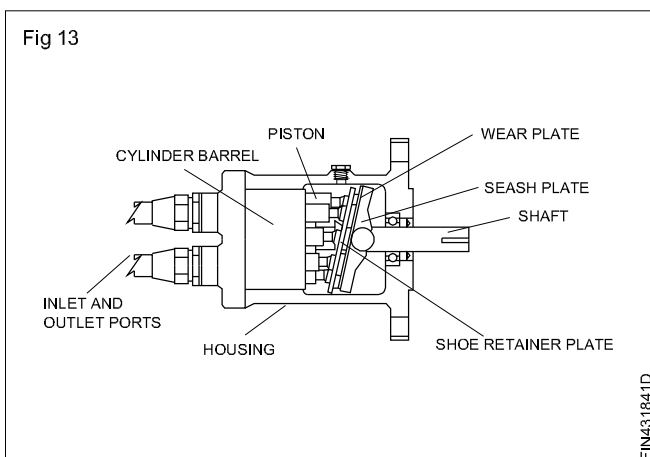
Axial piston pump

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.12)



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.13)



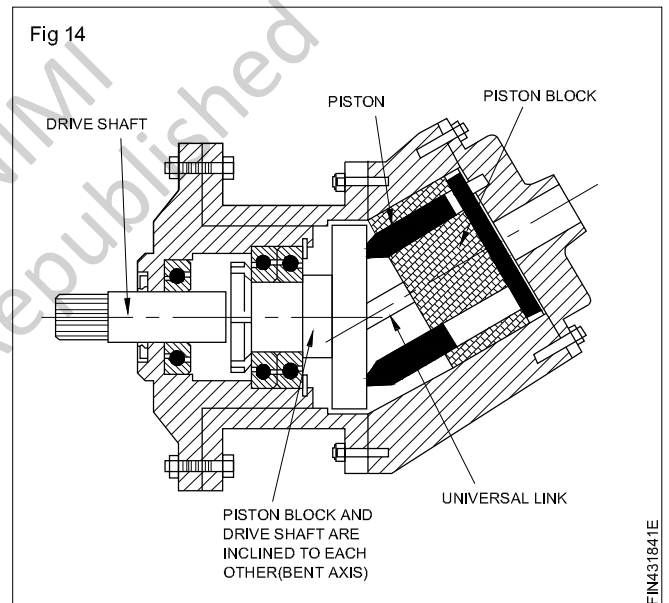
As the drive shaft rotates, it rotates the cylinder block and the pistons. The offset position of swash plate in pump block causes the pistons to move back and forth in the cylinder block. The shaft, pistons and cylinder block rotate together.

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 14).



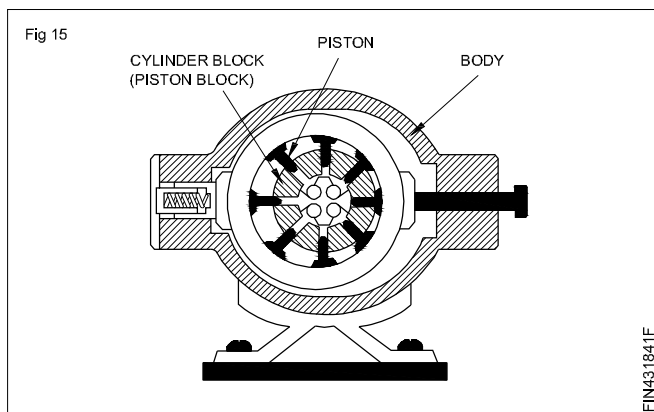
There are several piston housing within slots in the piston-block and they are connected to the drive shaft-flange. A universal link key the piston-block to the drive shaft to maintain alignment and to assure that they rotate together.

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.

Radial piston pump

A typical picture of a radial piston pump is illustrated. The pump has several pistons those are uniformly

spaced and housed radially in a cylinder block (Piston-block). The pistons reciprocate in radial direction to the cylinder-block axis and hence the term radial piston pump.(Fig.15)



The drive shaft transmits drive torque to the piston-block by means of a cross-disc coupling. The piston-block rotates around a pintle, which has ducts routed to inlet and outlet connections behind the pump. There are several pistons arranged radially inside slots in the piston-block, which against a stroke ring through slipper pads. The piston is connected to the slipper pad by means of a ball and socket joint and the slipper pad is guided in the stroke ring by means of two overlapping rings. The stroke ring is eccentrically located with respect to the piston-block.

When the piston block is rotated, the pistons are forced against the stroke ring by centrifugal force and hydrostatic pressure. Sometimes springs are also used for this purpose. Since the stroke ring is eccentric to the piston-block, in one half of the rotation the pistons move away from the piston-block. Thus liquid is drawn through inlet ports in the pintle into slots in the piston-block. In the other half of the rotation, the pistons move into the piston-block, thus forcefully discharge liquid trapped in the slots, into outlet ports in the pintle. If the eccentricity increases the stroke length also increases and it amounts to twice the eccentricity.

Important parameters

Piston pump applications:

Piston pumps are commonly used for high pressure and low discharge applications.

- Displacements to 750 cm³/r
- Pressure capabilities to 350/400 bar
- High noise level
- Sensitive to poor inlet conditions & contamination
- High overall efficiency
- Good life expectancy
- Large, bulky units
- High cost.

Piston pump applications

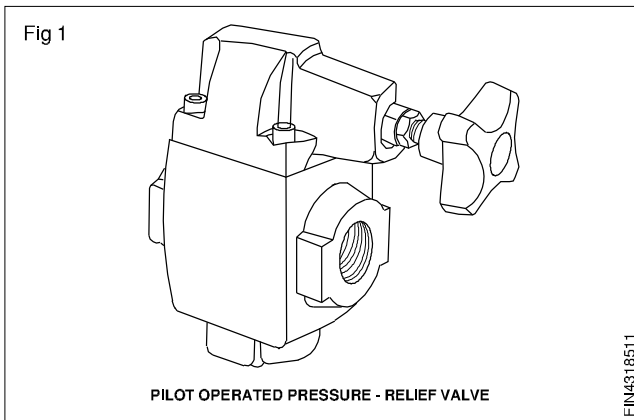
Piston pumps are commonly used for high pressure and low discharge applications.

Pressure relief valve

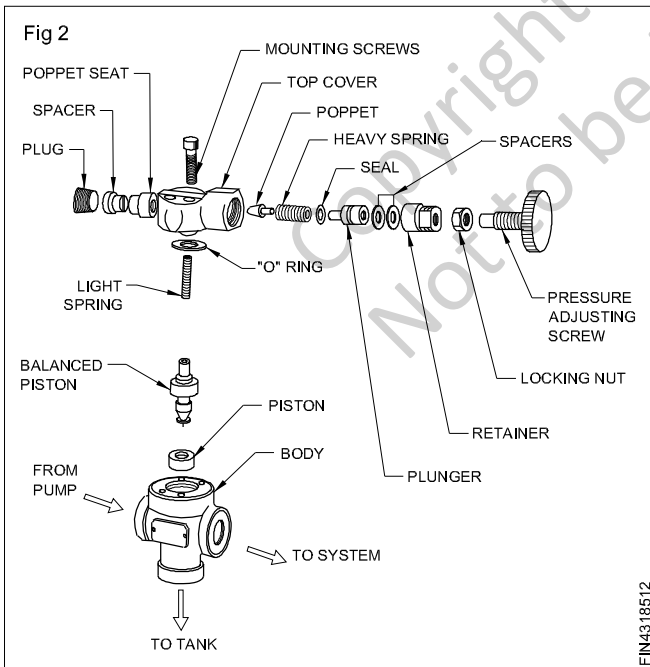
Objectives: At the end of this lesson you shall be able to

- 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.



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



Body
Top cover
Piston
Light spring
Piston seat

Poppet
Poppet seat
Heavy spring
Adjusting screw

Body

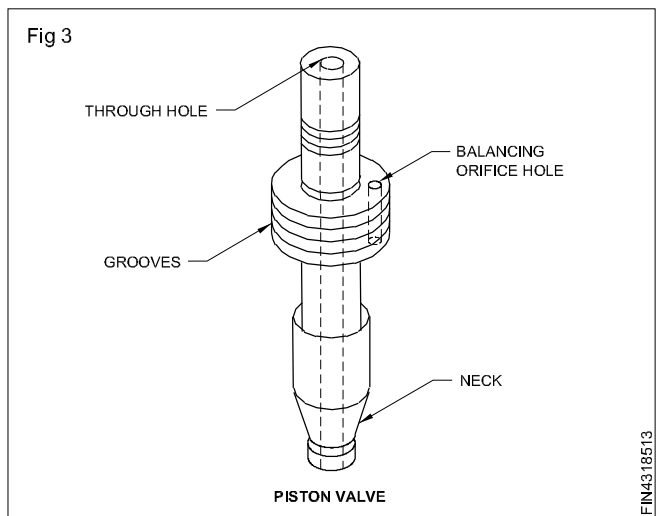
Body of the valve is a fine grade cast iron. The inside of the casting is accurately machined to accommodate piston, piston seat and tight spring. Body is fixed with top cover by screws. Ports for inlet outlet and drain connections are provided in the body, as threaded holes. The body accommodates the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

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.

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.

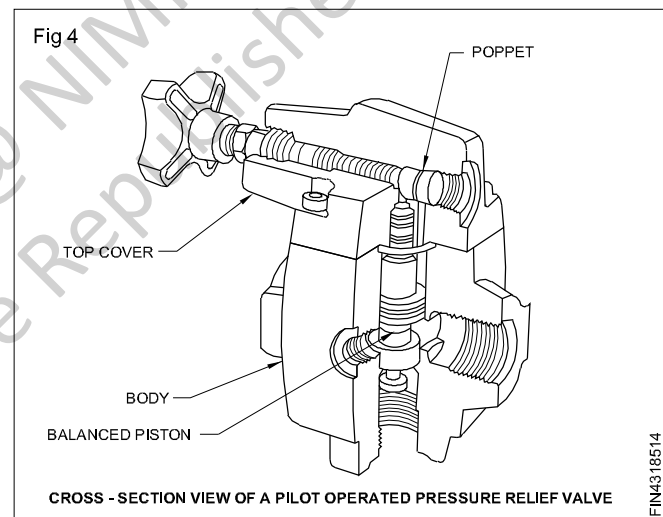
This spring is housed in between a plunger and maximum diameter of the poppet. When the force exerted by the oil at pilot port is more, the heavy spring lift off the poppet, to relieve oil. The tension of spring is adjustable by means of knob.

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.



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.

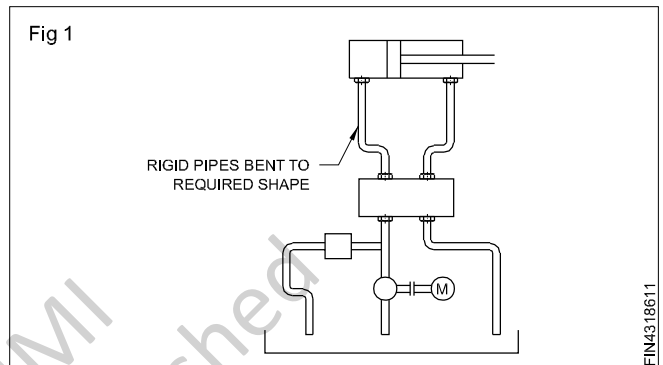
Tube material

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 is 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)

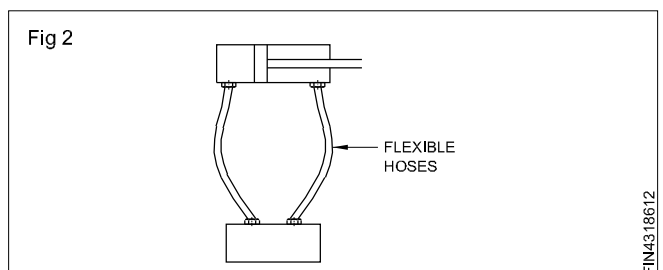
This type of connection is done where the circuit only built will not have any change in design or change in the position of the elements in future.

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)

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.

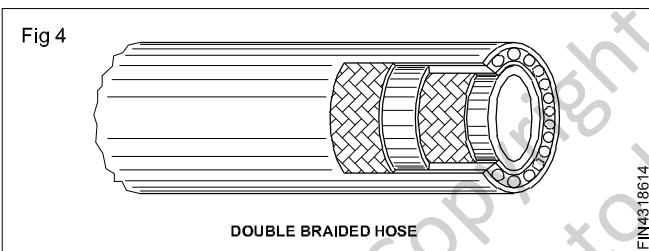
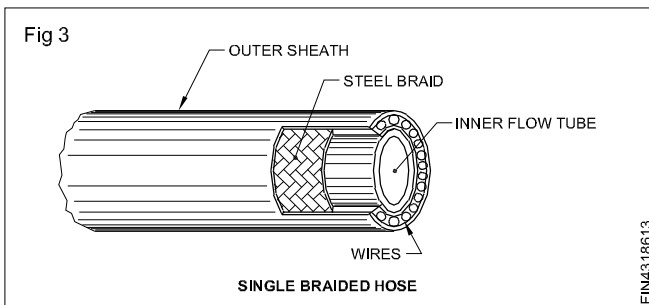
Types of flexible hoses

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.

Whereas wire braided hoses because of steel wire used is good in withstanding high pressures up to 300 cm² 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 values 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 be mounted to suit a variety of connectors, it is also available with various end fittings. There are many types of end fittings available as required by customer. Some of them are shown in Fig. 5.

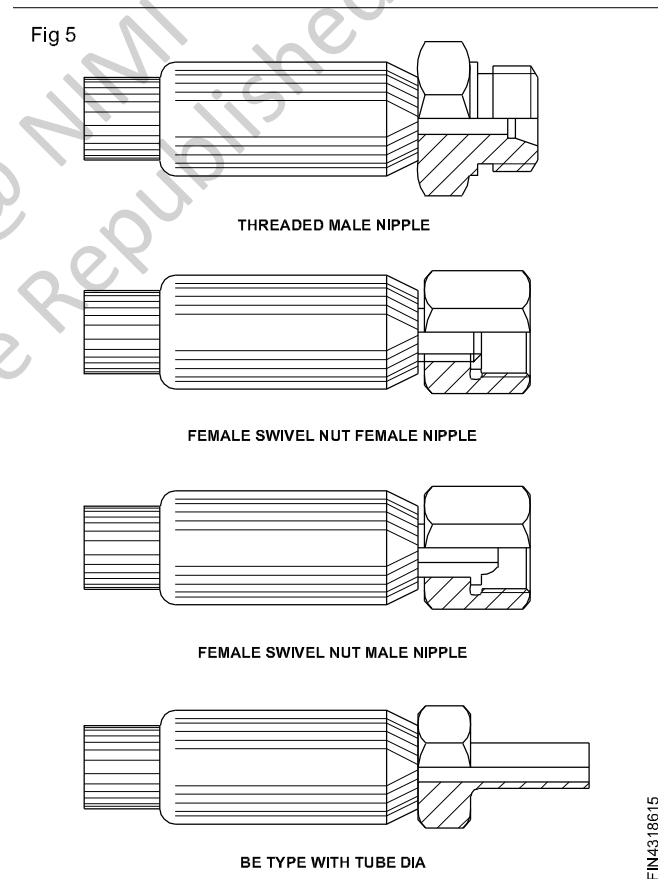
Specification of hoses

Flexible hoses are specified according to the following information,

- 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.



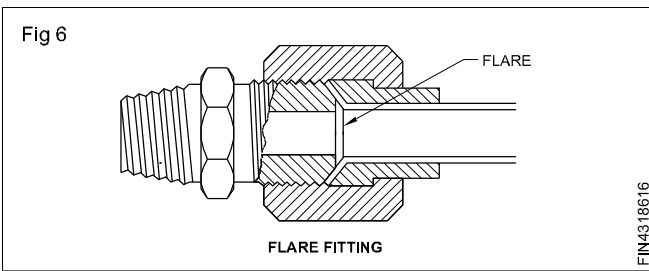
Connectors

Connectors are the elements which connect 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.

According to the type of sealing design

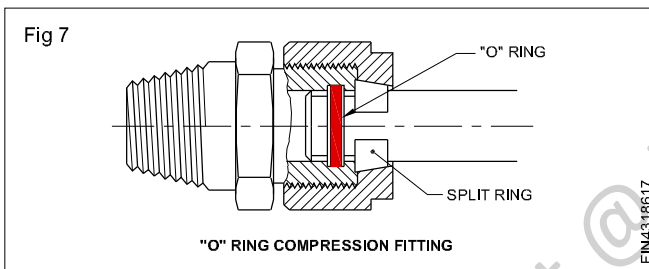
Flared fitting (Fig. 6)



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

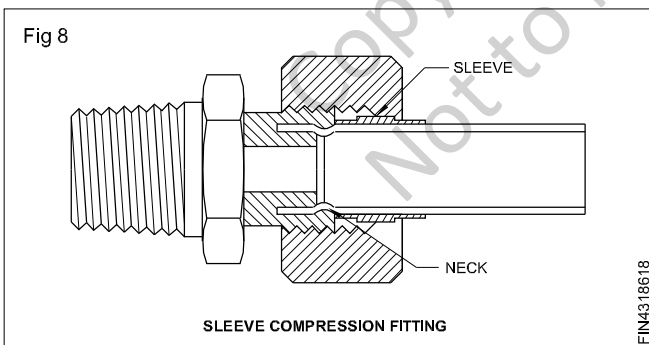
'O' ring compression fitting (Fig 7)

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



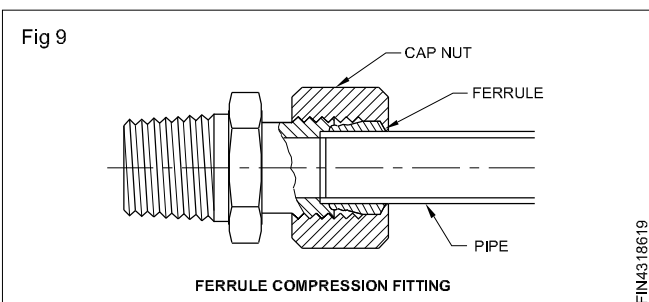
Sleeve compression fitting (Fig 8)

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



Ferrule compression fitting (Fig 9)

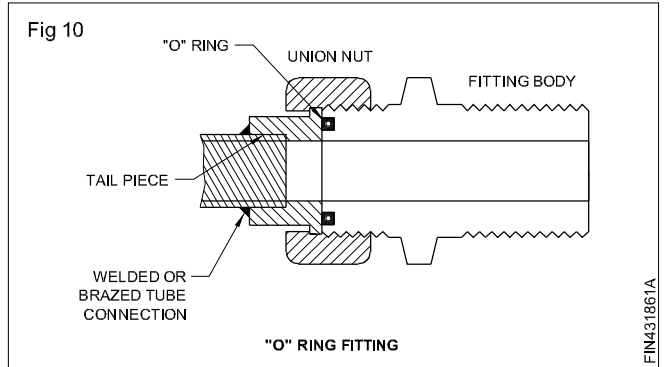
In this, the ferrule is of a special design, ferrule bites into the tube to form a permanent seal.



O' ring fitting (Fig. 10)

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.

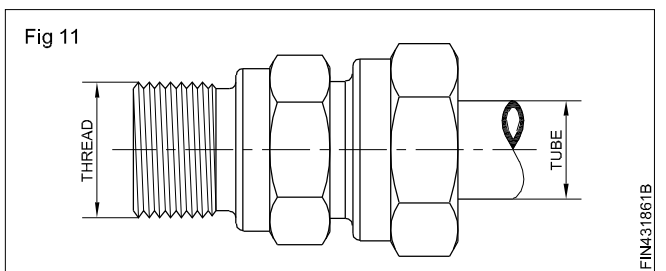
According to the size, shape and purpose of use

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.

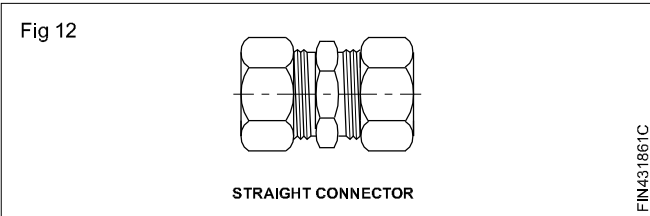


Pipe outside dia	British standard pipe thread (BSP)	Metric Fine thread
6	R 1/4"	M22 x 1.5
8	R 1/4"	M14 x 1.5
10	R 3/8"	M16 x 1.5
12	R 3/8"	M18 x 1.5
14	R 1/2"	M20 x 1.5
16	R 1/2"	M22 x 1.5
20	R 3/4"	M27 x 2
25	R 1	M33 x 2
30	R 1 1/4"	M42 x 2
38	R 1 1/2"	M48 x 2

The various types of connectors in this category to take care of the flow direction of fluid as follows

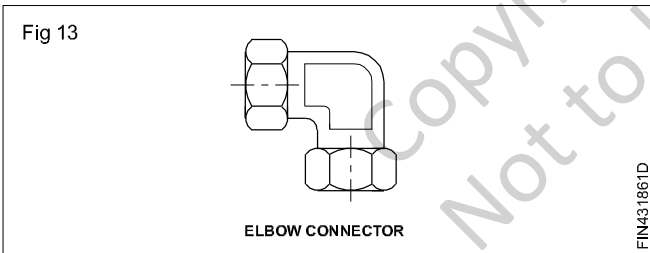
Straight connector (Fig 12)

To connect tube perpendicular to the body.



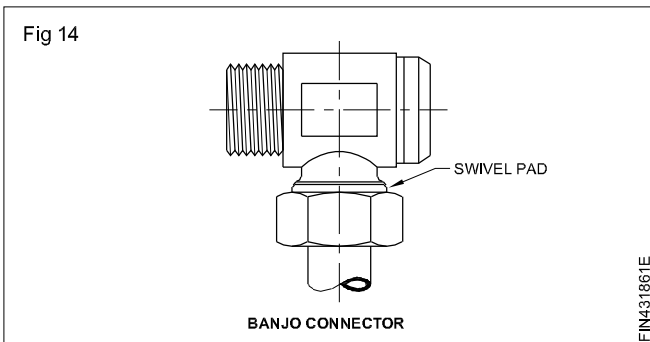
Elbow connector (Fig 13)

To connect the tube end parallel to the body of the hydraulic elements.

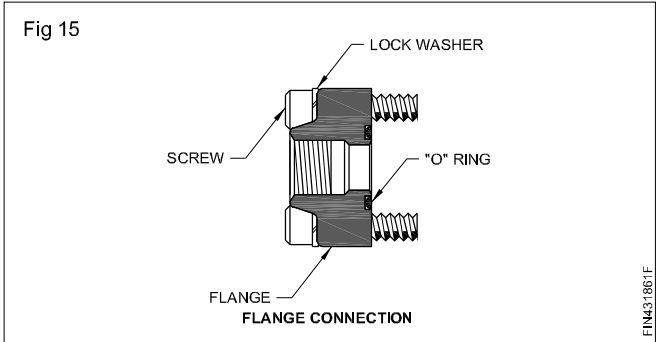


Banjo connector (Fig 14)

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.

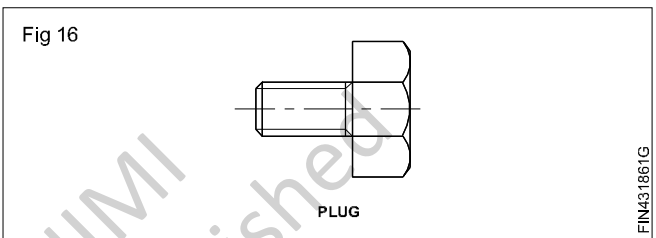


Flange connection (Fig 15)



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.

Plug (Fig 16)

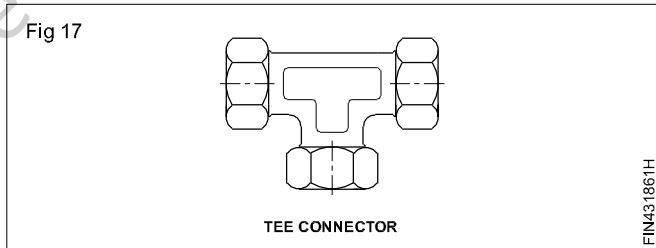


A plug is used to block any port of the hydraulic element.

To connect a tube end to another tube end

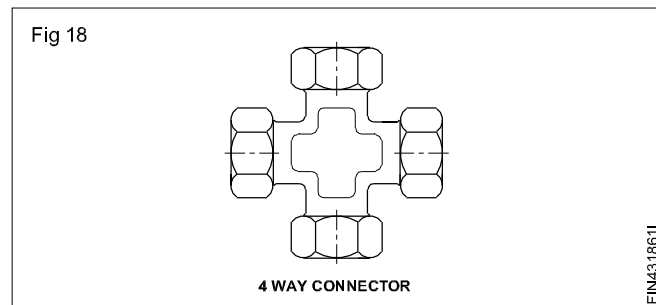
'T' connector (Fig 17)

Used to connect three pipe ends at a junction.



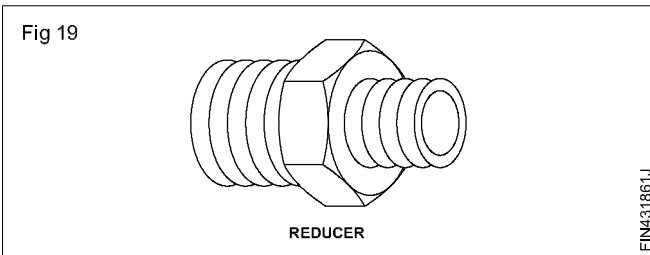
4 way connector (Fig 18)

Connect 4 pipe ends at a junction.



Reducer (Fig 19)

Connect two pipe ends of different size.

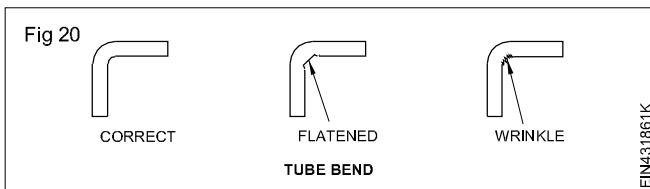


Do's and don'ts in tube/hose fitting:

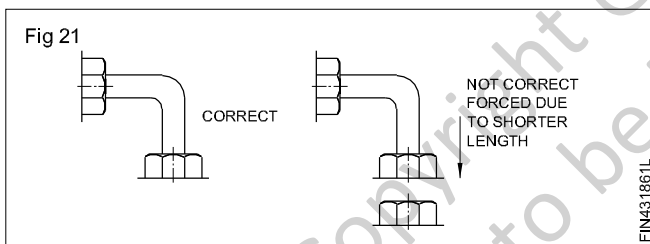
Life of tube/hose fitting depends very much on how the fitting has been designed and installed.

In case of the rigid connections the following has to be observed:

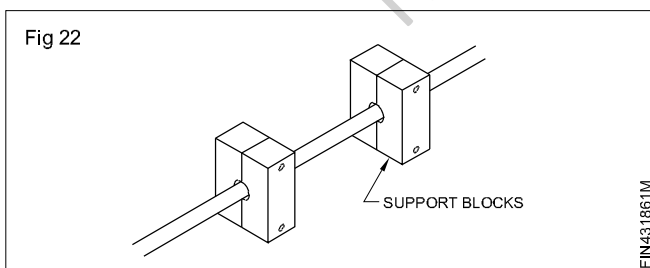
Tubes should be bent such that the bend has no flats or wrinkle at the bent corners. (Fig. 20)



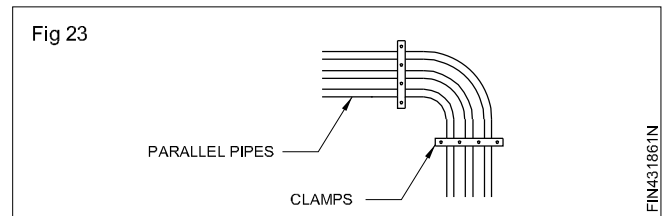
Tubes should be installed and removed without springing, bending or damaging the tubing. (Fig 21)



Support for tubes along the length if more than 1 meter long. (Fig 22)

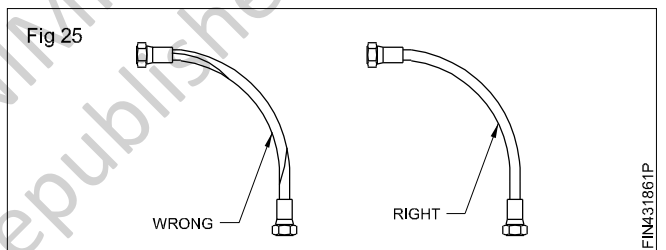
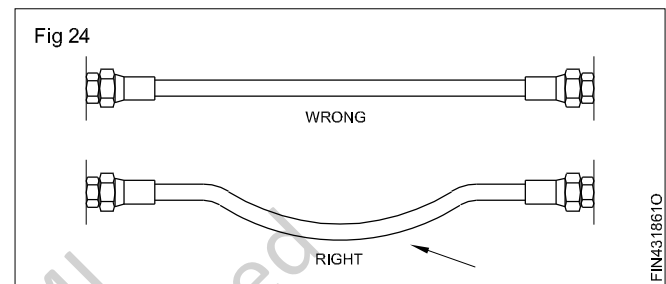


- Use minimum number of connectors.
- Use minimum number of bends in tubing.
- Design pipe lines in a neat and straight way to make fixing and maintenance easy. (Fig 23)
- Use tubes and connectors according to the working pressure of the circuitry.
- Make sure tubes are kept clean and clear from chips dust etc. that enables to deduct apparent oil leakages.

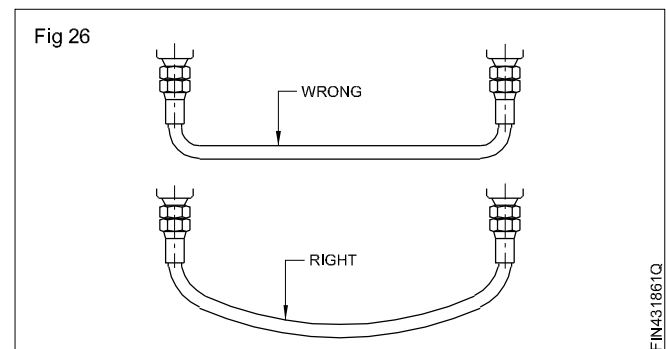


Points to note while using flexible hose connections

- 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)

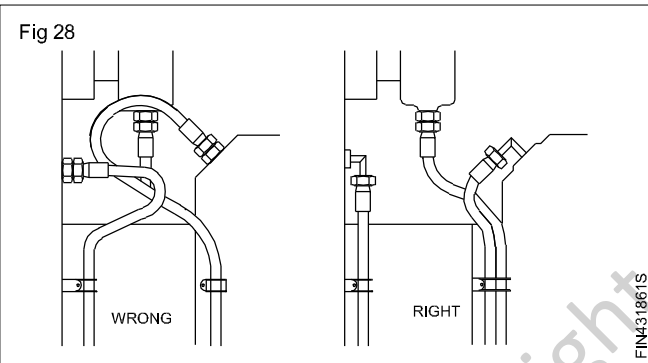
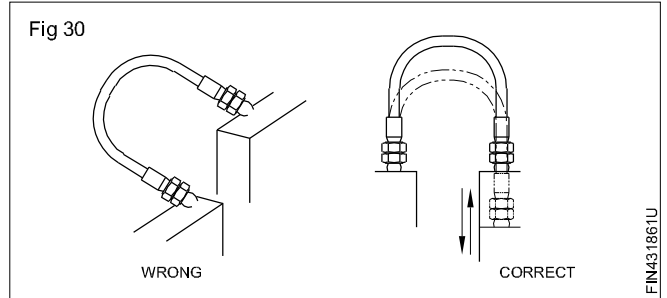
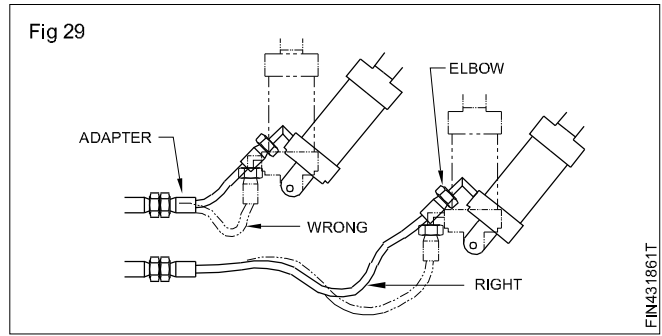
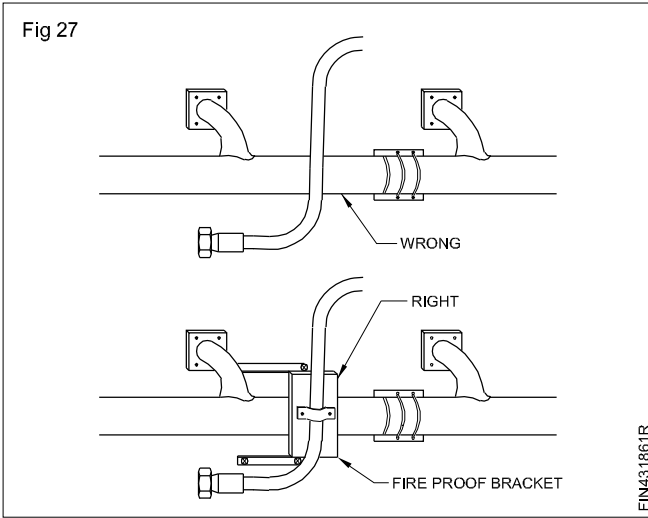


- If high operating pressures are applied to a twisted hose, the hose may fail or the attaching nut becomes loose.
- Keep the bend radii of the hose as large as possible to avoid collapsing of line and restriction of flow. (Figs 26 and Fig. 25)

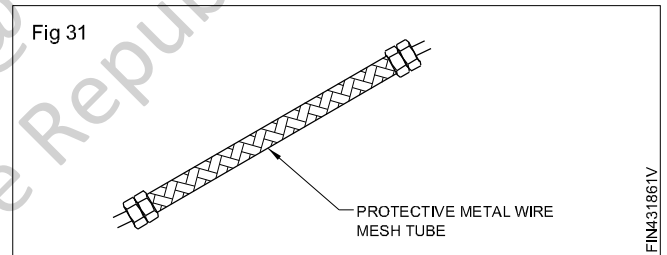


- When hose lines pass close to a hot exhaust manifold protect the hose with a fire proof boot or metal baffle. (Fig. 27)
- Use elbows and adapters to ensure easier, cleaner installation for quick inspection and maintenance. (Fig. 29)

- 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)



- 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)



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

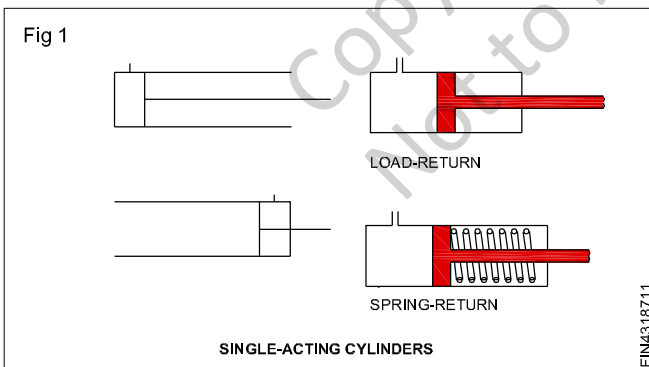
A hydraulic linear actuator is basically a cylinder, used to convert the hydraulic pressure and flow into a linear mechanical motion or force. Cylinder can be coupled with different types of mechanical linkages to produce enhanced or restricted movements in the combination of linear and rotary motions. 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.



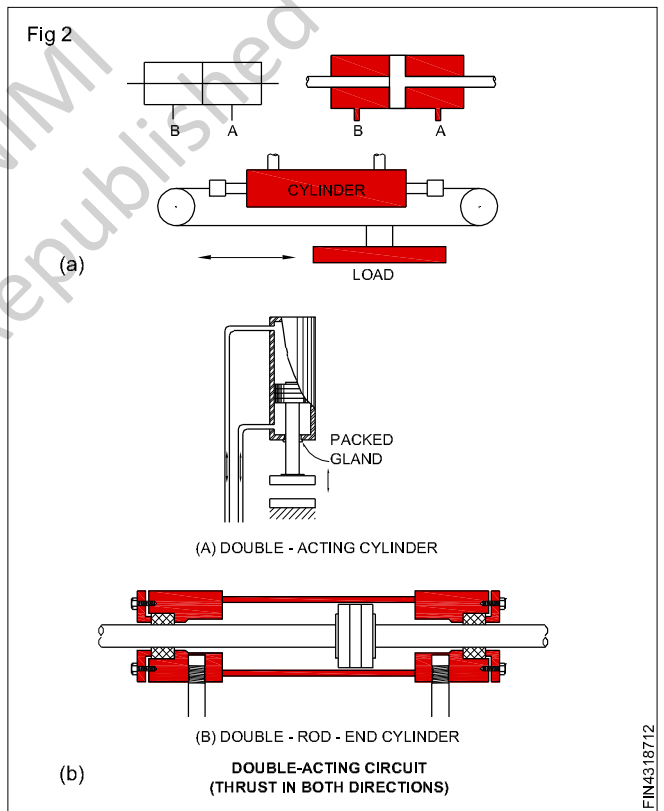
Useful work or movement can be attained from the free end of the piston-rod. After expansion of the oil, the spring tension overcomes the oil pressure. Now the spring pushes the piston to the left hand side. The oil is expelled through the same port.

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 propor-

tional 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)



Construction of a double acting cylinder (Fig 3a)

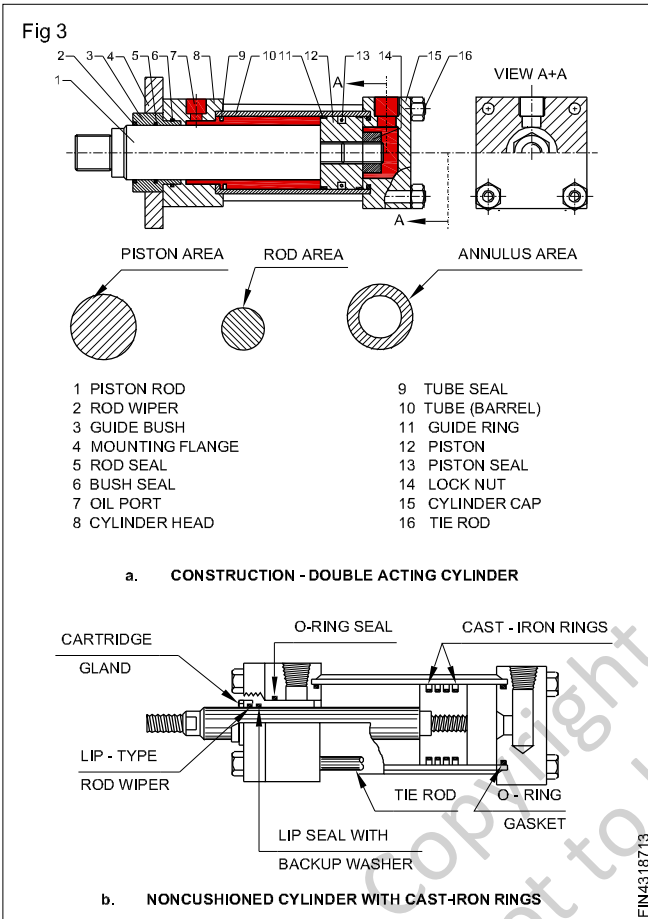
The general construction of a double acting cylinder is shown in Fig 3a. Piston rod is made of a chrome plated and piston is made of cast steel. Cylinder head is honed inside and has rod bearing support and a port. Cylinder cap blocks the end of the cylinder and firmly attached to head by means of tie-rods 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.



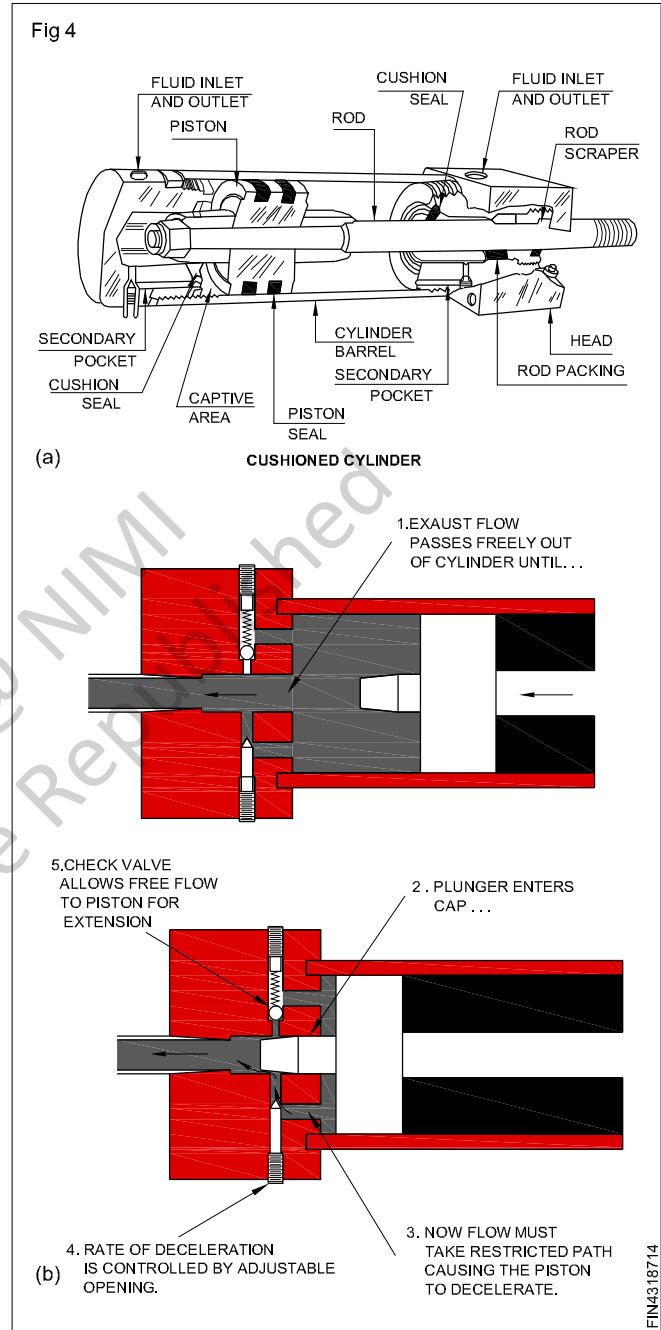
End cushioning

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

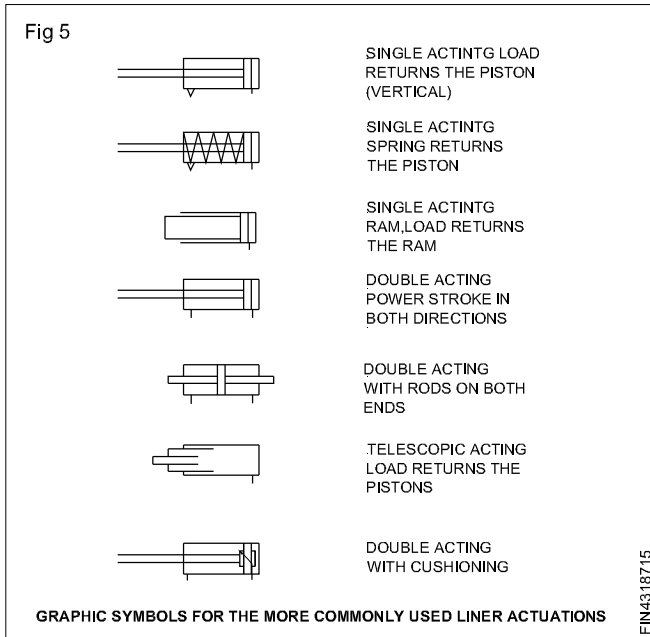
Pressure exerted by the piston = Pressure (Kg/cm²) x Area of cross section of piston (cm²)

$$\text{Speed of the piston (cm/min)} = \frac{1000 \times \text{LPM}}{\text{Area of piston (cm}^2\text{)}}$$

Where LPM = Litres Per Minute.

Symbol

The symbols for hydraulic cylinders resembles the symbols of pneumatic cylinders. The symbols for commonly used cylinders are given in Fig 5.



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.

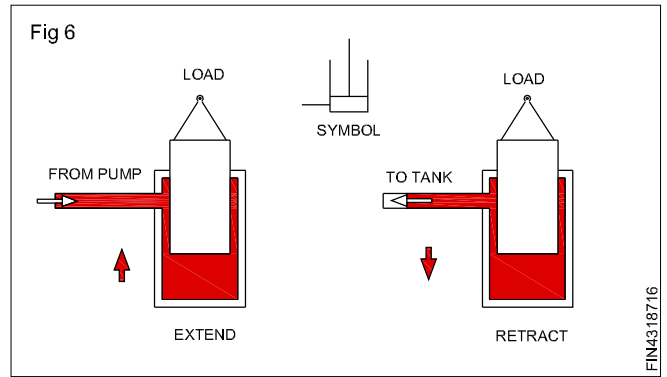
Double acting cylinders can be further classified into

- Single piston rod type
- Double sided piston rod
- D.A. cylinder with end cushioning
- Telescopic type
- Pressure intensifier
- Tandem cylinder.

Ram

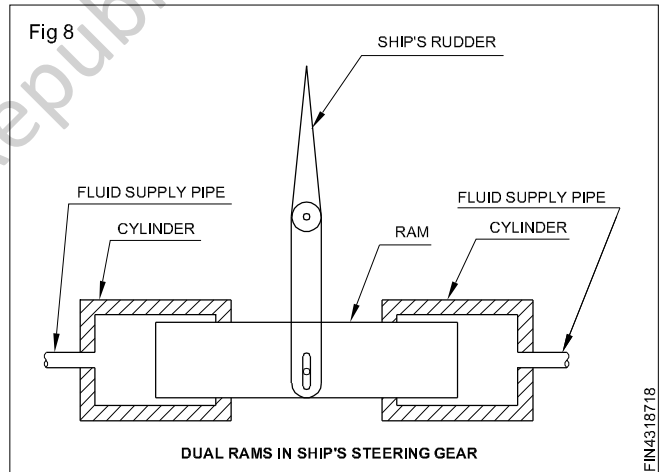
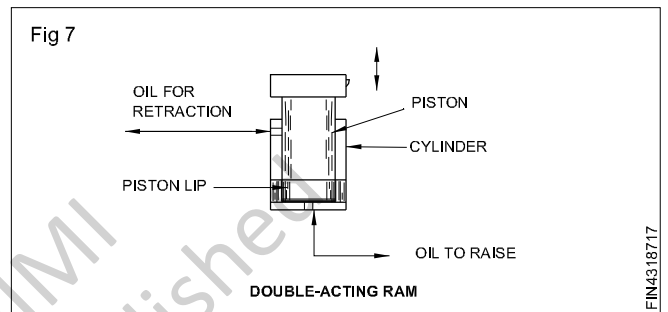
It is the simplest linear actuator as shown in Fig 6. It has only one chamber for oil. They are usually mounted vertical and ram descends down by its self weight. Rams are practically suitable for long strokes and used in elevators jacks and automobile.

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)



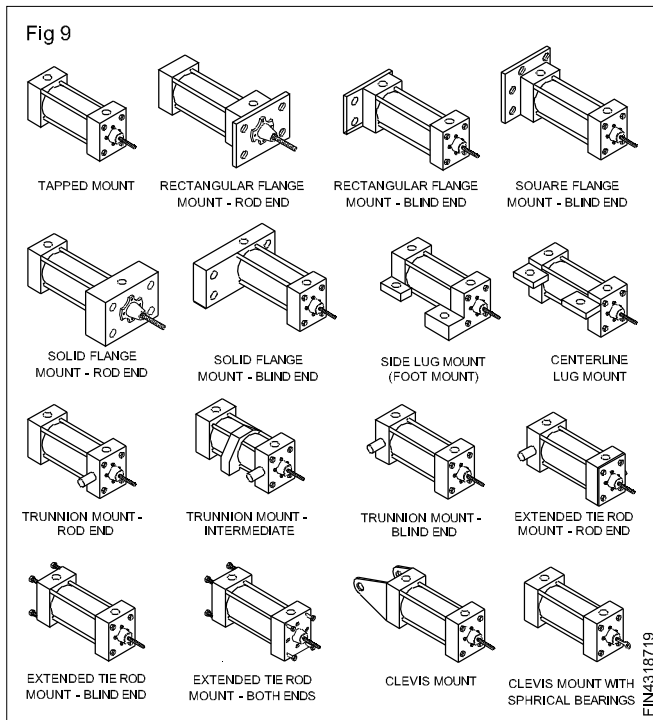
However, the diameter of the Ram can be reduced only to a little extent to have piston rod.

The application of a double sided or dual Ram in turning the rudder of a ship is shown in Fig 8.



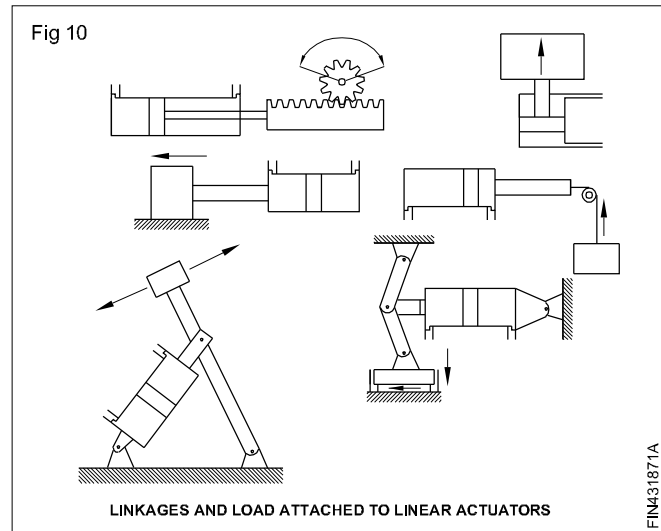
Mountings of cylinders

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.



Actuation by linkages

Fig 10 shows the various methods of handling load, clamping, oscillation, lift and other kinds of applications of a cylinder along with mechanical linkages.



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

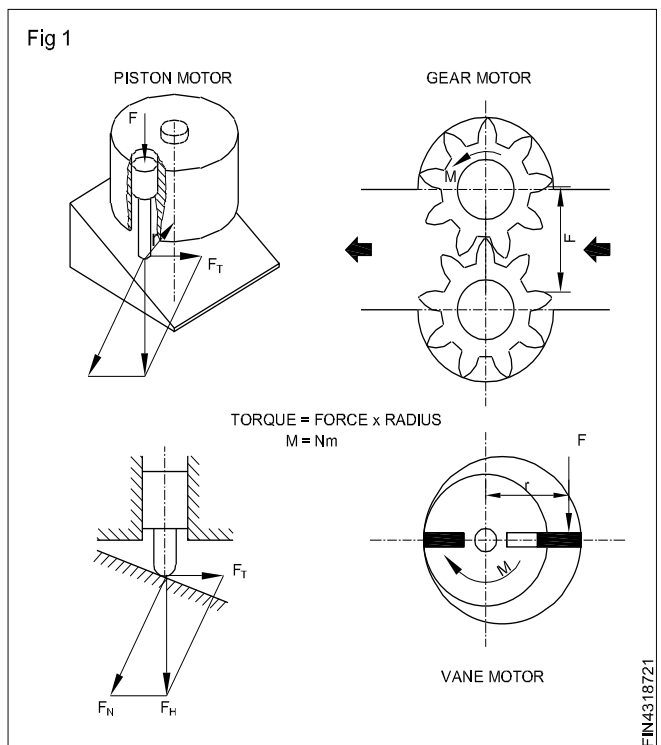
Hydromotors are classified according to their internal design. Hydromotors are of three types namely:

- 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

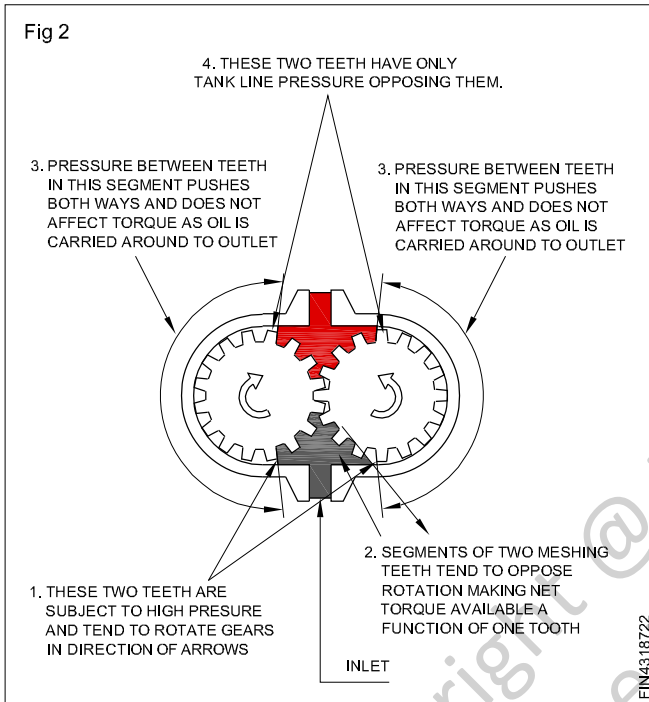


Gear type motors

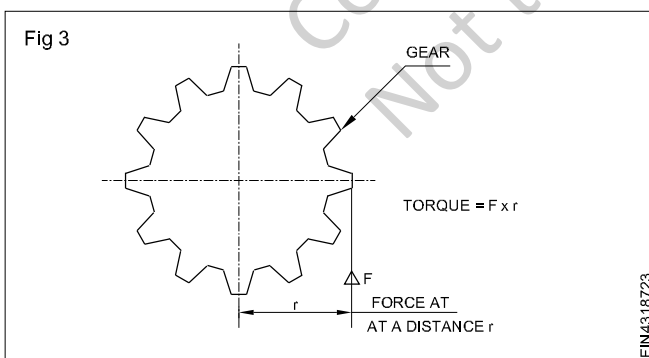
Gear motors are designed either as

- 1 Gear on gear motor (external gear)
or
- 2 Gear in gear motor (internal gear).

The figure 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%.



The pressure of oil creates the torque in the same way as that of on a lever. (Fig 3)

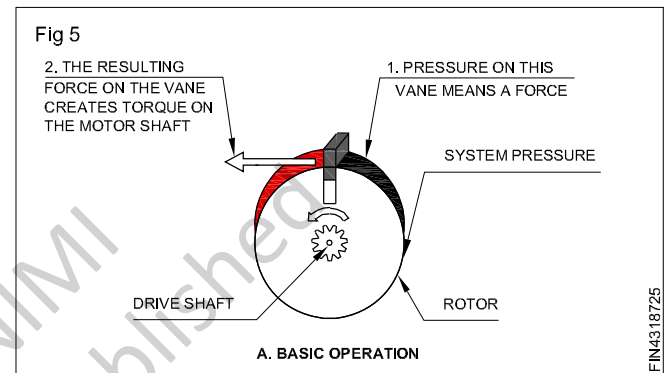
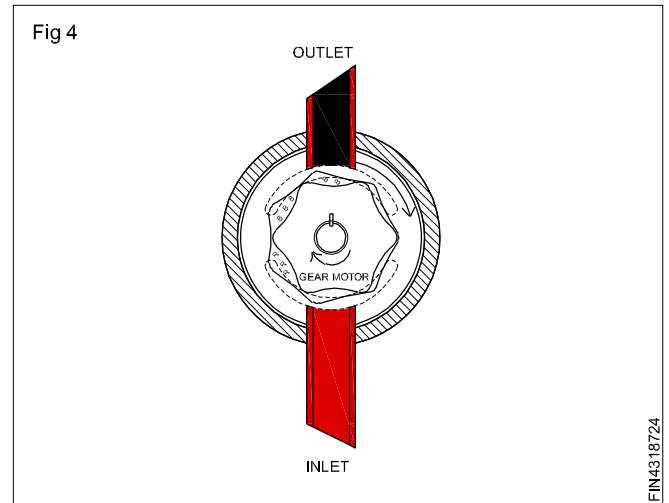


The internal gear motor usually of gear type shown in the Fig. 4.

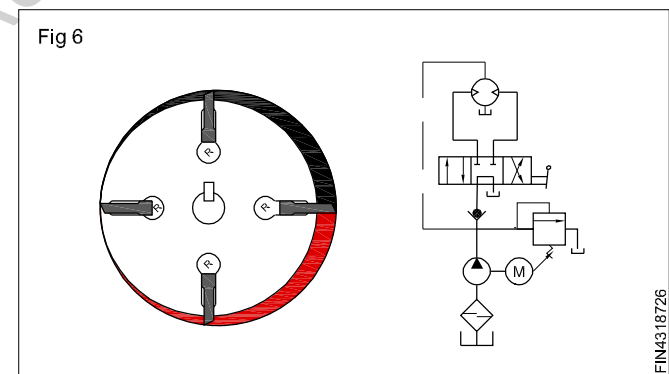
This is a motor which is very smooth in running and compact in design.

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)



The vanes in the slots extend out by the action of centrifugal force and oil pressure. This has a high speed operating character.

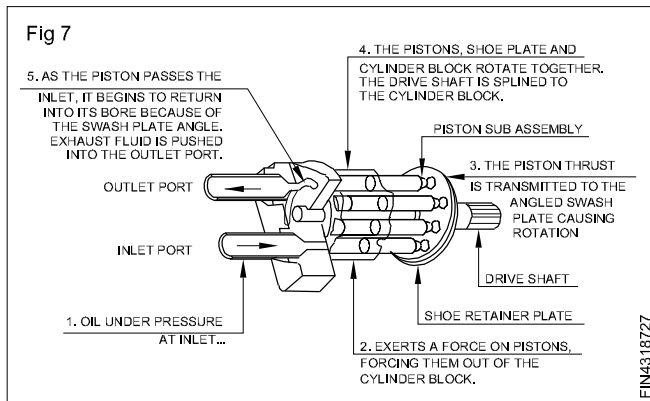
Piston type motor

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)

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

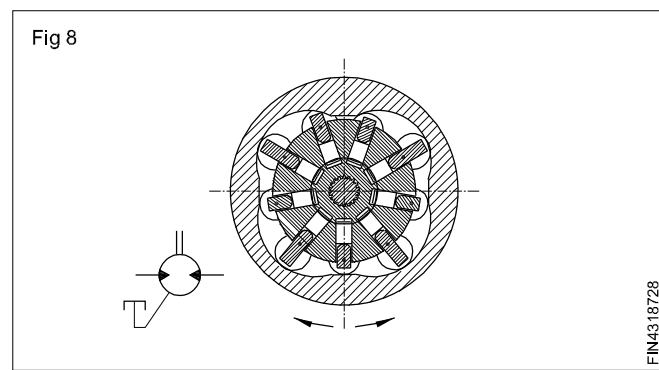
This is done by using a direction control valve in the circuit. This very much resembles the method of controlling the direction of movement of a double acting cylinder.

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

$$\eta(\text{Vol}) = \frac{\text{Theoretical flow rate}}{\text{Actual flow rate}}$$

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.

$$\eta(\text{Mech}) = \frac{\text{Actual torque}}{\text{Theoretical torque}} \times 100$$

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.

$$\eta_o = \frac{\eta_{\text{Vol}} \times \eta_{\text{Mech}}}{100}$$

Direction control valve

Objectives: At the end of this lesson you will 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.

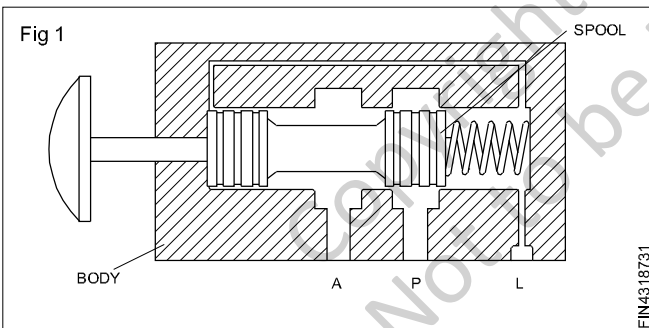
Direction control valves are classified as following according to the number of ports and positions:-

- 2/2- Way valve
- 3/2- Way valve
- 4/2-Way valve
- 4/3-Way valve

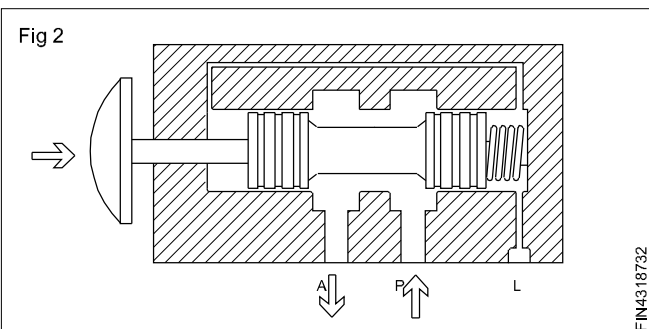
2/2 Way valve

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)

A relief line leading to the leakage - oil port is provided to prevent a build -up of pressure in the spring and piston chambers.

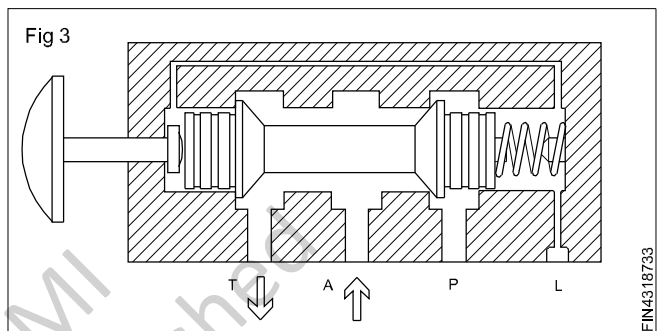


The 2/2-way valve is actuated and the passage from P to A is open. 2/2 -way valves are also available which are normally open from P to A. (Fig 2)

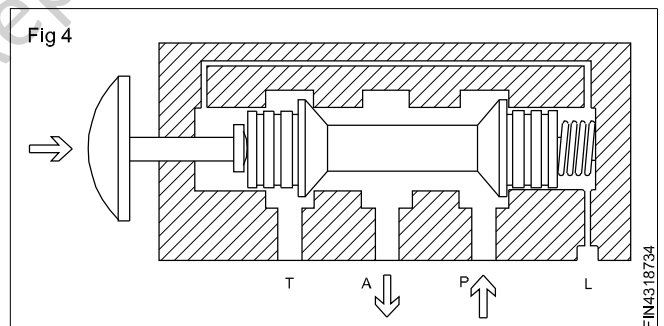


3/2-Way valve

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)



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)



Example of 3/2 way circuit with single acting cylinder. (Fig 5)

4/2 Way valve, two pistons

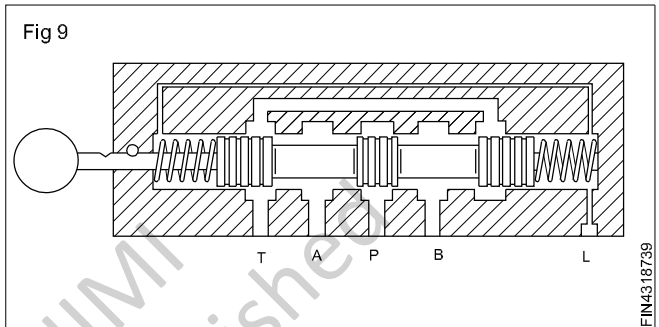
The 4/2-Way valve has two working ports A and B, a supply port P and a tank port T. The supply port is always connected to one of the working ports, while the second working port is routed to the tank. In the normal position, there is flow P to B and from A to T. (Fig 6)

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)

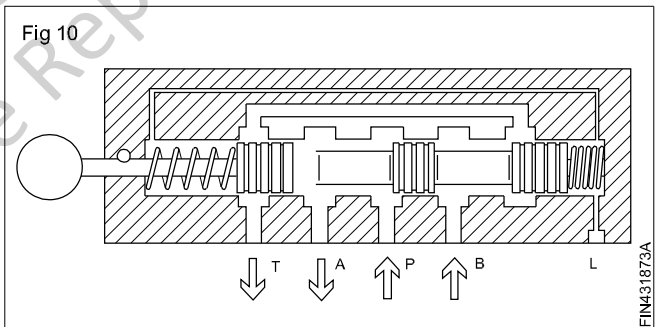
4/3- Way valve

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.

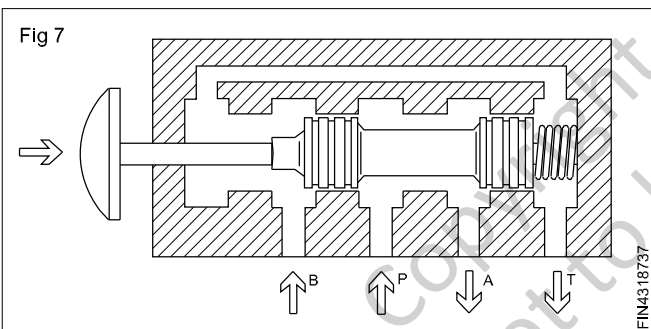
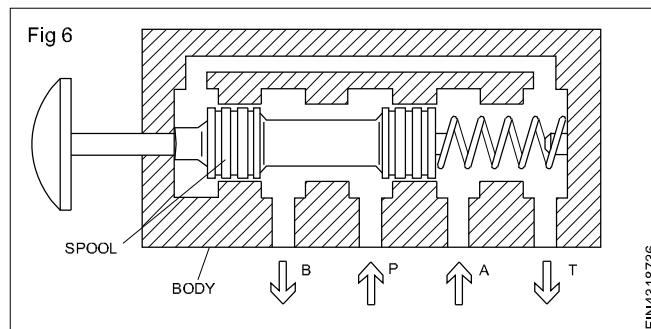
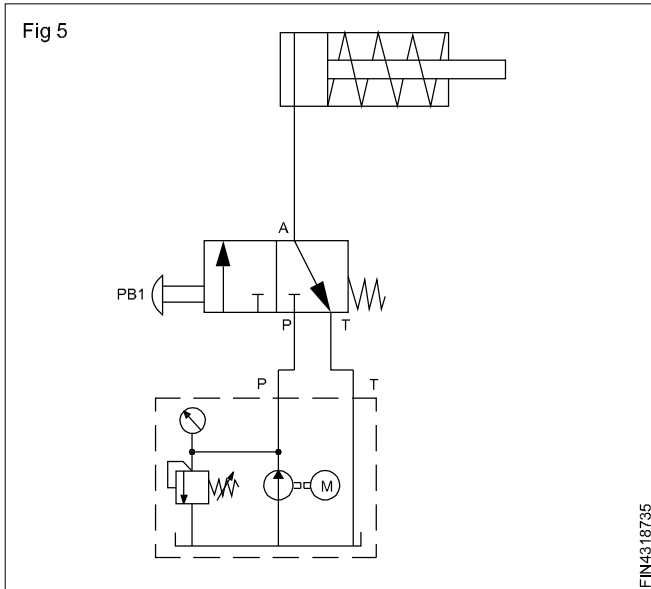
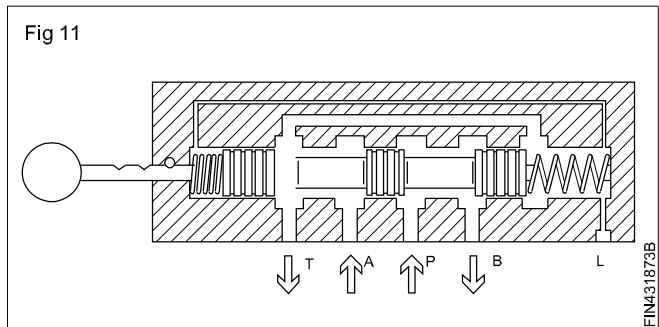
The 4/3-way valve is in its mid-position; there is flow from P to T, while A and B are closed. Since the output from the pump flows to the tank, this switching position is called pump bypass or also pump recirculation. In the case of pump bypass, the pump needs to operate only against the resistance of the valve, which has a favorable effect on the power balance. (Fig 9)



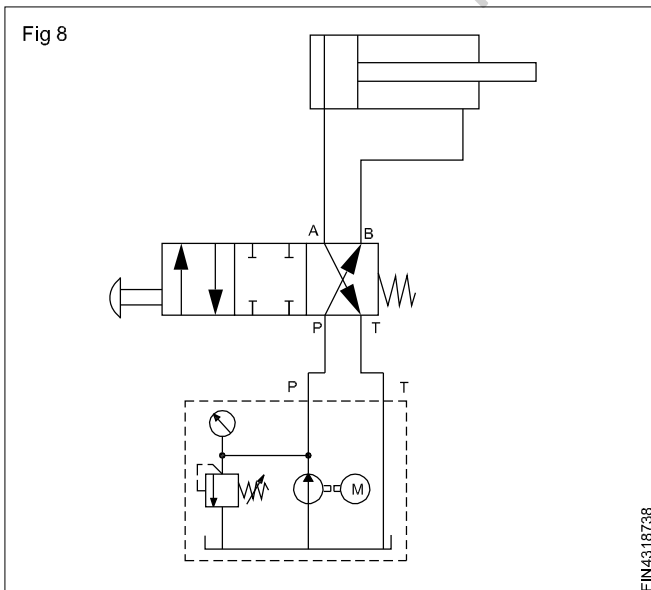
The valve is in its left-hand switching position; there is flow from P to A and from B to T. (Fig 10)



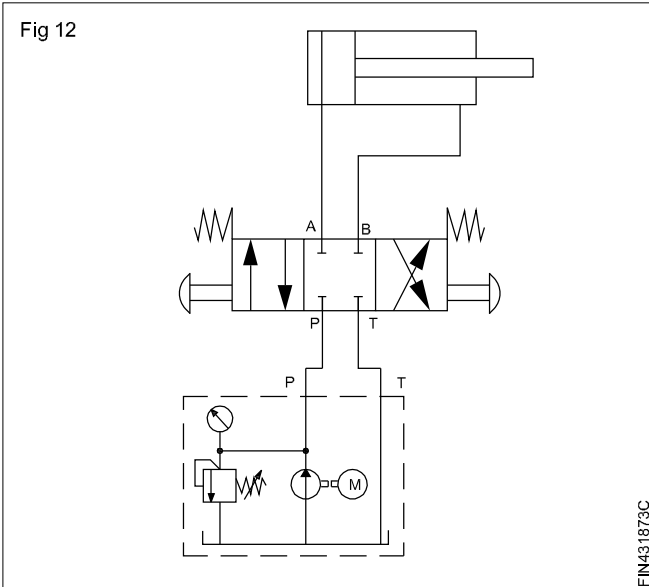
And the valve is in its right hand switching position there is flow from P to B and A to T. (Fig 11)



Example of 4/2 way circuit with double acting cylinder. (Fig 8)

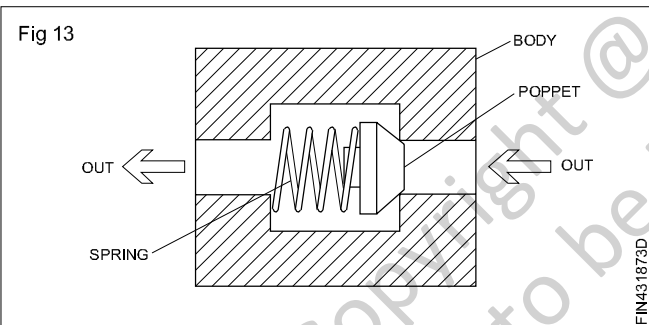


Example of 4/3 way circuit with double acting cylinder. (Fig 12)



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)



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)

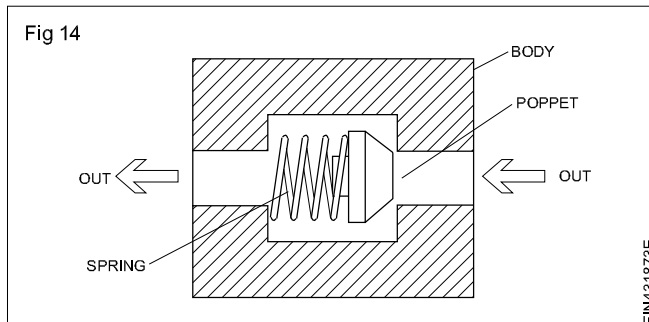
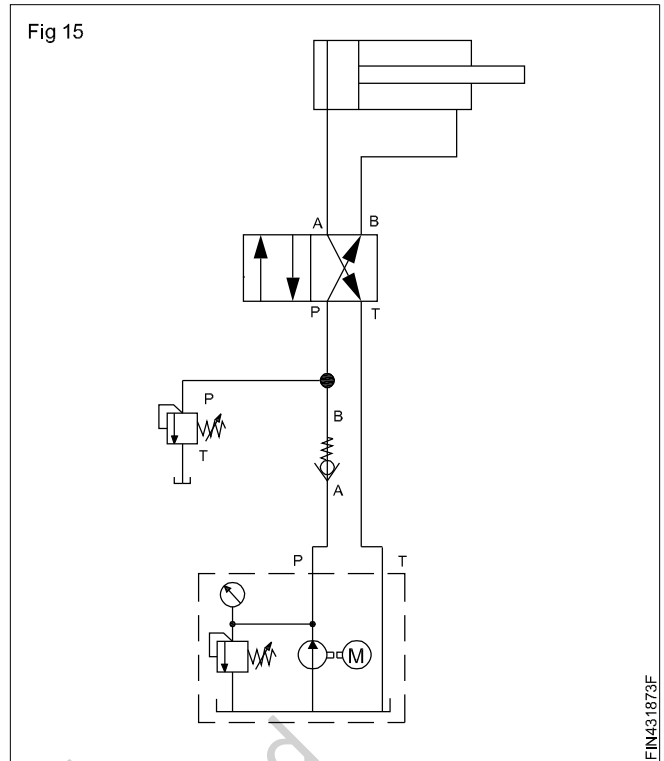


Fig 15 shows the application of non-return valve for pump protection. (Fig 15)



By-pass circuit

By-pass circuit is used to advance a cylinder rapidly than it could with pump flow alone. To achieve this, oil from the rod end of a cylinder is added to the pump flow to the blind end, increasing the rate of advance. Common applications of by-pass circuit are found in shearing and punching machines.

In general, differential cylinder is used in hydraulics machines. In this cylinder the area ratio of the full piston surface to the annular piston surface is 2:1, since as the result the piston rod area is only half the size of the piston area, the return stroke is twice as fast as the advance stroke.

In most of machines less advance speed is required, but in some machines high speed is required in forward stoke of piston like in shearing and punching machines.

For example the piston area A_p of the differential cylinder equal 10cm^2 , the annular piston surface $A_{PR} = 2\text{cm}^2$. The mp delivers $Q_p = 101/\text{min}$. So that speed of piston in advance and return stoke is given below: (Fig 16)

Note: Regeneration circuits apply only to single rod cylinders in the extended direction.

Advance and Return speed

As we know from previous topics

$$V = Q/A$$

$$Q_{\text{pump}} = 101/\text{min} = 10,000\text{ cm}^3/\text{min}$$

Advance speed

$$V_{ADV} = 10,000 \text{ cm}^3 / 10 \text{ cm}^2 \text{ min}$$

$$V_{ADV} = 10,00 \text{ cm} / \text{min}$$

$$V_{ADV} = 10 \text{ m} / \text{min}$$

Return speed

$$V_{RET} = 10,000 \text{ cm}^3 / 2 \text{ cm}^2 \text{ min}$$

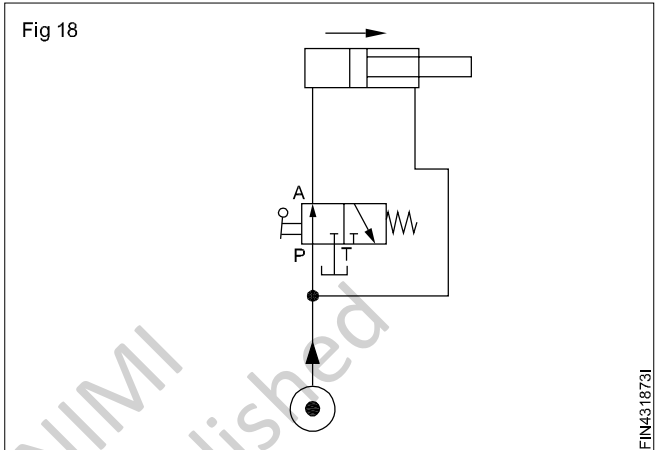
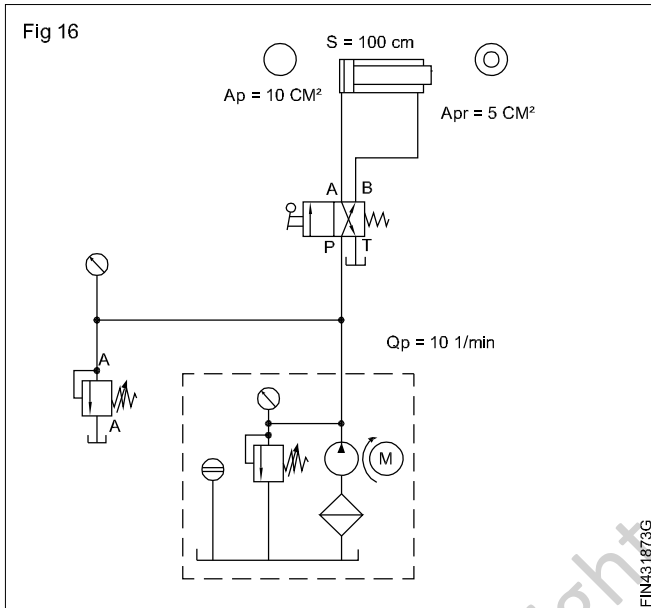
$$V_{RET} = 5000 \text{ cm} / \text{min}$$

$$V_{RET} = 50 \text{ cm} / \text{min}$$

It means oil which is going inside the piston end of cylinder is more than pump flow and more flow means more speed of actuator.

When the rod ends port is directly connected to the piston end port than during forward stroke of piston, rod end oil is recirculated and added on piston end of cylinder.

Below circuit is the example of a regeneration circuit along with 3/2 way valve. In normal condition (without actuation) oil is only going on the rod side of cylinder and from the piston end of cylinder oil is coming back into tank so that the piston remain in retracted position. (Fig 18)



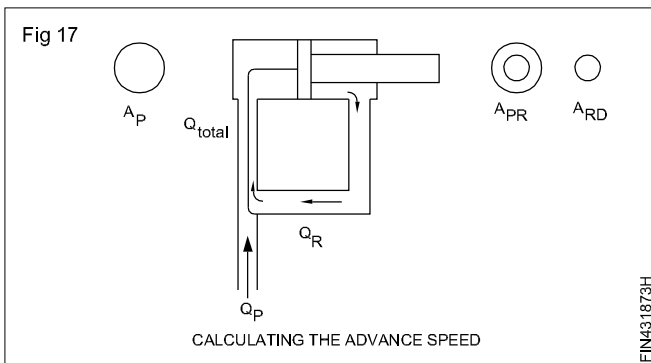
In actuated condition of valve, A port and B port are connected to P port, means pump flow is added with flow of rod side.

$$Q_{total} = \text{Pump delivery} + \text{return delivery}$$

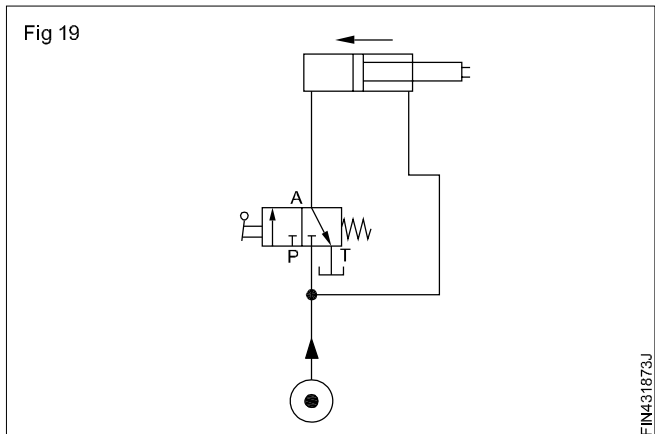
From this result it can be seen that the area ratio has a direct effect on speed and time.

For getting more forward speed in differential cylinder we can utilize the oil of rod side of cylinder into piston side, such a circuit is known as regeneration circuit or bypass circuit.

By- pass circuit (Fig 17)



More flow is going inside the cylinder in actuated condition so that speed becomes very high (Fig 19)



$$Q_p = \text{pump delivery}$$

$$Q_R = \text{return delivery from piston rod area}$$

$$Q_{total} = \text{Pump delivery} + \text{return delivery}$$

Flow control valve

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

- state the need for flow control in a hydraulic circuit
- state the principle of operation of flow control valve
- draw different symbols of flow control valves and state the functions from the symbols.

The whole purpose of a flow control valve is to vary the speed of an actuating cylinder or motor. This is possible by controlling the flow rate of the fluid.

A flow control valve accomplish any one or more of the following control functions:

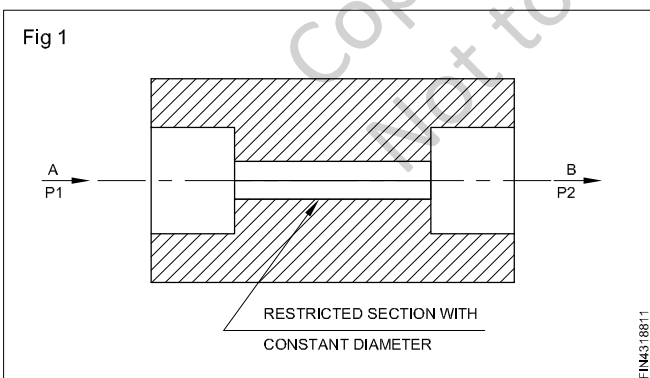
- To limit the maximum speed of the linear or rotary actuators

$$\left(\frac{\text{flow rate}}{\text{piston area}} = \text{piston speed} \right)$$

- To limit the maximum pressure available to branch circuits by limiting the flow. (power = flow rate x pressure)
- Proportionately divide or regulate the flow from pump to various branch circuits.

Principle of operation

As shown in Fig 1, the oil under pressure P1 enters the valve at A and flows through a restricted section, into the outlet B. While passing through the restricted passage, oil attains heat due to the friction. Thus the hydraulic energy in terms of pressure is converted into heat energy. The loss of energy is the result of drop in pressure.

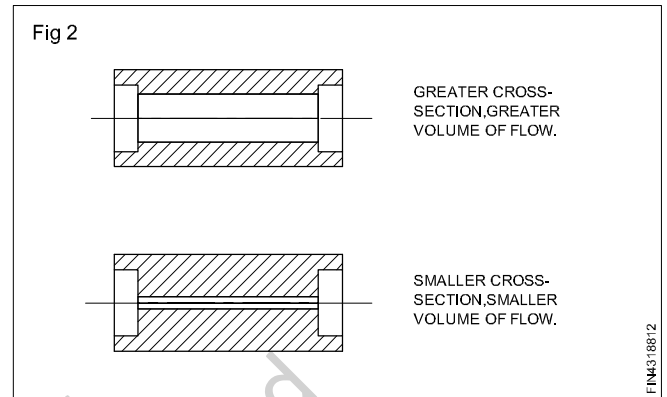


The difference between the two pressure is called pressure drop.

$$p = p_1 - p_2$$

The volume of flow (litres/min) is mainly dependent on the:

- Cross-section of restriction (Fig 2)
- Shape and length of orifice
- Pressure difference p
- Viscosity of the hydraulic oil.



The basic principle can be understood from Fig 3.

Symbol

As a general norm, the basic envelop is represented by a square to denote a valve. The flow line passes past through the square. The flow restrictions are denoted by curvatures above and below the flow line.

The arrow mark stroked across the curvatures means that, the flow restriction is adjustable. Sometimes full flow is to be ensured in the reverse direction. This can be made possible by connecting a check valve (non-return valve) in a right direction across the flow control valve. As indicated in Fig 3, in the forward direction, oil flows from pressure port (P) to working port (A). In the reverse direction oil flows from port A to port P, by pushing the spring loaded valve.

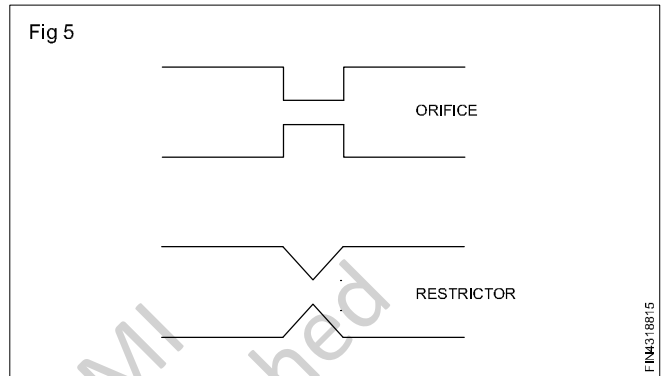
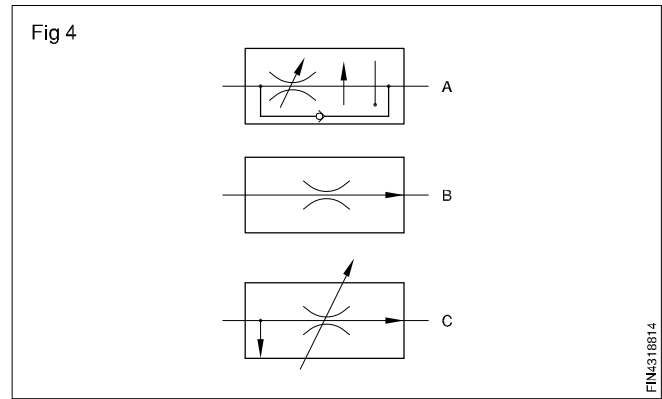
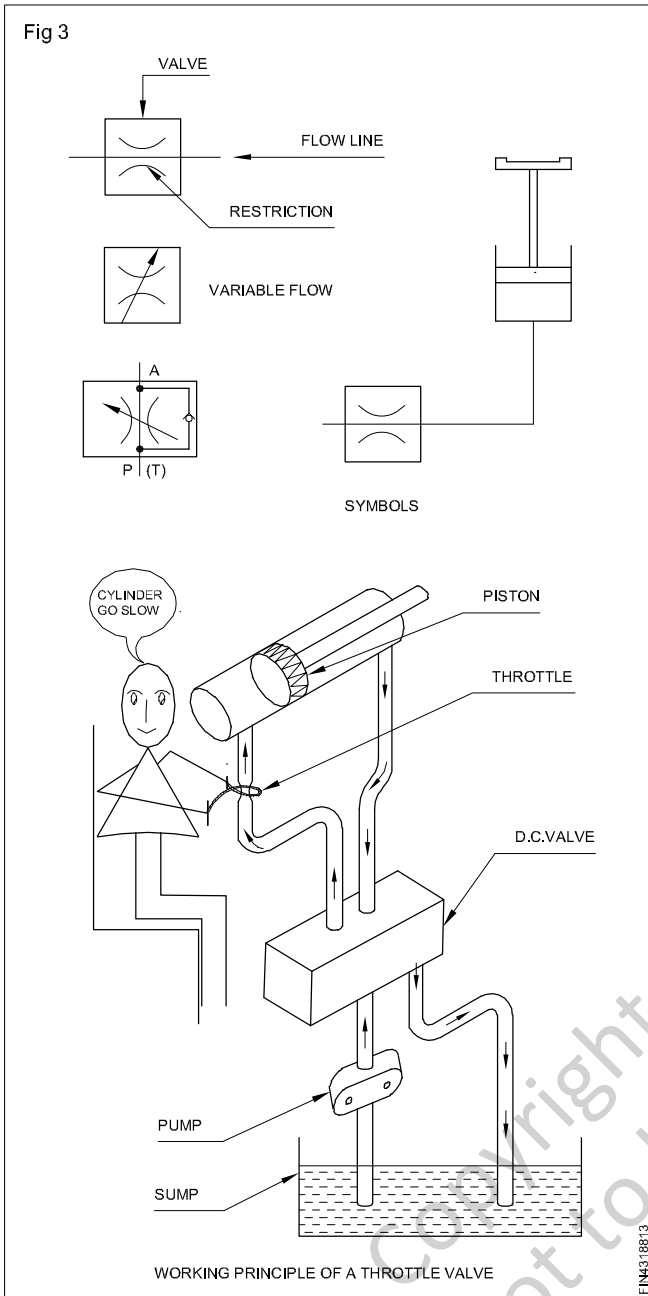
In case, if the return oil is to flow to the tank, the pressure port P will become tank port 'T' by means of a direction control valve in the circuit.

In Fig 4 symbols are given in combined operations. Fig 4A shows a control valve is adjustable and compensation is given for pressure as well as temperature. Fig 4B show a symbol for fixed type orifice and reducing valve-type compensation. Fig 4C indicates an adjustable orifice and relief valve type compensation.

The shape of an orifice and restrictor are shown in Fig 5. Restrictor is less sensitive to temperature variation.

The flow characters are changed in the following aspects

- The velocity past the valve.
- The pressure at the outlet of the valve is less than that of the inlet.



Variable flow control

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

- state the need for a flow control valve
- state the principle of operation of a simple flow control valve
- name the different area of applications of a variable flow control valve
- distinguish the construction of a one way flow control valve
- name the areas of applications of one way flow control valves and different adjustable restrictors
- state the concept of maintaining constant flow rate.

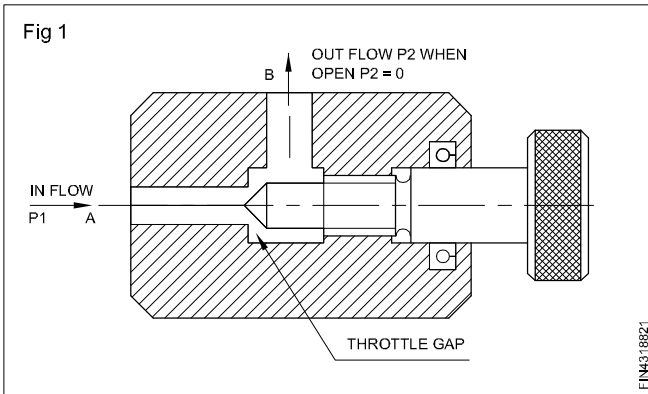
Need for flow control

In a hydraulic circuit, to have a control over the speed of an actuator, the flow rate should be under control. This can be done by adjusting a variable delivery pump and a pressure relief valve. But the frequent adjustment of these elements will result in a power loss and reduction in their efficiency. Hence the need for separate flow control valve arises.

To enable the supply of variable flow to the circuits a flow control valve can be made adjustable. Tuning of a flow control valve to supply different flow rates is called 'Throttling' and the valve is also called throttle valve.

Principle of operation

As shown in Fig 1 oil enters the port A and its restricted flow enters port B. Flow is limited in the restricted passage called throttle. The amount of this gap can be varied by throttling screw. When the screw is fully closed, there is no flow at the outlet B.



It can be understood that the flow rate is dependent on the

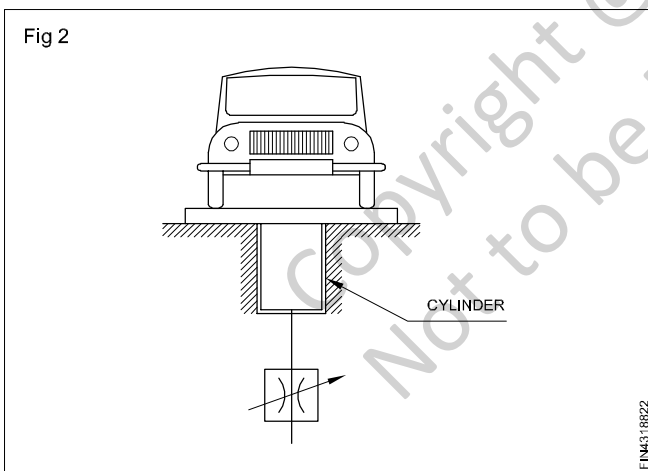
- Pressure difference $p = p_1 - p_2$
- The size of throttle gap and
- Viscosity of oil.

It is to be noted that valve can be operated in both the direction.

Application

By means of throttling, speed can be infinitely variable.

As shown in Fig 2, the platform for lifting a car can be raised faster or slower by means of cylinder movement. The cylinder movement, in turn can be varied by restricted oil supply through a flow control valve.



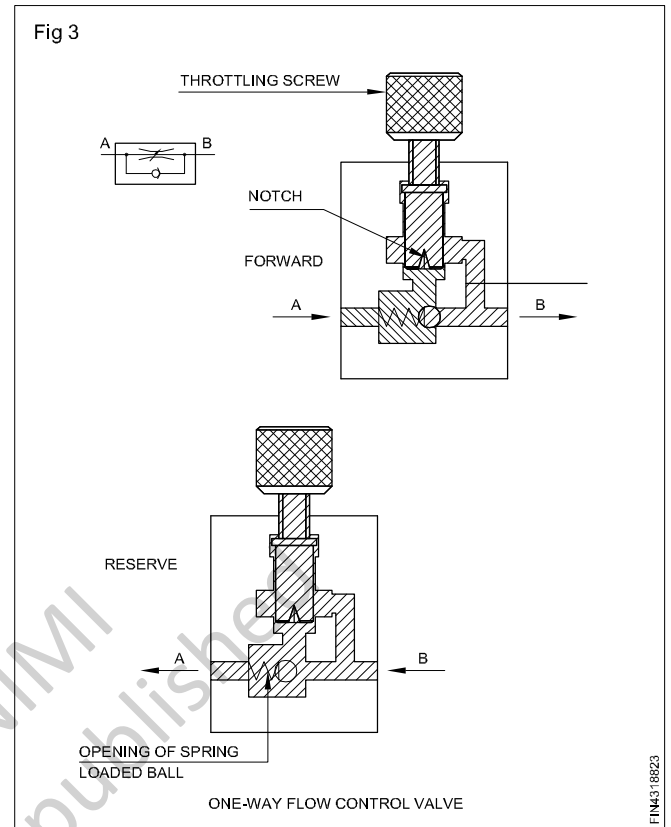
One-way flow control valve (Fig. 3)

A specific requirement of a flow control valve is that, an adjustable flow is required in one direction and a full flow is required in the reverse direction. It is possible, by the induction of a check valve.

As shown in Fig 3, the restricted passage is by means of a longitudinal notch in the valve body. Full flow oil coming from port A is restricted through this passage and only a limited oil flow through the outlet port B. It can be noticed that oil also acts on the ball in the spring direction, so that the ball firmly closes the port, that connects outlet port B.

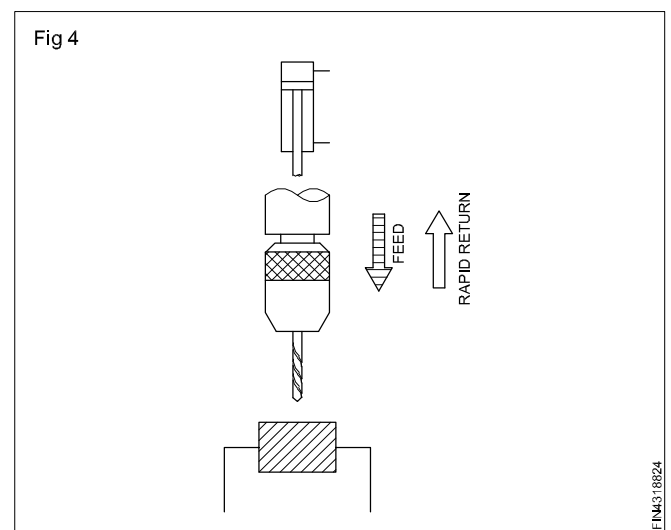
Whereas in the reverse direction, i.e. from B to A, oil force

acts on the ball against the spring force. Thus the ball is lifted off its seat and oil rushes to port A. At the same time, a limited passing of oil through the throttling passage also enters port A. Thus the full flow of oil is ensured at port A.



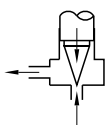
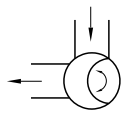
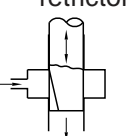
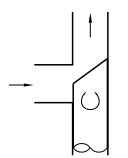
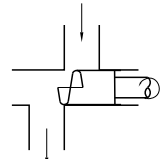
Application

For a auto feed of the drilling operation as shown in Fig 4, the slow feed in vertical direction is imparted by a cylinder, receiving restricted flow of oil. After finishing the operation the drill head has to move fast in upward direction. This is possible by admitting full flow of oil against the check valve.



The following chart illustrates various designs of orifice restrictions, resistance offered, their dependence on viscosity, case of adjustment and effectiveness of the design.

Adjustable restrictors

Type	Resistance	Dependence on viscosity	Ease of adjustment	Design
Needle restrictor 	Increase in velocity, high friction owing to long throttling path	Considerable due to high friction	Excessive cross-sectional design	Economical simple
Circumferential restrictor  By radial slot	As above	As above, but lower than for the needle restrictor surface, total adjustment travel only 90°	Steady cross-sectional enlargement. Adjustment upto 90°	Economical, simple design more complicated than the needle restrictor
Longitudinal restrictor  (By linear slot)	As above	As above	As above, however sensitive adjustment owing to long adjustment travel	As for circumferential restrictor
Gap restrictor or poppet 	Majority; increase in velocity, low friction short throttling path	Low	Unfavourable, even cross-sectional enlargement, adjustment travel of 180°	Economical
Gap restrictor with helix 	Increase in velocity, maximum friction	Independent	Sensitive, even cross-sectional enlargement adjustment travel to 360°	Expensive to produce helix

Requirements of adjustable restrictions

- Build-up of resistance
- Change in temperature and in turn the viscosity should not affect the resistance
- Adjustment of flow depends on the orifice cross-sectional area and control surface area
- It should be economical in design
- Possibly it could allow the flow in either directions.

on the throttle passage, pressure difference and oil viscosity, set by the temperature.

The viscosity and passage remaining constant, the pressure difference on either side of the throttle alone affects the amount of flow. Hence if the flow is to be constant, the pressure, differential should also be constant. The flow control valve operating on this principle is called "Pressure compensated flow control valve". This type of valve can be also operated in either directions.

Maintaining constant flow-rate

The amount of flow out of a flow control valve, depends

Common maintenance procedures for hydraulic and pneumatics control system

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

- **plan hydraulics and pneumatic maintenance practices**
- **select proper practices of hydraulics and pneumatics maintenance.**

Key concepts

- Trouble shooting, done in a logical manner, can solve most hydraulic and pneumatic system problems.
- Safety should be the first consideration when trouble shooting.
- Inspect the equipment and question the operator to help solve problems in hydraulic and pneumatic systems.

Safety Precautions

Hydraulic systems operate under very high pressures. Shut the system down and relieve system pressure before opening any part of the system that is under pressure. Do not allow spray from any high pressure leak to contact any part of the body, as serious injection injuries may result. Pumps, valves and motor may become hot; be cautious of incidental contact between bare skin and hot surfaces. Keep hands and clothing away from moving parts of the system.

Basic hydraulics system maintenance

Weekly

- Check the systems performance and general condition.
- Check that the oil level in the reservoir is correct on the sight glass. (Hydraulic cylinder should be fully retracted when doing this) Check the oil color as compared to the sample of new oil.
- Check reservoir cover, solenoids and pipe connections for leaks and tighten as required.
- Check the indicator on filters and replace elements if required. When replacing elements, inspect for tell tale signs of impending unit failure, e.g., metal particles.
- Inspect relief valve locks, checking for unauthorized tampering.
- Check accumulator pre-charge (where fitted).

Annually and or every 3000 operation hours

- Check all mounting bolts for tightness. Remove coupling guards from pump / motor and check flexible couplings for wear. Replace the rubber sleeve if necessary.
- Check all the valve, pump and actuator for oil leak. Remove and replace the seals if necessary.
- Check filler breather, suction filter and system filters element for cleanliness and replace if necessary.
- Check the cooler and clean the element. If necessary replace the seals.

- Have a sample of oil in the reservoir checked by a specialized laboratory for size end type of particle contamination. Drain the reservoir if recommended, clean the tank interior and refill with fresh oil of correct type if necessary.

Hydraulic system maintenance

Hydraulic system is recommended to be serviced at every 3000 operational hours or at least once a year. Continuous operation exceeding the mentioned period may cause increased contamination that may ruin components such hydraulic pump, valves, actuator, etc.,

More than 90% of all hydraulic systems failure are caused by contaminated hydraulic fluid. In order to reduce the contamination level, regular or schedule maintenance are essential.

Basic pneumatic system maintenance

Once in a Week

- Drain compressor, tank, filter, bowl, and any air lines that have drain cocks.
- Check compressor crankcase oil level
- Check compressor safety - relief valve

Once in a Month

- Inspect discharge air filter.
- Check pressure - reducing valve setting

Once in Every 3 Months

- Change crankcase oil
- Oil the compressor motors.
- Check compressor pressure switches.

Once in Every 6 Months

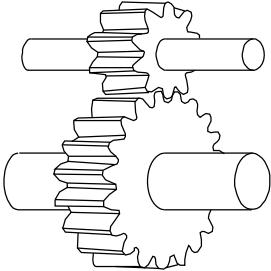
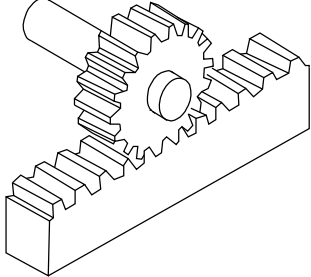
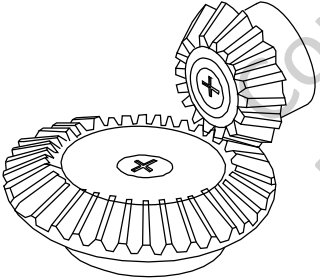
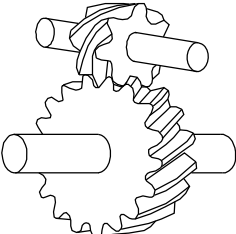
- Check for moisture, oil, and dirt in air lines.
- Clean the intake air filter, felt and screen types
- Check the compressor belt
- Check the pressure relief valves
- Check calibration, operation, nozzles, and restrictors of transimt - temperature controllers, pressure controllers, thermostats and humidistats
- Check piping of pressure transmitters and controllers
- Clean elements and humidistats

Once in Year

- Replace cartridge - type intake air filters
- Check calibration of receiver controllers
- Check valves for tight close - off

Fixing gear wheel for various purpose drives

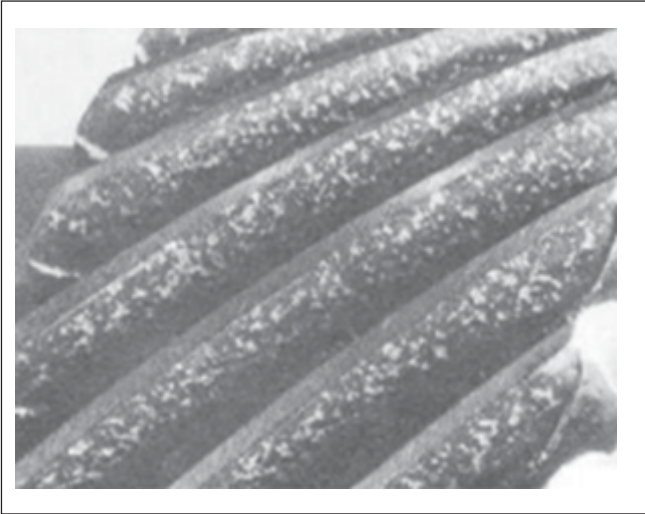
- Objectives :** At the end of this lesson you shall be able to
- name the different methods of gear fixing for different drives
 - list the use of each type gear
 - state the cause and remedies of gear tooth wear
 - state the methods of fitting different type gears

 <p>The diagram shows two shafts with gears mounted on them, positioned parallel to each other. The gears are meshing together, illustrating a parallel shaft gear arrangement.</p>	<p>Parallel axes</p> <p>Transmit power and motion between parallel shafts. Spur gears and helical gears are used. Example: Lathe gear box</p>
 <p>The diagram shows a cylindrical gear (pinion) meshing with a straight-toothed gear rack. The rack is a long, flat bar with teeth, and the pinion is mounted on a shaft perpendicular to the rack's length.</p>	<p>Change the rotary motion into the rectilinear motion and vice versa. A combination of spur gear and rack or a combination of helical gear and helical rack is needed to do work. Example: Dial test indicator</p>
 <p>The diagram shows two shafts intersecting at a 90-degree angle. Each shaft has a bevel gear mounted on it, and the two bevel gears are meshing together at the point of intersection.</p>	<p>Intersersecting axes</p> <p>Transmit power and motion between intersecting shafts at right (90°) angles. Straight bevel gears or spiral bevel gears are used. Example: Shaping machine table</p>
 <p>The diagram shows two shafts that are neither parallel nor intersecting. They are positioned at an angle to each other. Each shaft has a gear mounted on it, and the gears are meshing together, illustrating a screw gear or worm gear pair.</p>	<p>Non parallel, non intersecting axes</p> <p>Transmit motion and power between nonparallel, nonintersecting shafts that are usually at right angles (90°). Screw gears and worm gear pair are used. Example: Dividing head</p>

Wear and tear of toothed wheel and their remedies

Wear: A surface phenomenon in which layers of material is removed or “worn away”

Moderate wear



Excessive wear



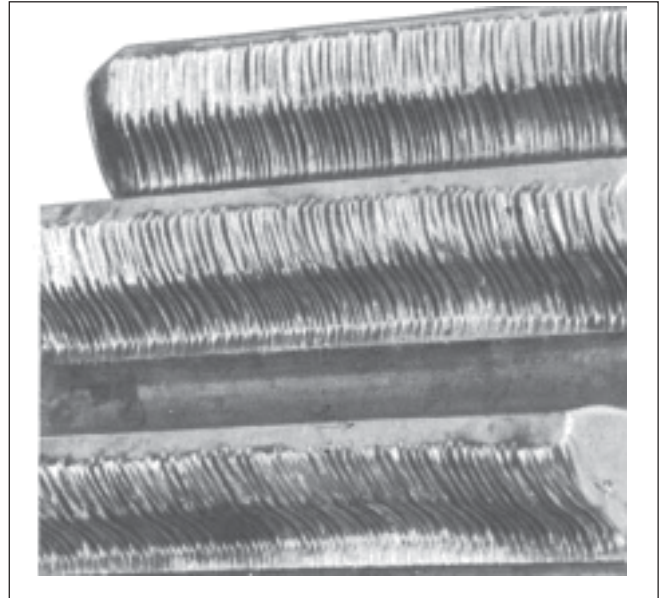
Cause: Wear in progress, in a dequate lubricant film

Remedies: Increasing lubricating film strength, sufficient oil is supplied to working surfaces.

Abrasive wear

Cause: foreign material in the lubrication metallic debris. from the gear.

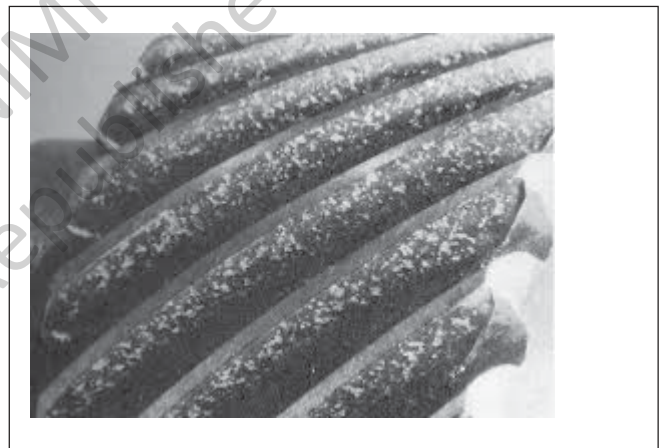
Corrosive wear



Cause: Corrosive elements in oil

Remedies: Use of filter and use high thick lubricating oil.

Crushing



Causes: Surface irregularities, misalignment of gears.

Remedies: Smooth gear surfaces, reduce dynamic loading limit, keeping the load below the endurance limit.

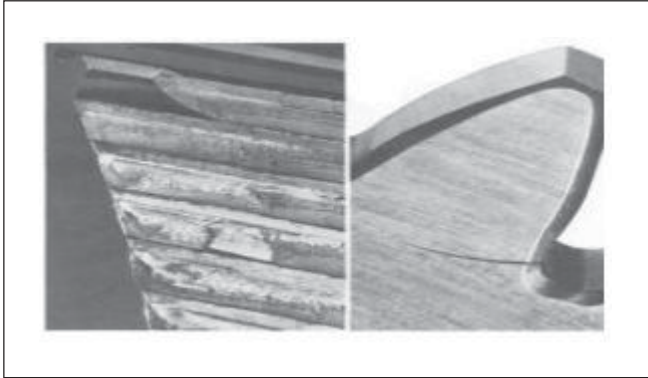


Fracture: Fracture is caused by breakage of whole tooth

Fatigue breakage

Cause: Extreme tooth loads, notches

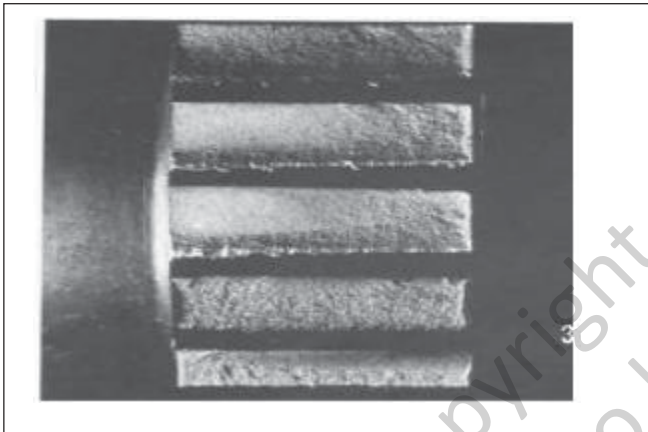
Remedy: Higher strength material, load in with endurance limit



Overload

Cause: Overload which exceeds tensile strength

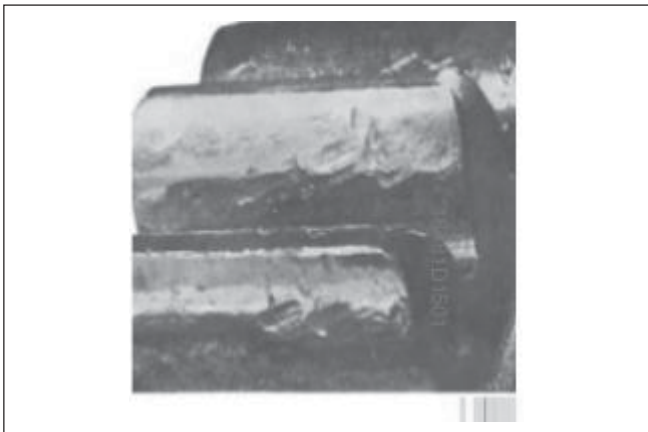
Remedy: Torque limiting overload protection devices



Plastic flow: Cold working of tooth surfaces caused by high contact stress.

Cold flow

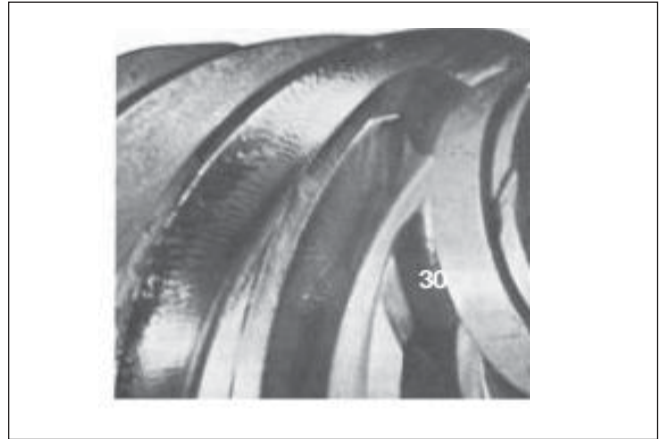
Causes: Rolling and peening action of much under heavy loads.



Rippling

Cause: Cyclic loads under high contact stresses.

Remedy: Case hardening of tooth surface.



Method of fitting spiral gear, helical gear, bevel gear and worm gear

Worm and worm wheel

The mounting of worm gears is critical to their implementation. Multiple points of contact are necessary between the drive and gear, so high work loads do not overwork the same lead angle, which could lead to gear failure. Enveloped worm gear sets are normally assembled in the same housing, to ensure proper mating and due to the sets' small footprint.

Consider the gear center, bore diameter and shaft diameter. The gear center can be a bored hole or an integral shaft. The bore diameter is the diameter of the center hole. The shaft diameter is the diameter of the shaft for gears with an integral shaft. Worms and worm gears can be mounted on a hub or shaft. A hub is a cylindrical projection on one or both sides of a worm or worm gear, often for the provision of a screw or other shaft attachment mechanism. Hubless gears are typically attached via press fit, adhesive or internal keyway.

Shaft mounting choices include the following:

Keyword: One or more square cutouts exist in the gear bore for exact mounting on the shaft.



Set screw: The gear is attached to the shaft by screws through the hub.



Simple bore: A straight bore designed for adhesive attachment.



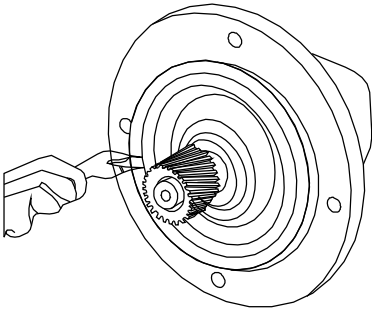
Split: The hub is split into several pieces that are tightened down by a separate clamp to grip the shaft.



Helical gear

Consider the gear center, bore diameter and shaft diameter. The gear center can be a bored hole or an integral shaft. The bore diameter is the diameter of the center hole. The shaft diameter is the diameter of the shaft for gears with an integral shaft. Helical gears can be mounted on a hub or shaft. A hub is a cylindrical projection on one or both sides of a helical gear, often for the provision of a screw or other shaft attachment mechanism. Hubless gears are typically attached via press fit, adhesive or internal keyway.

Illustration	Procedure
	<ul style="list-style-type: none"> • Prepare the input side. • Important: The round chamfer on the bore of the pinion must lie in the direction of the shaft shoulder.
	<p>Mount the pinion onto the shaft.</p>

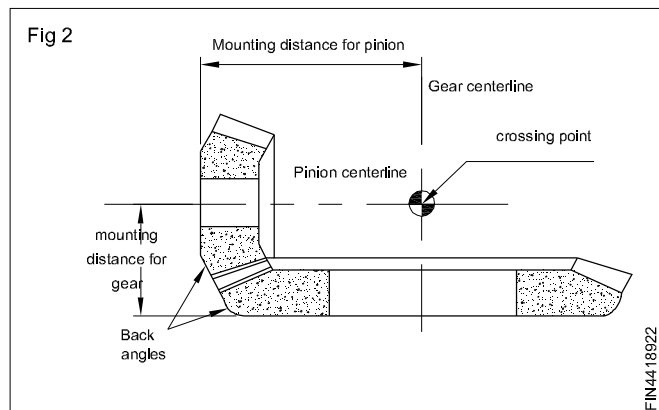
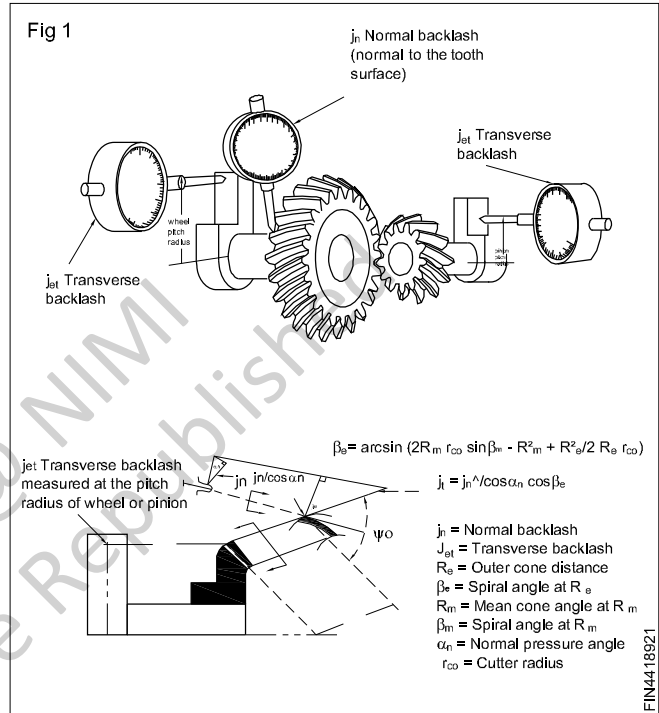
Illustration	Procedure
	<p>Fit the retaining ring using the pliers.</p>

Bevel gear

Bevel gears are **gears** where the axes of the two shafts intersect and the tooth-bearing faces of the **gears** themselves are conically shaped. **Bevel gears** are most often **mounted** on shafts that are 90 degrees apart, but can be designed to work at other angles as well.

Several parameters contribute to proper assembly to operate the gear box smoothly and efficiently. The most important are

- Back lash Fig 1
- Mounting distance Fig 2



Lubrication methods

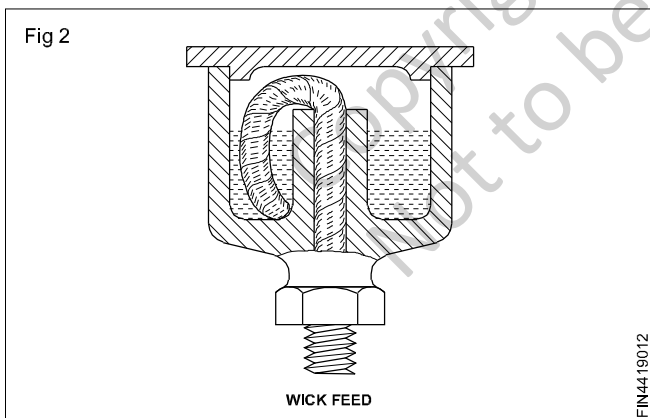
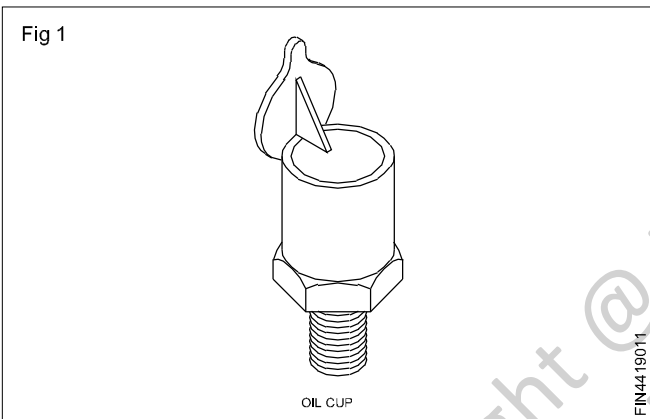
Objective: At the end of this lesson you shall be able to
 • state the systems of lubrication and their application

There are 3 systems of lubrication.

- Gravity feed system
- Force feed system
- Splash feed system

Gravity feed

The gravity feed principle is employed in oil holes, oil cups and wick feed lubricators provided on the machines. (Figs 1 & 2)

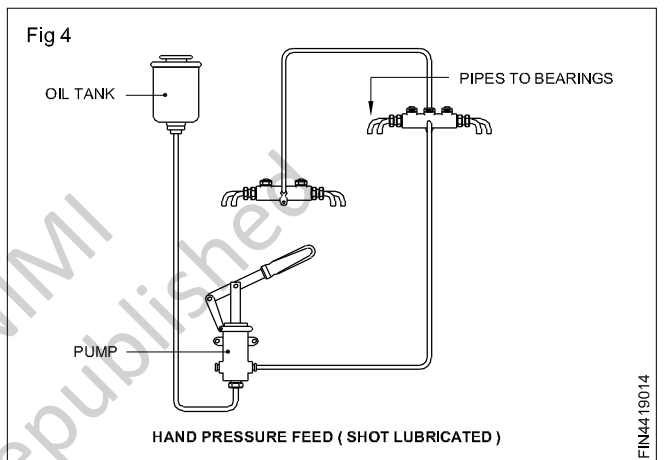
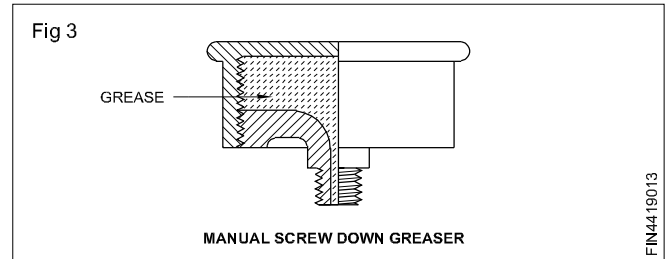


Force feed/Pressure feed

Oil, grease gun and grease cups

The oil hole or grease point leading to each bearing is fitted with a nipple, and by pressing the nose of the gun against this, the lubricant is forced to the bearing. Greases are also force fed using grease cup. (Fig 3)

Oil is also pressure fed by hand pump and a charge of oil is delivered to each bearing at intervals once or twice a day by operating a lever provided with some machines. (Fig 4) This is also known as shot lubricator.

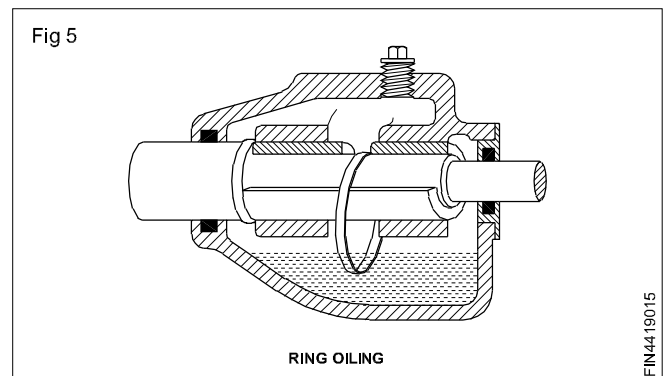


Oil pump method

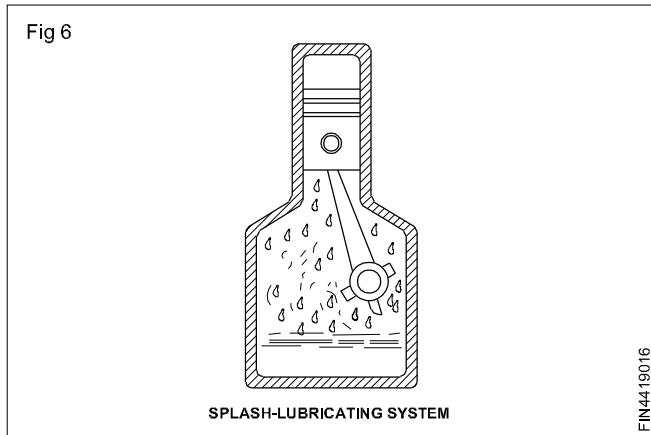
In this method an oil pump driven by the machine delivers oil to the bearings continuously, and the oil afterwards drains from the bearings to a sump from which it is drawn by the pump again for lubrication.

Splash lubrication

In this method a ring oiler is attached to the shaft and it dips into the oil and a stream of lubricant continuously splashes around the parts, as the shaft rotates. The rotation of the shaft causes the ring to turn and the oil adhering to it is brought up and fed into the bearing, and the oil is then led back into the reservoir. (Fig 5) This is also known as ring oiling.



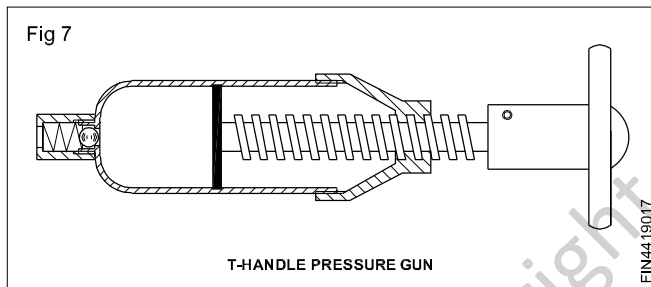
In other systems one of the rotating elements comes in contact with that of the oil level and splash the whole system with lubricating oil while working. (Fig 6) Such systems can be found in the headstock of a lathe machine and oil engine cylinder.



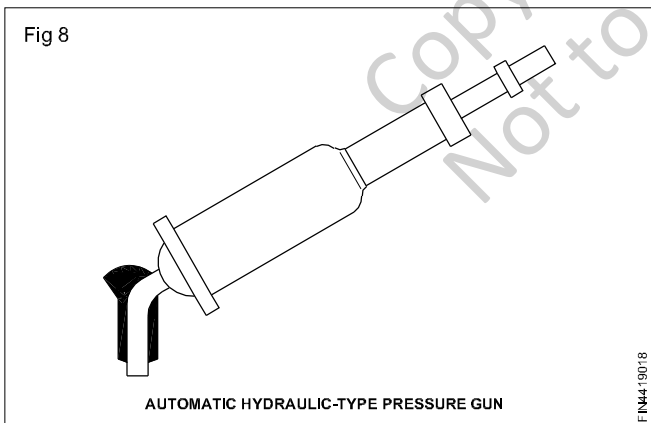
Types of grease guns

The following types of grease guns are used for lubricating machines.

- 'T' handle pressure gun (Fig 7)



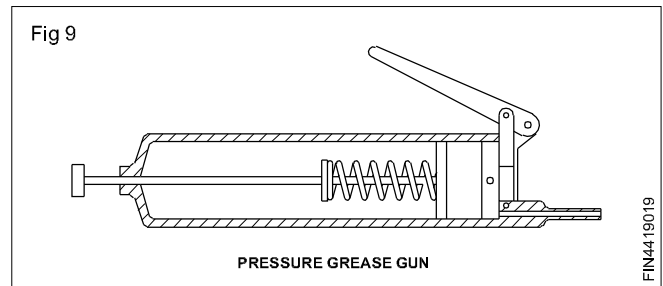
- Automatic and hydraulic type pressure gun (Fig 8)



- Lever-type pressure gun (Fig 9)

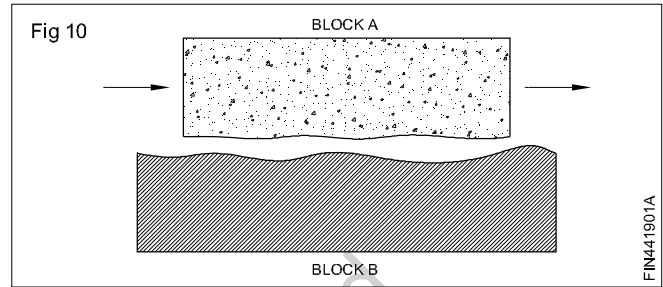
Lubrication to exposed slideways

The moving parts experience some kind of resistance even when the surface of the parts seems to be very smooth.

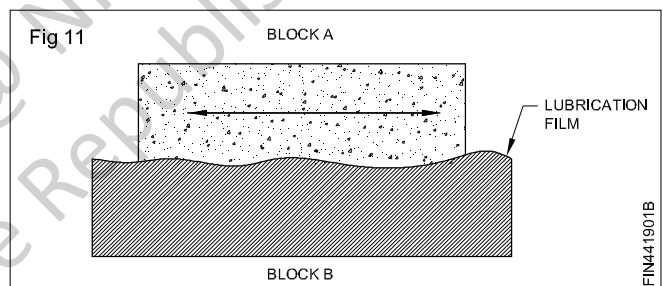


The resistance is caused by irregularities which cannot be detected by the naked eyes.

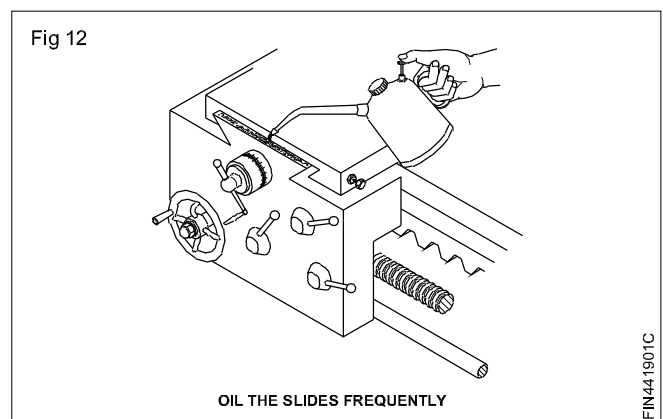
Without a lubricant the irregularities grip each other as shown in the diagram. (Fig 10)



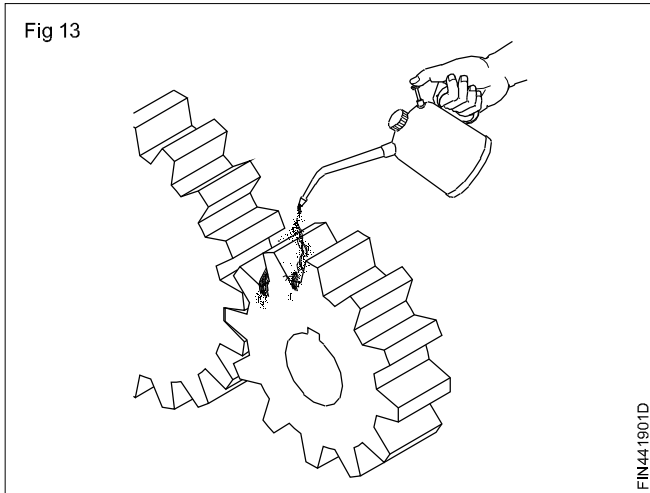
With a lubricant the gap between the irregularities fills up and a film of lubricant is formed in between the mating components which eases the movement. (Fig 11)



The slideways are lubricated frequently by an oilcan. (Fig 12)



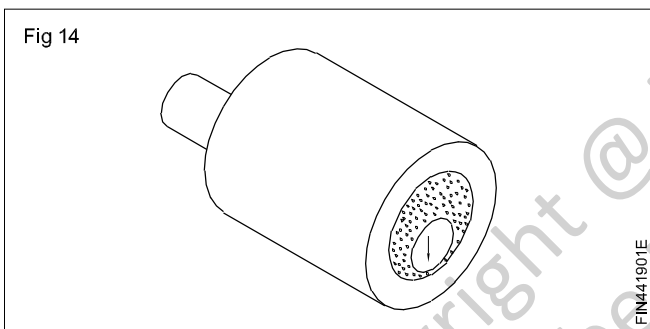
After cleaning the open gears, oil them and repeat lubrication regularly. (Fig 13)



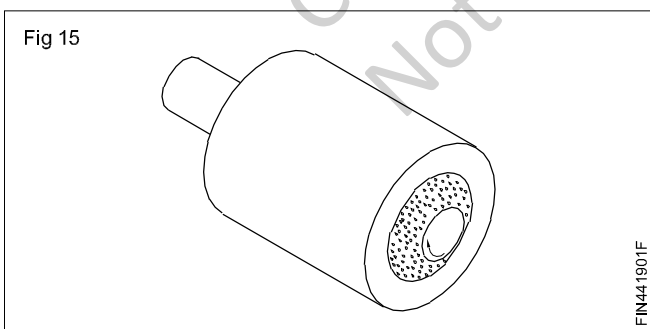
Lubricate bearings

A shaft moving in a bearing is also subjected to frictional resistance. The shaft rotates in a bush bearing or in ball/roller bearing, experiencing friction.

When the shaft is at rest on the bottom of the bush bearing, there is hardly any lubricant between the shaft and the bush. (Fig 14)

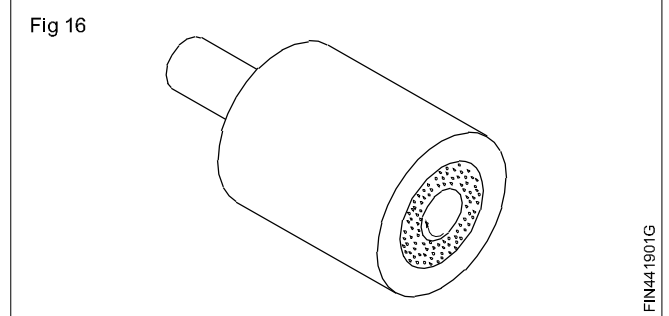


When the shaft starts rotating the lubricant maintains a film between the shaft and the bush and an uneven ring of lubricant builds up. (Fig 15)

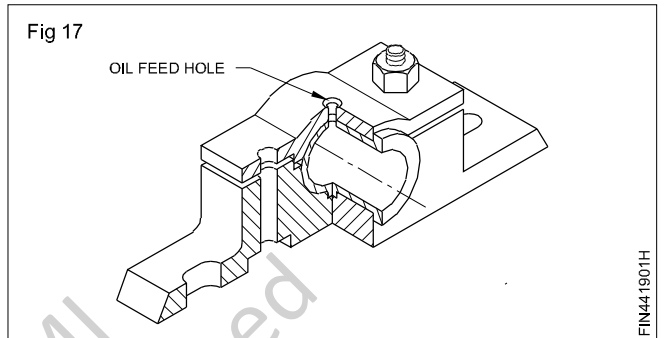


When the shaft is rotating at full speed a full ring of lubricating film surrounds the shaft (Fig 16) which is known as hydro dynamic lubrication.

This lubrication ring decreases the frictional resistance very much and at the same time protects the mating members against wear and changes.



Some bush bearings have oil feeding holes over which the oil or grease cup is mounted and the lubricant is fed through the holes into the bearing by gravity feed system.(Fig 17)



Hints for lubricating machines:

- identify the oiling and greasing points
- select the right lubricants and lubricating devices
- apply the lubricants.

The manufacturer's manual contains all the necessary details for lubrication of parts in machine tools. Lubricants are to be applied daily, weekly, monthly or at regular intervals at different points or parts as stipulated in the manufacturer's manual.

These places are indicated in the maintenance manuals with symbols as shown in Fig 18.

Fig 18

FREQUENCY CLASSIFICATION SYMBOLS

	DAILY
	WEEKLY
	MONTHLY
	SCHEDULED FOR FREQUENCIES OTHER THAN THOSE ABOVE

Cutting fluids

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

- state what is cutting fluid
 - state the function of cutting fluids & their advantages
 - state the properties of a good cutting fluid
 - identify different types of cutting fluids
 - select appropriate cutting fluids for different materials.
-

Cutting fluids and compounds are the substances used for efficient cutting while cutting operations take place.

Functions

The functions of cutting fluids are:

- to cool the tool as well as the workpiece
- to reduce the friction between the chip and the tool face by lubricating
- to prevent the chip from getting welded to the tool cutting edge
- to flush away the chips
- to prevent corrosion of the work and the machine.

Advantages

As the cutting fluid cools the tool, the tool will retain its hardness for a longer period; so the tool life is more.

Because of the lubricating function, the friction is reduced and the heat generated is less. A higher cutting speed can be selected.

As the coolant avoids the welding action of the chip to the tool-cutting edge, the built up edge is not formed. The tool is kept sharp and a good surface finish is obtained.

As the chips are flushed away, the cutting zone will be neat.

The machine or job will not get rusted because the coolant prevents corrosion.

Properties of a good cutting fluid

A good cutting fluid should be sufficiently viscous.

At cutting temperature, the coolant should not catch fire.

It should have a low evaporation rate.

It should not corrode the workpiece or machine.

It must be stable and should not foam or fume.

It should not create any skin problems to the operator.

Should not give off bad smell or cause itching etc. which are likely to irritate the operator, thus reducing his efficiency.

Should be transparent.

Types of cutting fluids

The following are the common cutting fluids.

- Straight mineral oil
- Chemical solution (synthetic fluids)
- Compounded or blended oil
- Fatty oils
- Soluble oil (Emulsified oil-suds)

Straight mineral oil

Straight mineral oils are the coolants which can be used undiluted. Use of straight mineral oil as a coolant has the following disadvantages.

It gives off a cloud of smoke.

It has little effect as a cutting fluid.

Hence straight mineral oils are poor coolants. But kerosene which is a straight mineral oil is widely used as a coolant for machining aluminium and its alloys.

Chemical solution (Synthetic oil)

These consist of carefully chosen chemicals in dilute solution with water. They possess a good flushing and a good cooling action, and are non-corrosive and non-clogging. Hence they are widely used for grinding and sawing. They do not cause infection and skin trouble. They are artificially coloured.

Compounded or blended oil

These oils are used in automatic lathes. These oils are much cheaper and have more fluidity than fatty oil.

Fatty oil

Lard oil and vegetable oil are fatty oils. They are used on heavy duty machines with less cutting speed. They are also used on bench-works for cutting threads by taps and dies.

Soluble oil (Emulsified oil)

Water is the cheapest coolant but it is not suitable because it causes rust to ferrous metals. An oil called soluble oil is added to water which gets a non-corrosive effect with water in the ratio of about 1: 20. It dissolves in water giving a white milky solution. Soluble oil is an oil blend mixed with an emulsifier.

Other ingredients are mixed with the oil to give better protection against corrosion, and help in the prevention of skin irritations.

Soluble oil is generally used as a cutting fluid for centre lathes, drilling, milling and sawing.

Soft soap and caustic soda serve as emulsifying agents.

A chart showing coolants for different metals is given below.

Recommended cutting fluids for various metals and different operations

Material	Drilling	Reaming	Threading	Turning	Milling
Aluminium	Soluble oil Kerosene Kerosene and lard oil	Soluble oil Kerosene Mineral oil	Soluble oil Kerosene Lard oil	Soluble oil	Soluble oil Lard oil Mineral oil Dry
Brass	Dry soluble oil Mineral oil Lard oil	Dry soluble oil	Soluble oil Lard oil	Soluble oil	Dry soluble oil
Bronze	Dry soluble oil Mineral oil Lard oil	Dry soluble oil Mineral oil Lard oil	Soluble oil Lard oil	Soluble oil	Dry soluble oil Mineral oil Lard oil
Cast iron	Dry Air jet Soluble oil	Dry soluble oil Mineral lard oil	Dry sulphurized oil Mineral lard oil	Dry soluble oil	Dry soluble oil
Copper	Dry soluble oil Mineral lard oil Kerosene	Soluble oil Lard oil	Soluble oil Lard oil	Soluble oil	Dry soluble oil
Steel alloys	Soluble oil Sulphurized oil Mineral lard oil	Soluble oil Sulphurized oil Mineral lard oil	Sulphurized oil Lard oil	Soluble oil	Soluble oil Mineral
General purpose steel	Soluble oil Sulphurized oil Lard oil Mineral lard oil	Soluble oil Sulphurized oil Lard oil	Sulphurized oil Lard oil	Soluble oil	Soluble oil Lard oil

Clutches and types

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

- state the function of clutches
- name the different types of clutches
- state the application of the different types of clutches.

Power transmission by clutches

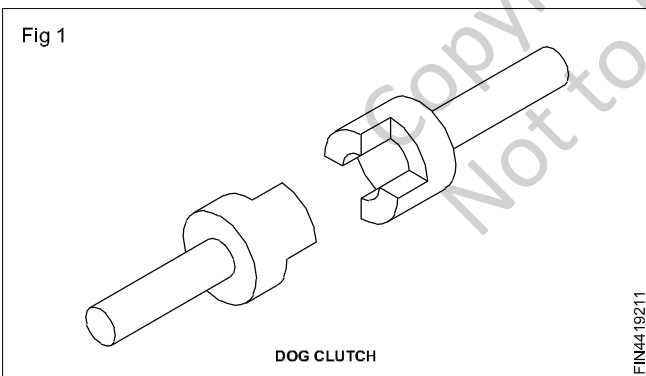
The purpose of the clutch is to connect or disconnect the various mechanisms to the power source. Various types of clutches are incorporated in machine tools.

Types of clutches

- Dog clutch
- Cone clutch
- Multi-plate clutch
- Electromagnetic multiple disc clutch.
- Air clutch
- Centrifugal clutch
- Overriding clutch
- Single plate clutch

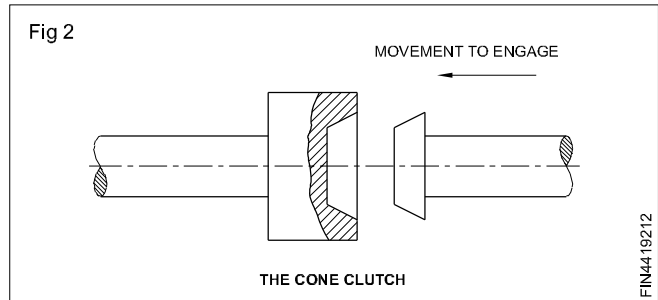
Dog clutch (Fig 1)

The dog clutch provides a positive drive but can only be engaged when two elements of the clutch are stationary or are being gently moved by hand.



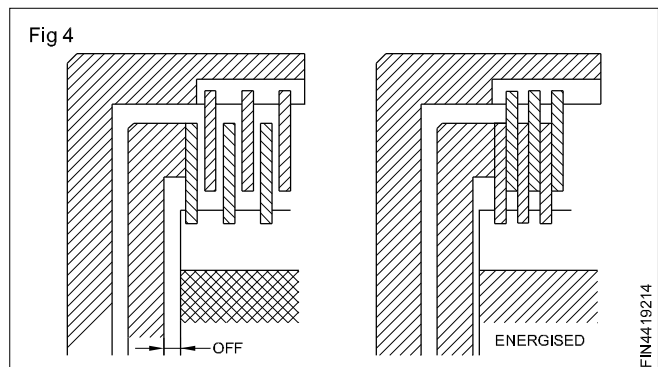
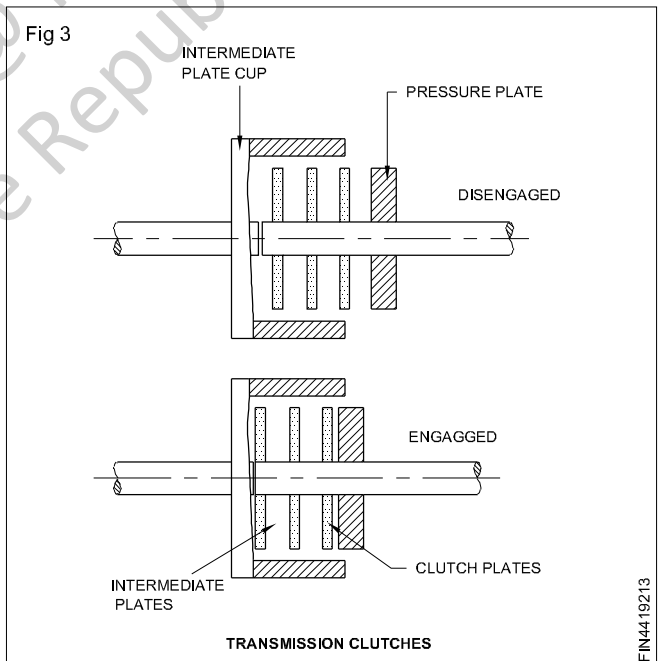
Cone clutch (Fig 2)

The cone clutch can be engaged progressively whilst one or both of the elements are rotating. It can transmit low power.



Electromagnetic multiple disc clutch (Fig 4)

This clutch joins the shaft and the gear. It can be operated through a cable from a distance. If direct current is applied, it builds a magnetic field on a magnetic coil. It flows through the discs and firmly pulls and attracts the armature disc. The armature clamps the plates together so that they transmit the drive.

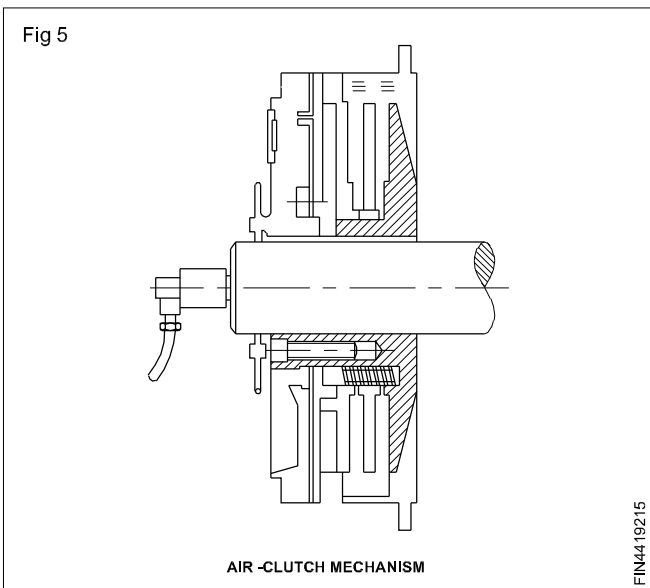


Multi-plate clutch (Fig 3)

The multi-plate clutch is widely used in machine tools to connect the transmission gearbox to the driving motor. It is compact, smooth in operation and very powerful. A brake is frequently built into the clutch so that the transmission gearbox is rapidly brought to rest when the clutch is disengaged.

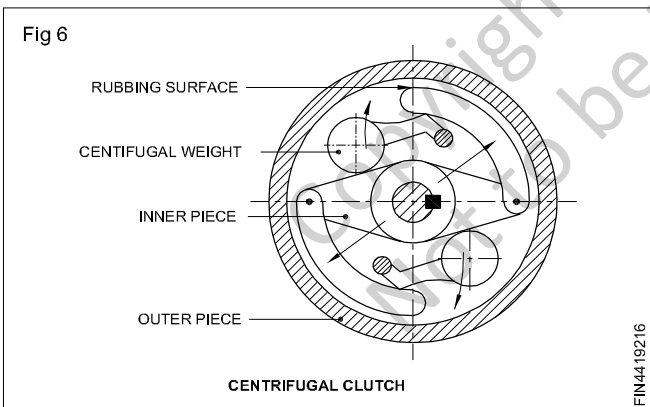
Air clutch (Fig 5)

An air clutch requires no mechanical adjustment since the moving parts automatically take up any wear on the friction surface. Air pressure must be maintained continuously while the clutch is engaged.



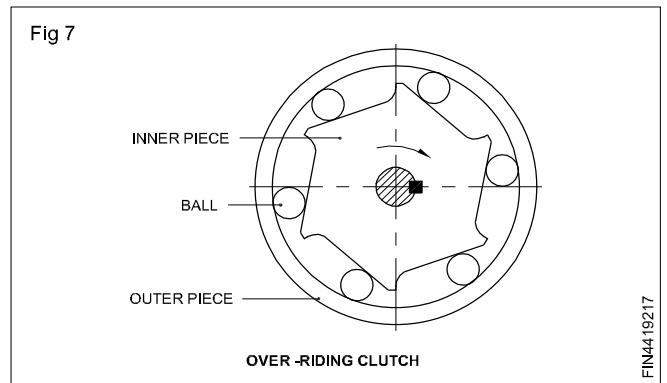
Centrifugal clutch (Fig 6)

When the inner piece has achieved a sufficiently high speed, the centrifugal weights swivel towards the outside, press the jaws on the outer piece with the friction lining and the clutch is closed. When the speed is reduced, the clutch opens by itself. Eg. moped.



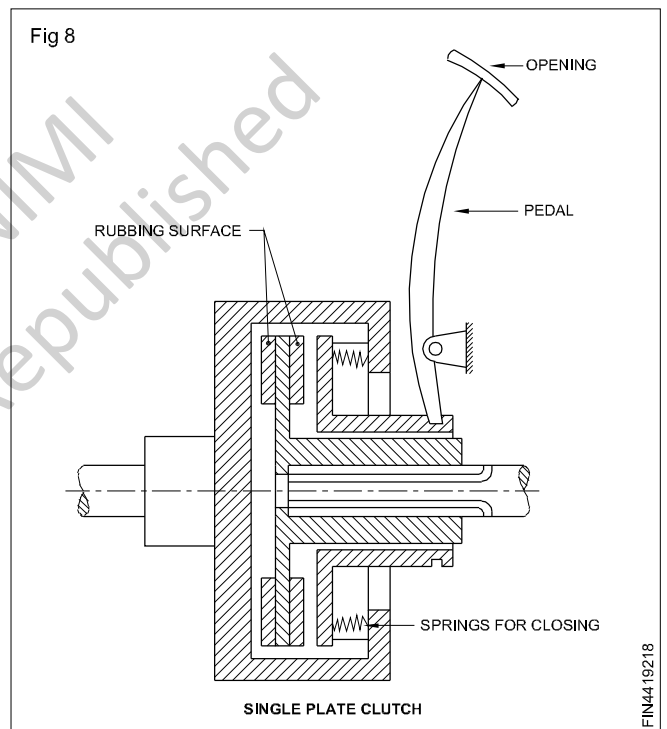
Overriding clutch (Fig 7)

When the inner piece has to be faster the overriding clutch transfers the turning moment by the climbing of balls or the cylindrical rollers. It opens in the opposite case.



Single plate clutch (Fig 8)

This is used in automobile vehicles. The rubbing surface is covered with friction lining of asbestos/plastic/cotton, with steel wires. The contact force is produced by springs which effect the continuous closing of the clutch. The pedal force acts against the spring force and opens the clutch.

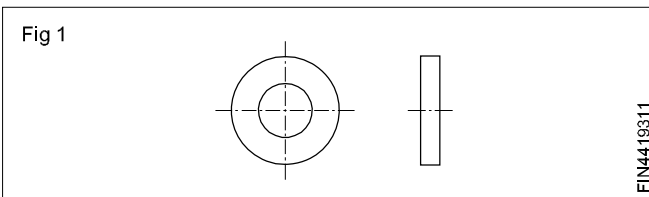


Washer types and calculation of sizes

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

- state the various types of washers
- determine the sizes of washers
- state the uses of washerWashers

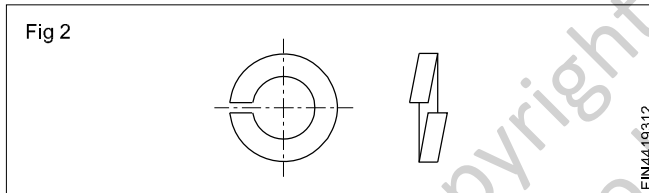
Washers are used to distribute the clamping pressure over a larger area, and prevent the surface damaged (marking). they are also provide an increased bearing surface for bolt heads and nuts. Washers are manufactured in light, medium, heavy and extra heavy series. (Fig 1)



Lock washers

A lock washer is used to prevent a bolt or nut from loosening under vibration.

The split ring lock washer is being rapidly replaced by lock washers designed for specific applications. (Fig 2)

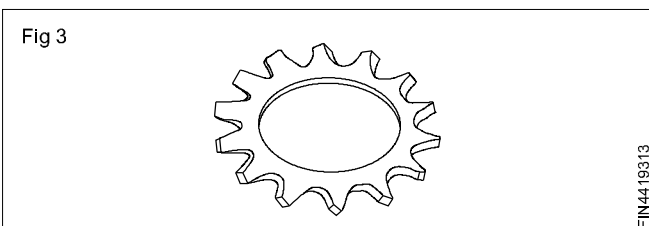


Tooth type lock washers

These washers have teeth that bite deep into both screw head and work surface. Their design is such that they actually lock tighter as vibrations increase.

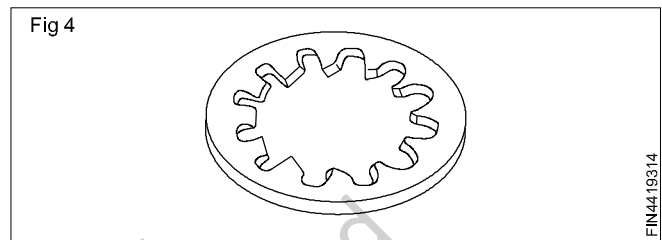
External type

Should be used where possible as it provides the greatest resistance. (Fig 3)



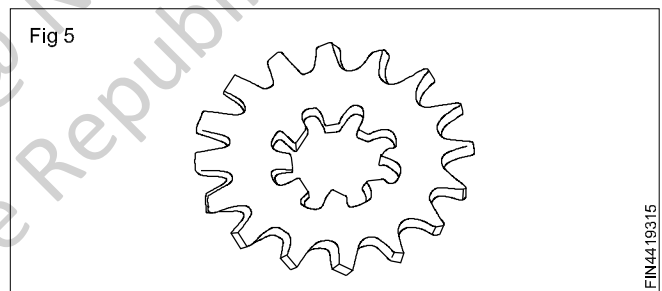
Internal type

Used with small head screws and where it is desirable to hide the teeth either for appearance or to prevent snagging. (Fig 4)



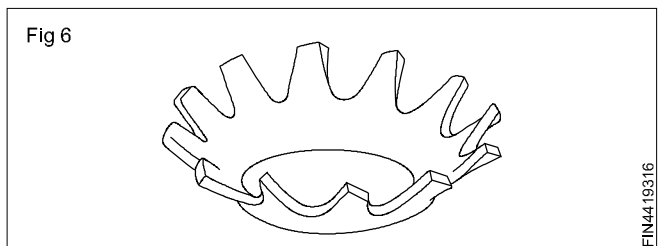
Internal and external type

Used when the mounting holes are over size. (Fig 5)

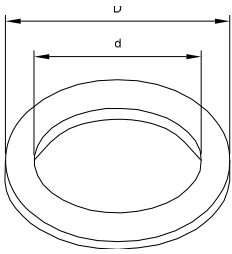


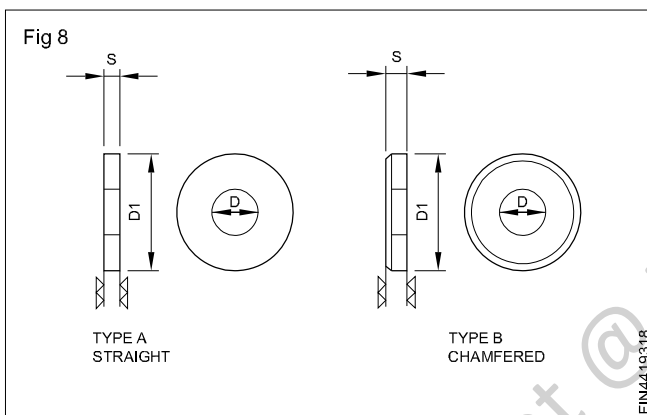
Countersunk type

For use with flat or oval type head screws. (Fig 6)



Calculation of washer

	<p>Specific bearing load (N/mm²)</p> $P = \frac{4W_t}{\pi(D^2 - d^2)}$	<p>Sliding speed (m/s) rotation</p> $V = \frac{\pi \times D \times N}{60 \times 10^3}$	p	Specific bearing load	N/mm ²
			d	inside diameter	mm
			D	outside diameter	mm
			W _t	load on thrust washer	N
			N	Speed of rotation	rpm
			∂	angle of oscillations	degrees
			Nos	frequency of oscillations	cycles /min
			V	sliding speed	m/s
		<p>Sliding speed (m/s)</p> $V = \frac{\pi \times D}{60 \times 10^3} \times \frac{2a \times N \times \partial}{360}$			



Washer sizes

Nominal diameter		D	D1	S	Weight kg/1000 pcs
M3		3.2	7	0.5	0.12
M4		4.3	9	0.8	0.3
M5		5.3	10	1	0.44
M6		6.4	12.5	1.6	1.14
M7		7.4	14	1.6	1.39
M8		8.4	17	1.6	2.14
M10		10.5	21	2	4.08
M12		13	24	2.5	6.27
M14		15	28	2.5	8.6
M16		17	30	3	11.3
M18		19	34	3	14.7
M20		21	37	3	17.2
M22		23	39	3	18.4
M24		25	44	4	32.3
M27		28	50	4	42.8
M30		31	56	4	53.6
M33		34	60	5	75.4
M36		37	66	5	92

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Chain and wire rope for power transmission

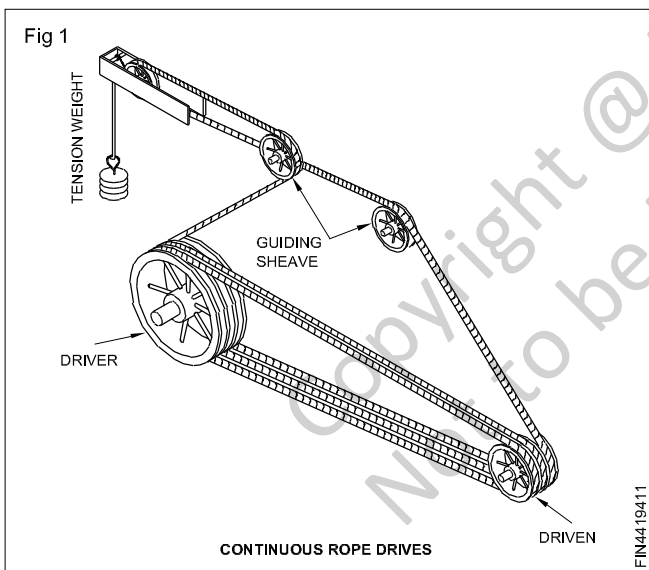
Objectives : At the end of this lesson you shall be able to

- state the uses of rope drives
- list the materials of rope
- state the purpose of jackey pulleys
- state the uses of chain drive
- list the advantages of chain drive.

Ropes and rope drive

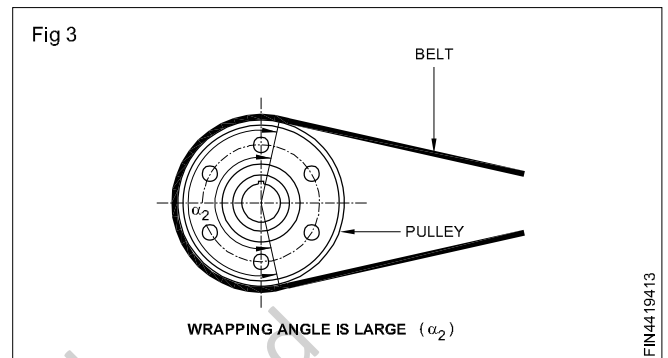
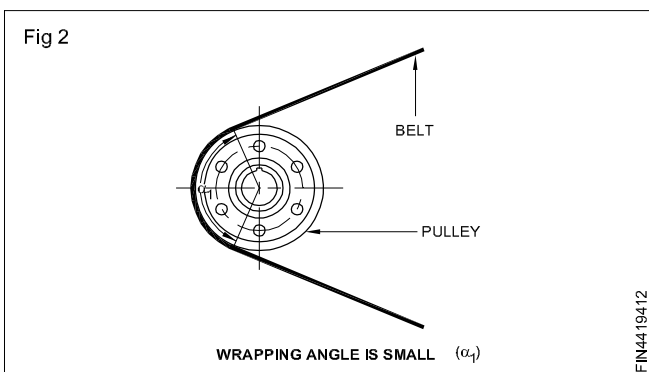
The ropes are made from cotton, hemp, manila, synthetic jute, steel wire, etc.

Rope drives are used for long distance and for large amounts of power transmission. The rope drives are mainly employed in mining and textile industries. Rope drives can be employed when there is a misalignment between the pulleys within limits and in fluctuating temperature and humidity conditions. Fig 1 shows a continuous rope drive in which a single rope passes over the sheaves several times, and the slackness being taken up by a tension carriage.



Wrapping angle of pulley

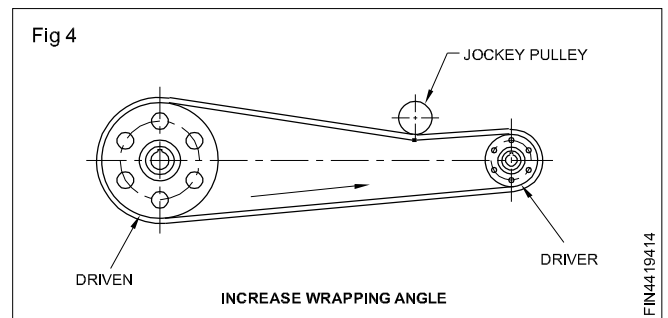
Fig 2 and 3 illustrate the contact area of the belt and wrapping angle. If the wrapping angle is big, the pulley can transmit high torque. If the contact area and wrapping angle is less, it can transmit low torque.



Jockey pulley

The contact surface between the belt and the pulley is increased by providing a jockey pulley which increases the wrapping angle and transmits high torque.

The jockey pulley should be put on the slack side of the belt near the driving pulley. (Fig 4)



Chains and sprockets

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

- state the advantages of chains drives
- state the use of a jockey sprocket
- state the types and specifications of chains
- brief the maintenance features of the chain drive.

Chain drive (Fig 1)

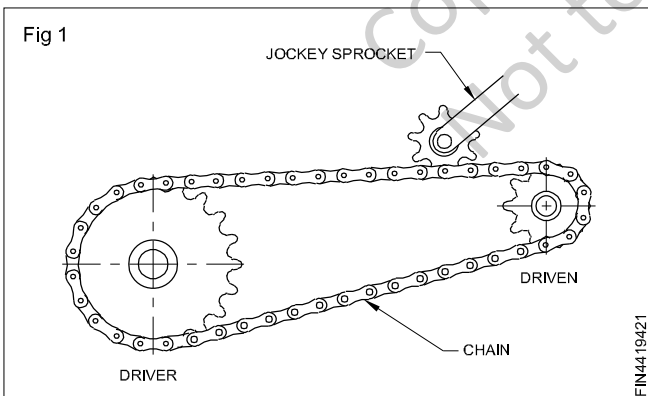
Chain drives are used for transmission of motion at constant velocity ratio without creep and slippage. Chains are used in conjunction with sprocket pinions and sprocket wheels. Chains and sprockets are available in both british and metric standards. The sprockets are generally keyed to the shafts.

Advantages of a chain drive

- Positive contact between the chain and the drive sprockets eliminates the possibility of slips.
- Has a wide range of driving power.
- Can be used where there is a large distance between the driving and driven shafts.
- Useful for low speed and high torque transmissions.
- Can absorb shocks.
- Chain drives are compact.
- Chain drives withstand heat, dirt and weather exposure when properly lubricated.

Jockey sprocket (Fig 1)

A spring-loaded jockey sprocket can be used to tension a chain which transmits the drive between the sprockets with fixed centres.



Types of chains

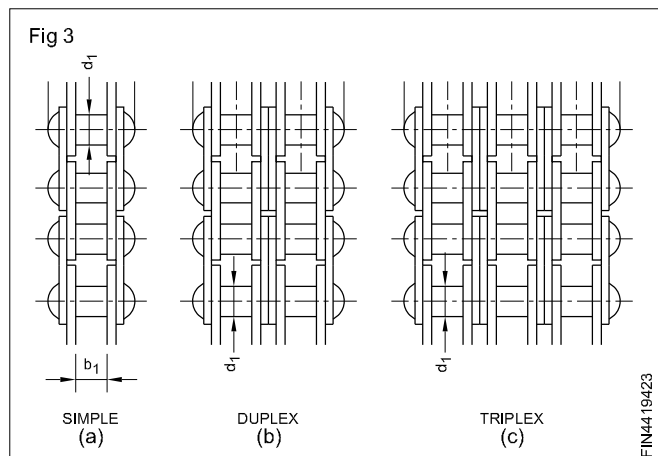
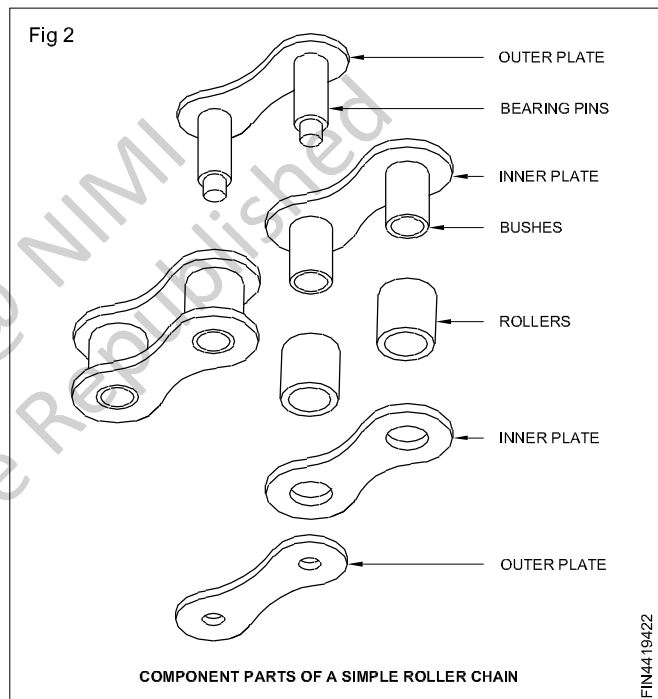
There are many types of chains but follow two types are commonly used.

- Roller chain
- Toothed chain

Roller chain (Fig 2)

Rollers are housed between the connecting links and rotate freely on the bush. The bush is pressed in the holes of internal link and can rotate about the pin.

- Single roller type chain is called a Simplex chain. (Fig 3a)
- Double roller type chain is called a Duplex chain. (Fig 3b)
- Triple roller type called a Triple chain. (Fig 3c)



Toothed chain or silent chain

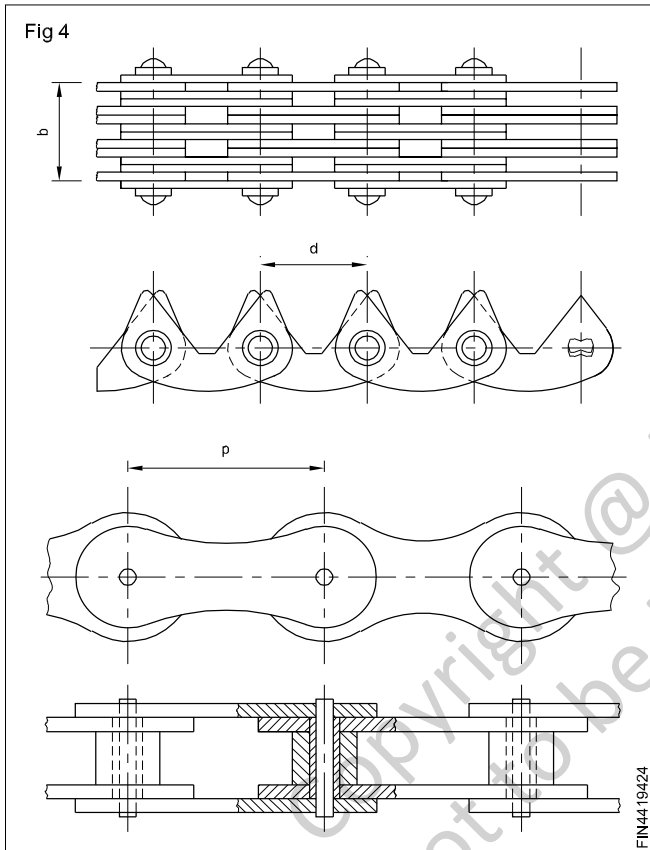
These chains are provided for noiseless and uniform

drive. It consist of a row of toothed links connected through bushes.

Chain specification

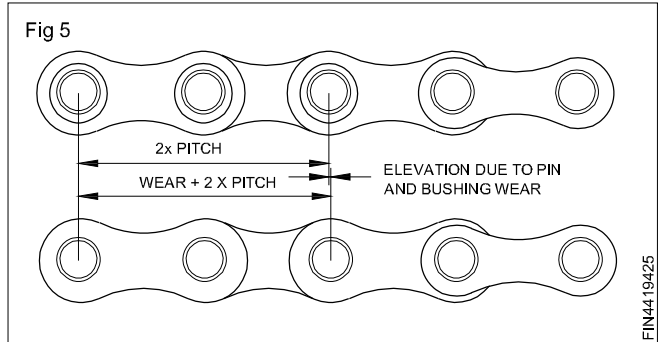
Chains are specified by the pitch. For roller chains pitch is the distance between the centre-to-centre of adjacent pins. Width refers to normal width of the link measured within the side of the plates. Diameter means the actual outside diameter of the roller. (Fig 4)

ISI 2403-1975 gives the specifies dimensions for standard chains of different diameters.



Maintenance features for chain drive

- Check alignment periodically and rectify if necessary.
- Inspect the chain for elongation. Excess clearance at point signifies elongation as shown in fig 5. The chain should be replaced as excess elongation spoils the sprocket.



Lubricants and lubrication

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

- **state the purpose of using lubricants**
- **state the properties of lubricants**
- **state the qualities of a good lubricant.**

With the movement of two mating parts of the machine, heat is generated. If it is not controlled the temperature may rise resulting in total damage of the mating parts. Therefore a film of cooling medium with high viscosity is applied between the mating parts which is known as a 'lubricant'.

A 'lubricant' is a substance having an oily property available in the form of fluid, semi-fluid, or solid state. It is the lifeblood of the machine, keeping the vital parts in perfect condition and prolonging the life of the machine. It saves the machine and its parts from corrosion, wear and tear, and it minimises friction.

Purposes of using lubricants

- Reduces friction.
- Prevents wear.
- Prevents adhesion.
- Aids in distributing the load.
- Cools the moving elements.
- Prevents corrosion.
- Improves machine efficiency.

Properties of lubricants

Viscosity

It is the fluidity of an oil by which it can withstand high pressure or load without squeezing out from the bearing surface.

Oiliness

Oiliness refers to a combination of wettability, surface tension and slipperiness. (The capacity of the oil to leave an oily skin on the metal.)

Flash point

It is the temperature at which the vapour is given off from the oil (it decomposes under pressure soon).

Fire point

It is the temperature at which the oil catches fire and continues to be in flame.

Pour point

The temperature at which the lubricant is able to flow when poured.

Emulsification and de-emulsibility

Emulsification indicates the tendency of an oil to mix intimately with water to form a more or less stable emulsion. De-emulsibility indicates the readiness with which subsequent separation will occur.

Film of oil formed in journal bearing

In a sliding contact bearing, the journal is directly inserted into the bearing. This results in direct metal to metal contact between them. As a consequence the friction is higher between the inner surface of the bearing and the outer surface of journal, if there is no lubricating film present in between them. Bearings can be lubricated with three kinds of lubricants, viz. Liquids like mineral oil or vegetable oils, semi - solids like grease, and solids like graphite or molybdenum di-sulfide. These lubricants are used to reduce friction and wear, dissipate the frictional heat and to protect against corrosion. There are two basic modes of lubrication: (a) thick film and (b) thin film lubrication.

Thick film lubrication

In thick film lubrication, two surfaces of bearing in relative motion, (Viz., the journal and the bearing inner surface) are completely separated by a fluid film. The resistance to relative motion arises from the viscous resistance of the fluid. This does not depend on the structure of journal surface and bearing inner surface as they are not in contact with each other. Thick film lubrication is classified into: hydrodynamic and hydrostatic lubrication.

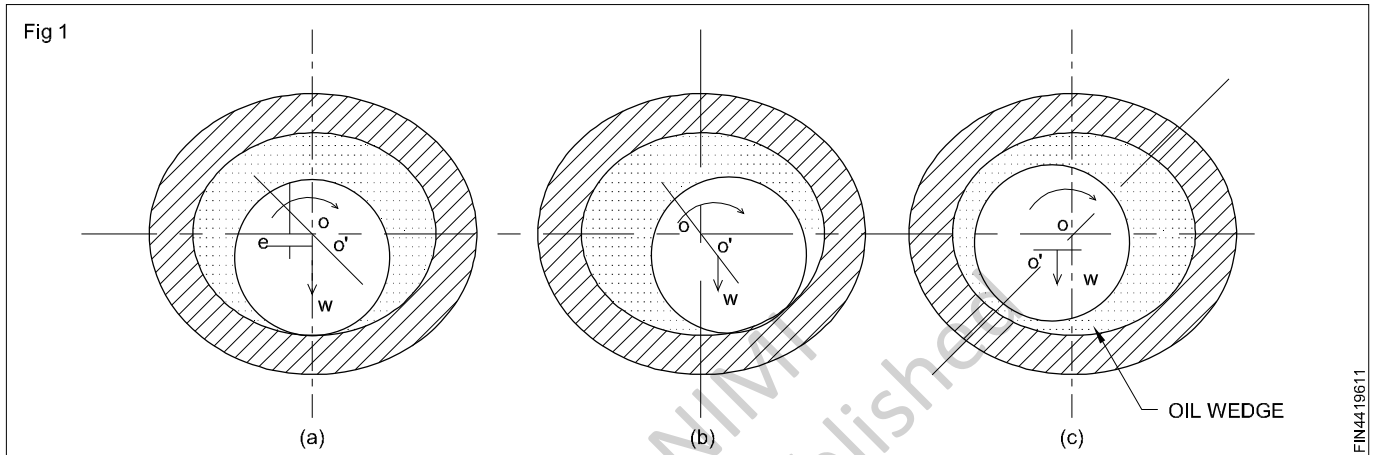
Hydrodynamic lubrication

Hydrodynamic lubrication is defined as a system of lubrication in which the load supporting fluid film is created by the shape and relative motion of the sliding elements. The principle of hydrodynamic lubrication in journal bearing is shown in Fig 1

Hydrodynamic lubrication (a) Journal at rest (b) journal starts to rotate (c) journal at full speed

When the shaft (Centered at o') is at rest, it goes to the bottom of bearing (centered at O) under the action of load W. This load is due to the weights of shaft and various elements (gears, pulleys) supported by the shaft. The outer surface of journal and inner surface of bearing touch each other during rest, with no clearance at the bottom. The letter 'e' denotes the eccentricity, the offset between the axes of the journal and the bearing.

As the journal starts to rotate, it will climb bearing surface. When the speed is increased further, it forces the fluid into the wedge-shaped region between the journal and bearing. As more and more fluid is forced into the wedge shaped region, pressure is generated within the fluid as shown in Fig.1 This fluid pressure generated in the clearance space supports the external load (W). It can be seen that the pressure distribution around journal varies greatly. Hydrodynamic lubrication does not need a supply of lubricants at high pressure from external source (pumps), as enough fluid pressure is, generated within the system. Bearings that use 'hydrodynamic lubrication' are called 'Hydrodynamic bearings'.



INDUSTRIAL LUBRICATING OILS

Annexure I

Product	Kinematic viscosity Cst at 40°C.	VI	Flash point COC°C	Description/Application
General Purpose Machinery Oils Lubrex 57 Lubrex 68	54.60 64.72	160 160	Lubrex oils are low viscosity index straight mineral lubricants having good inherent oxidation stability; they protect machine elements from excessive wear and provide economical lubrication. These oils are recommended for lubrication of bearings, open gears, lightly loaded slides and guideways of machine tools.
Flushing Oil Lubrex Flush 22	19.22	..	150	Lubrex Flush 22 is a light coloured, low viscosity, straight mineral oil specially developed for slushing of automotive and industrial equipment. The characteristics of Lubrex Flush 22 make it possible to easily clean all inaccessible internal surfaces of various equipments.
Circulating and Hydraulics Oils (Anti-wear Type) Servosystem 32 Servosystem 57 Servosystem 68 Servosystem 81 Servosystem 100	29.33 55.60 64.72 78-86 95-105	95 95 95 90 90	196 210 210 210 210	Servosystem oils are blended from highly refined base stocks and carefully selected anti-oxidant, anti-wear, anti-rust and anti-foam additives. These oils have long service life, and are recommended for hydraulic systems and a wide of circulation

Servosystem 150	145-155	90	230	systems of industrial and automotive equipment. These oils are also used for compressor crank case lubrication, but are not recommended for lubrication of turbines and equipment having silver coated components.
Spindle Oils				
Servospin 2	2.0-2.4	..	70	Servospin oils are low viscosity lubricants containing anti-wear, anti-oxidant, anti-rust and anti-foam additives. These oils are recommended for lubrication of textile and machine tool spindle bearings, timing gears, positive displacement blowers, and for tracer mechanism and hydraulic systems of certain high precision machine tools.
Servospin 5	4.5-5.0	..	70	
Servospin 12	11-14	90	144	
Machinery Oils				
Servoline 32	29.33	..	152	Servoline oils provide good oiliness for general lubrication even under boundary lubrication conditions, protect parts against rust and corrosion and maintain thin film strength and anti-rust additives. Servoline oils are general purpose lubricants for all loss lubrication systems of textile mills, paper mills, machine tools.
Servoline 46	42.50	..	164	
Servoline 68	64-72	..	176	
Gear Oils				
Servomesh 68	64-72	90	204	Servomesh oils are industrial gear oils blended with lead and sulphur compounds. These oils provide resistance to deposit formation, protect metal components against rust and corrosion, separate easily from water and are non-corrosive to ferrous and non-ferrous metals. Servomesh oils are recommended for lubrication of industrial gears, plain and anti-friction bearings subjected to shock and heavy loads and should be used in systems were operating tem
Servomesh 150	145-155	90	204	
Servomesh 257	250-280	90	232	

Foundation bolts and types

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

- state the purpose of foundation bolts
- state the different types of foundation bolts and their uses
- designate the foundation bolts as per BIS
- mention the purpose of grouting
- name the different types of grouting.

Purpose of foundation bolts

For some machine tools, it is very essential to hold down the machines firmly on the foundation to prevent them from moving. For this purpose various types of foundation bolts or anchor bolts are used.

Types of foundation bolts

Foundation bolts are divided into two groups. They are:

- fixed type
- removable type.

Fixed type of bolts

Fig 1 shows the ordinary foundation bolt with mild steel plate. The rag bolt shown in Fig 2 is usually forged and filled up with lead or cement. A simple form, shown in Fig 3, is known as eye foundation bolt. A bent type of bolt is shown in Fig 4.

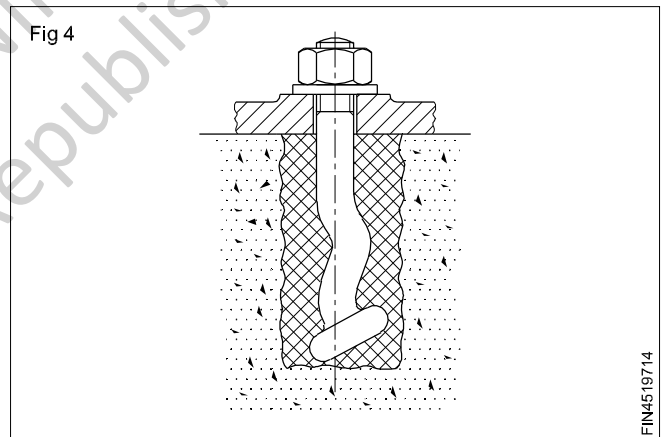
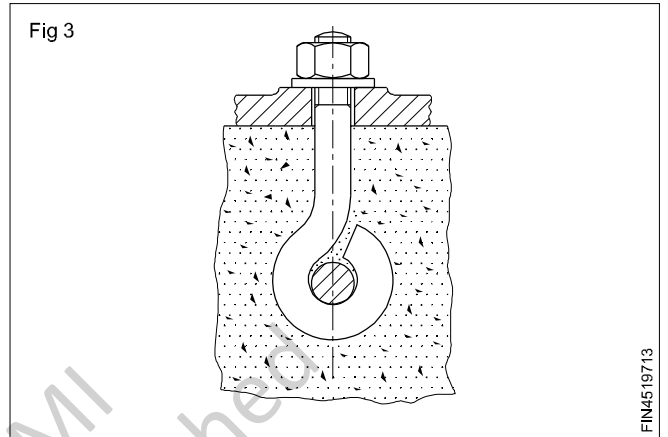
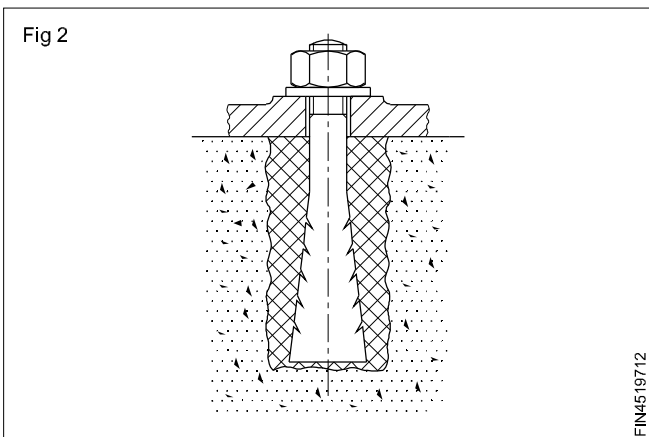
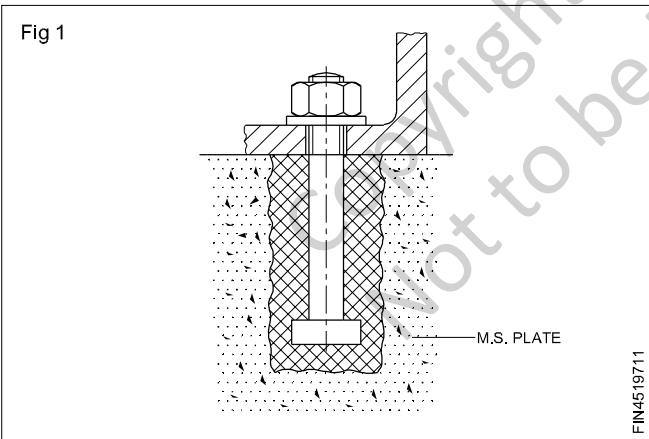
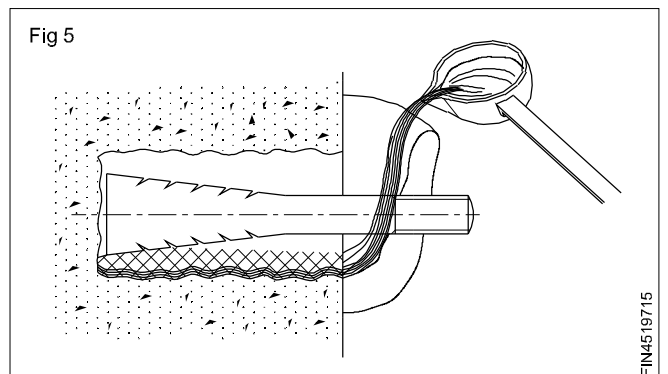


Fig 5 shows running up bolts in a horizontal position. A clay cap is formed around the bolt to support this and direct the lead into the hole. After running up, the lead should be caulked in position to consolidate this.

When running with lead, care should be taken to see that no water is collected in the hole; otherwise steam will be rapidly generated which will blow the lead out, which may cause serious burns.



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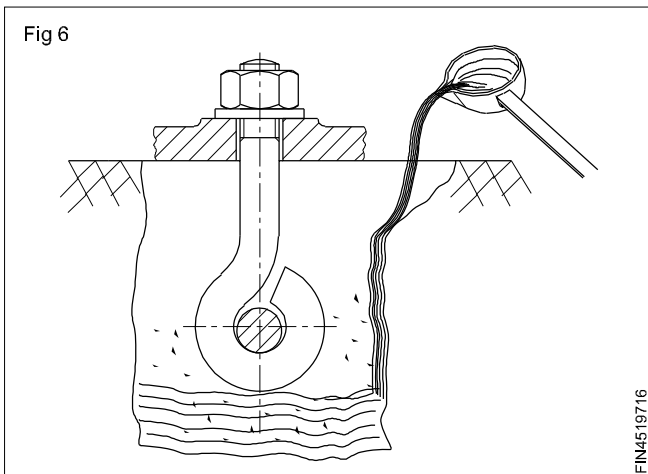
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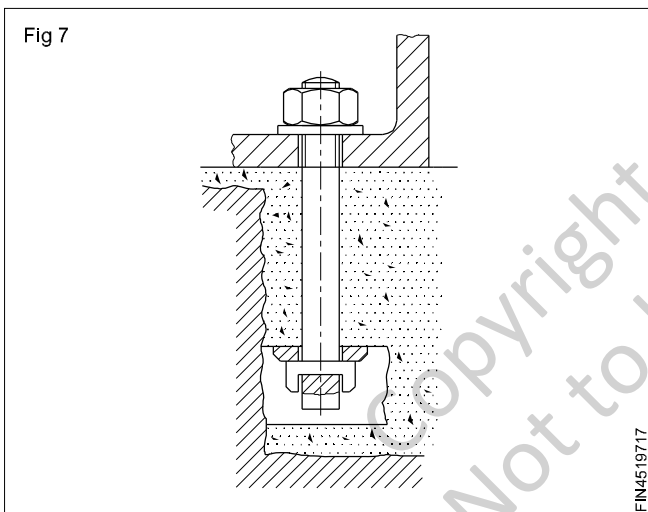
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As an alternative to lead, where quick setting is required, rock sulphur can be melted down in an old kettle or ladle and run into the bolt hole as quickly as possible. (Fig 6)



Removable type (Fig 7)

For large machines a long cotter bolt is commonly used. This bolt is provided with a square foundation plate and a removable cotter at the bottom. In forming the foundation, pockets are left in the sides of the bolt holes which are then capable of being replaced at any time, if necessary.



The rawl bolt (Fig 8)

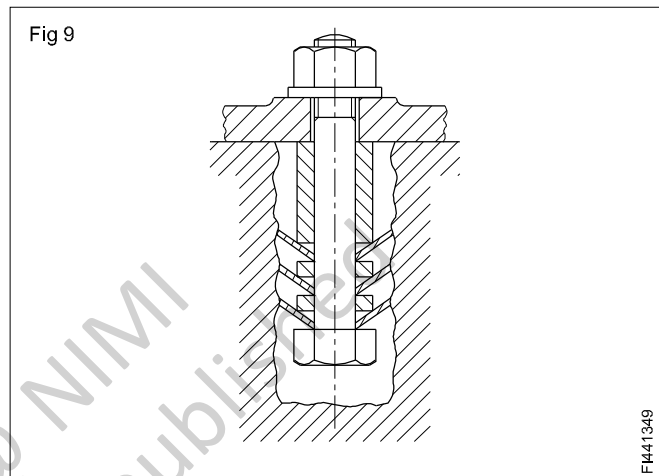
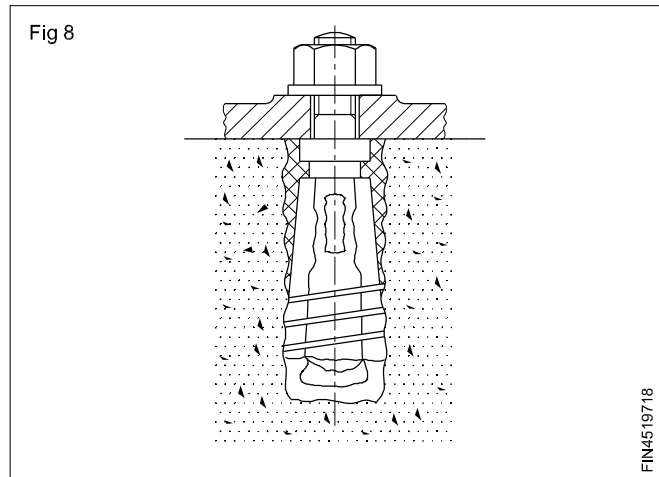
In this type four clamps are flexibly mounted on the bolt which expand by wedge action when tightened up. The advantage is that they can be removed and used again, if necessary.

Expanding conical washer foundation bolt (Fig 9)

This consists of a bolt on which are threaded conical washers and ferrule. On drawing up the bolt, the washers are flattened which grip the inside of the hole by expansion.

Grouting

After levelling the machines in the aligned condition with the foundation bolts and wedges, there will be a gap left over between the bottom of the machine and the top of the floor or foundation block. This space is filled up with grouting materials such as cement concrete or sulphur or lead and the process is known as 'grouting'.



When 'mould' boxes are used and the anchor or foundation bolts are suspended in their respective pockets, the pockets are filled up with the grouting material.

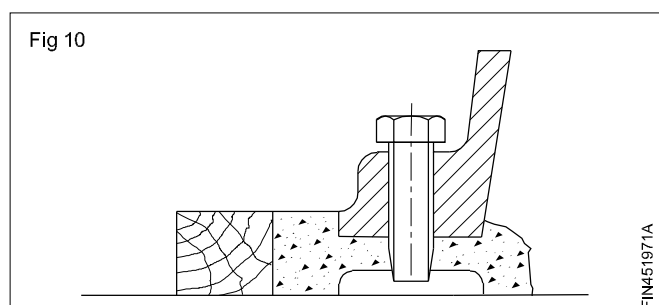
Purpose

- To ensure that the machine rests firmly on the top of the foundation block or the floor.
- To prevent lateral shifting particularly for the machines like shaper, planer, surface grinder etc. which are having reciprocating motion.

Types of grouting

Cement concrete grout (Fig 10)

It is a most common grouting process wherein cement concrete mixture is used. This mixture can bear the compressive load of the machine. This is quite cheap and strong to withstand the displacement of the machine. This is not suitable for oil-soaked areas.



Sulphur grouting

Since sulphur remains unaffected by oil or grease it is recommended as grouting material for oil-soaked areas.

Lead grout

Lead is mainly used as a grouting material for steam turbines. It is too expensive to be used for general machine foundation.

Moving equipment with crowbars

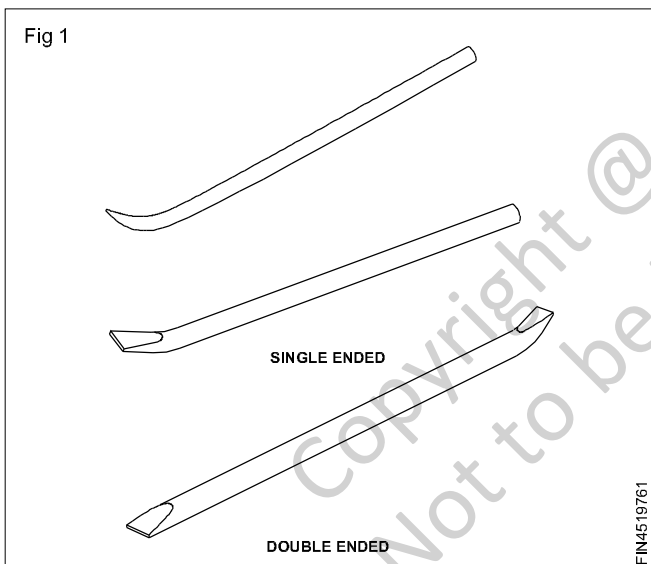
Objectives : At the end of this lesson you shall be able to

- name the different types of crowbars
- state the uses of crowbars
- state the methods of lifting and moving machines with crowbars and rollers.

Crowbars give leverage, so that heavy loads can be lifted or moved. They are made in different lengths with hexagonal or octagonal steel bars. Short crowbars are easier to handle and the point will fit into a narrow gap, but requires more force. Long crowbars provide a greater leverage.

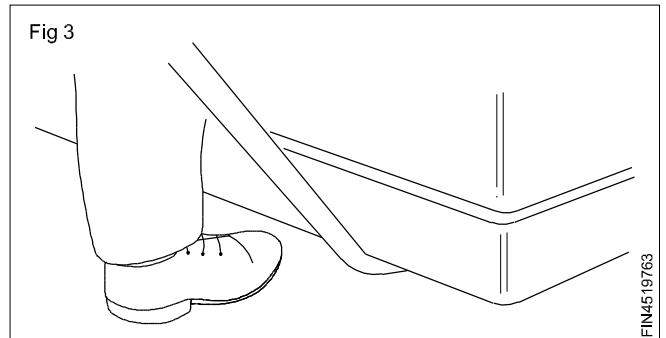
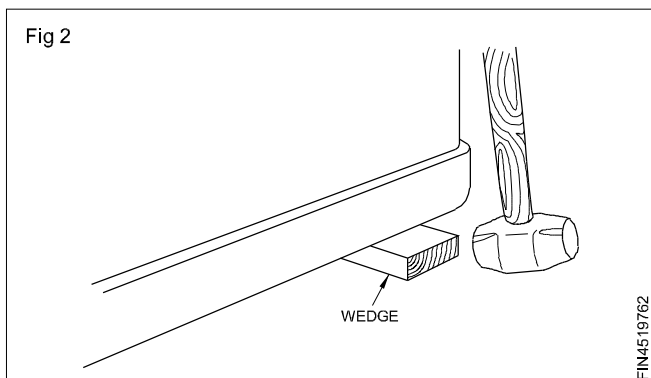
Types of crowbars (Fig 1)

There are two types of crowbars, single or double ended. A single ended crowbar is safer to use as the handle has a rounded end. The double ended crowbar normally has a curved end used for lifting, and a straight end used for pushing.



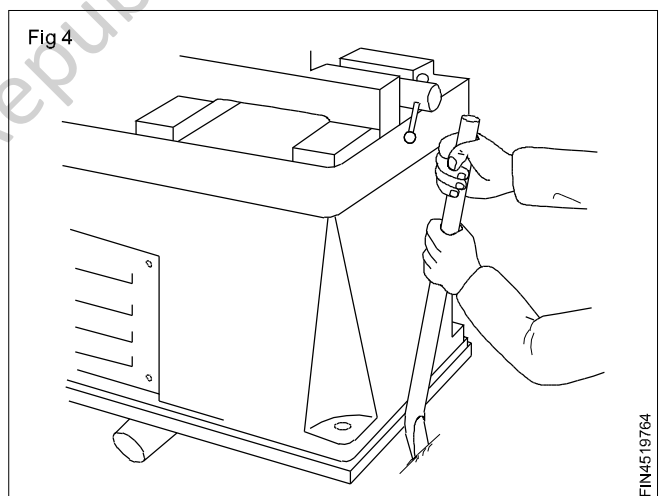
Lifting equipment by crowbars

If the gap under the machine is not good enough to accept the tip of the crowbar, tap a small steel wedge under the machine to increase the gap and place the toe of the crowbar under the machine and press the other end down to lift the machine. (Figs 2 & 3)

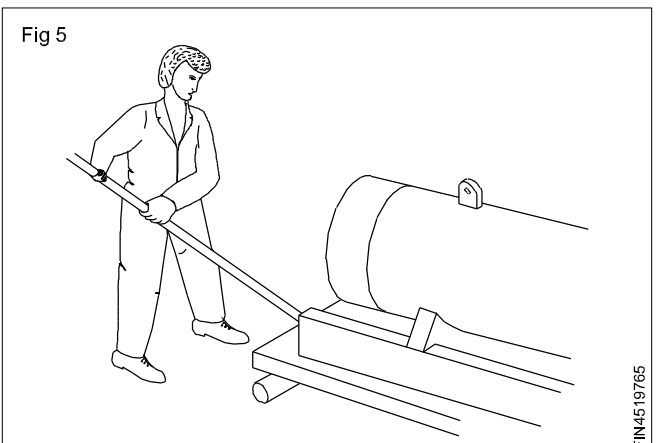


Position the handle so that no one will be endangered if the crowbar slips. When pushing or lifting, never push the crowbar close to the load or to the ground, as your fingers might be caught if the bar slips.

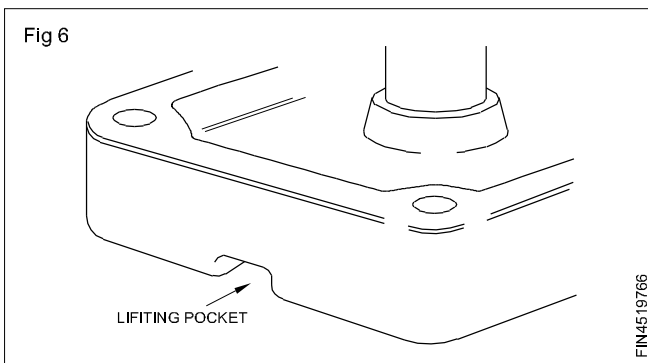
Always use both hands and hold close to the end of the crowbar to get maximum leverage. (Fig 4)



Stand with the legs apart so that the balance is not lost if the crowbar slips. (Fig 5)

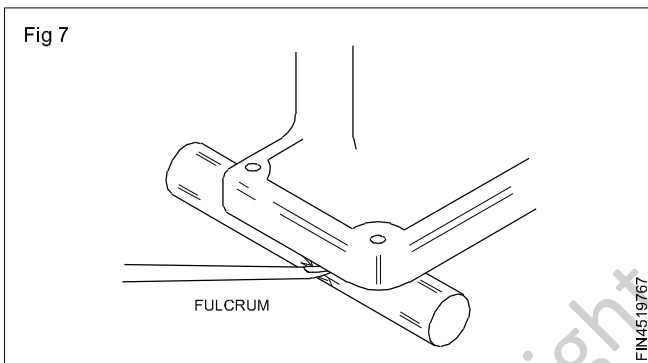


Equipments are provided usually with a lifting pocket. Place the toe of the crowbar in it for lifting the machine and moving it. (Fig 6)



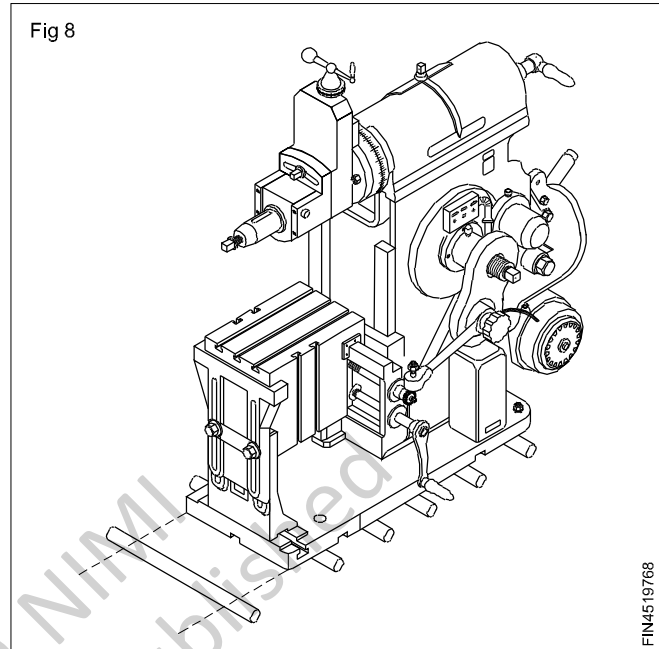
The fulcrum point must be firm enough to take the force. If the point of the crowbar is used as the fulcrum, it must be dug in firmly to prevent slipping. (Fig 7)

Check the condition of the crowbar, and if found bent or cracked, it must not be used. The burrs or sharp edges on the crowbar must be removed before using it.



Rollers

Rollers are placed under the equipment so that they can be moved easily. Mild steel or G.I pipes of sufficient wallthickness can be used as rollers. The rollers should be long enough to project from both sides of the load so that they can be positioned easily. The diameter must be large enough to roll over any unevenness along the route but small enough so that they can be lifted easily. (Fig 8)



Moving equipment using rollers

Before starting to move a load, check the route and remove any obstructions. The route should be flat and firm enough to take the weight of the moving equipment.

Precision spirit level

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

- state the construction of a spirit level
- state the importance of a precision spirit level
- define the sensitivity of a precision spirit level
- state the relationship between vial radius and the sensitivity of a spirit level
- state the causes of errors in spirit level.

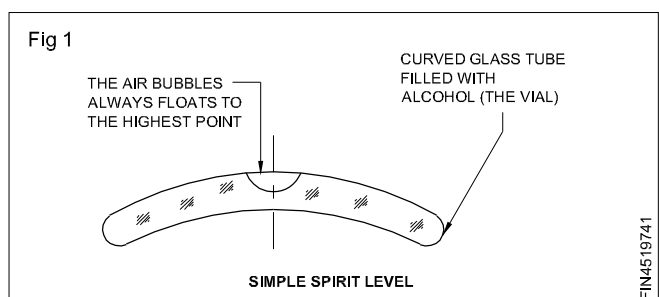
Levelling of the machine is a very important operation before proceeding to conduct geometrical tests. A precision spirit level is used to level the machine tools accurately.

Spirit level

It consists of a curved glass tube called 'VIAL' containing industrial alcohol 'spirit' and a bubble of 'AIR' trapped in the tube. The spirit and the bubble are both acted upon equally by the force of gravity. (Fig 1)

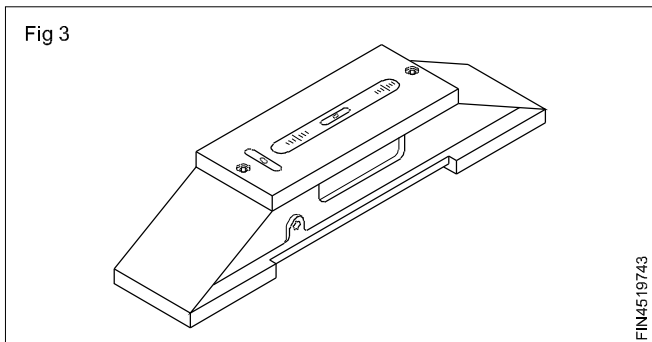
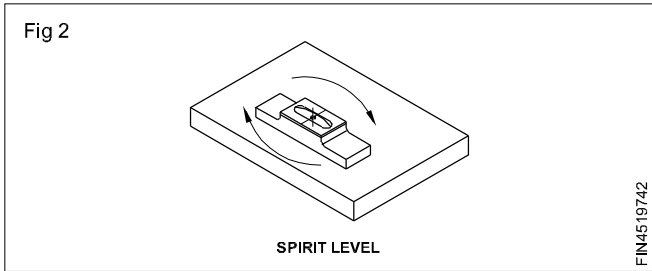
Since the spirit has a higher density, it is pulled down to the bottom of the tube and the bubble always floats to the top.

The vial is set in a cast iron base and adjusted such that the bubble rests at the centre of a scale (Fig 2) when the base is horizontal.



Precision spirit level (Fig 3)

Spirit levels used for high precision measurements should have a sensitivity of about 0.02 to 0.05 millimetre per 1000 millimetres for each division.



If the movement of the bubble by one division corresponding to a change in slope of 6 to 12 seconds of a level of 0.04mm per 1000mm is chosen, then

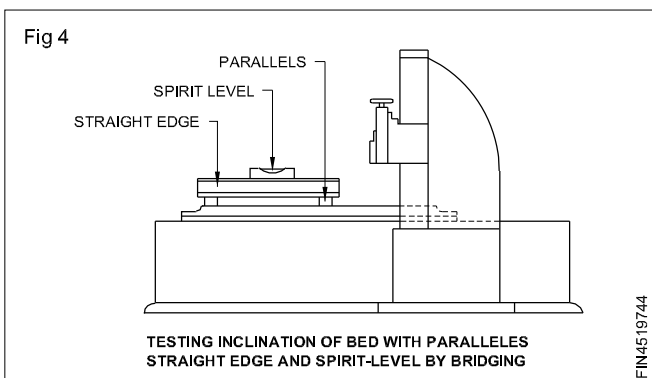
- 1 division = 0.04 mm/1000 mm
- 3/4 division = 0.03 mm/1000 mm
- 1/2 division = 0.02 mm/1000 mm
- 1/4 division = 0.01 mm/1000 mm.

It is quite easy to estimate within a quarter of a division.

Hints on spirit level

Spirit levels which are too sensitive are difficult to bring to rest in a workshop in which machines are running. Levels with low sensitivity result in insufficient reading accuracy, as very small fractions of a division have to be estimated.

The bearing surfaces of spirit levels should be as long as possible. For testing medium size machines the level should not be less than 200mm long. It is often advisable to use a bridge piece (Fig 4) the feet of which are about 300 mm apart. The spirit level can then be placed on the scraped surface of the bridge. This method avoids errors which could be caused by irregular scraping of the surface to be measured.

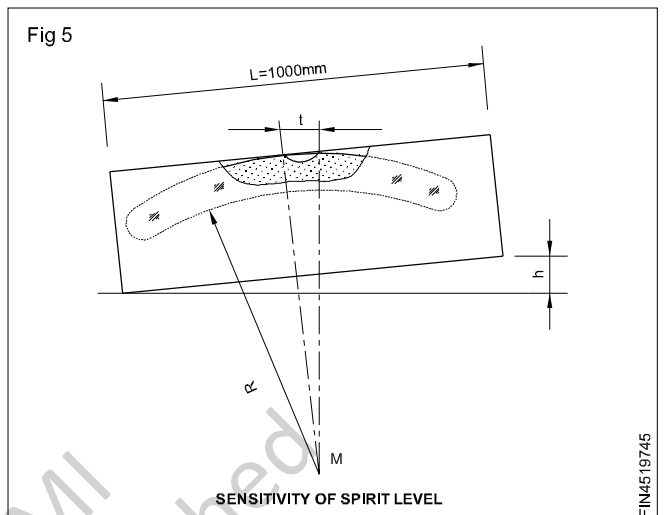


Sensitivity of spirit level

The sensitivity E of the spirit level is the movement of the bubble in millimetres which corresponds to a change in slope of 1 millimetre per 1000 millimetres.

$$E = \frac{\text{Movement of bubble in mm}}{1 \text{ milli metre per metre}}$$

The inside of the glass tube of a spirit level has a shape



of a circular arc of radius R which moves during a change of slope around the centre M of its curvature. (Fig 5)

If the slope is measured as a ratio of h/L, and the movement of the bubble is t then

$$t/h = h/L \text{ and}$$

$$R = \frac{t}{h/L}$$

$$\text{Since } E = \frac{t}{h/L}$$

$$R = E.$$

Radius and sensitivity

The sensitivity of the spirit level is equal to the radius of curvature of the barrel shaped bubble tube. Therefore the sensitivity of the level depends only on the radius of the curvature of the bubble tube and not on the length of its bearing surface.

Causes for errors in spirit level reading

- Wrong position of the vial in the housing
- Faulty graduation
- The surface finish of the piece to be tested
- The influence of temperature
- Personal errors of the inspector

Reading spirit levels depends on:

- the quality and length of the bearing surface of the workpiece
- dimensional stability of the metal housing.

Common instruments for geometrical test

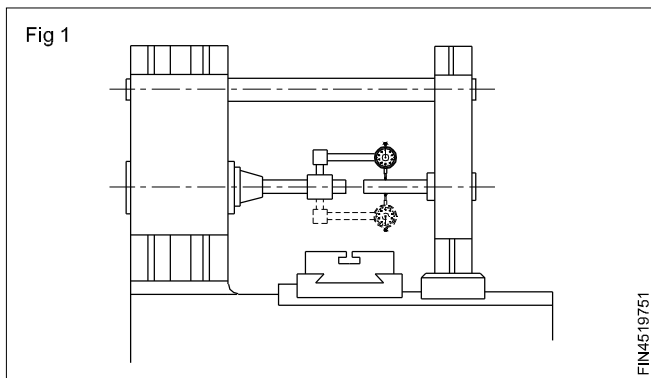
Objectives : At the end of this lesson you shall be able to

- state the purpose of test mandrels
- name the different types of test mandrels
- state the applications of straight edge and block spirit level and master square.

Test mandrels

Test mandrels are widely used as inspection tools during the manufacture and acceptance tests of new machine tools, and the repair of old ones. The quality as far as straightness and roundness are concerned is of paramount importance for accurate results.

The application of a test mandrel in measuring the swing over of a horizontal boring machine is shown in Fig 1.



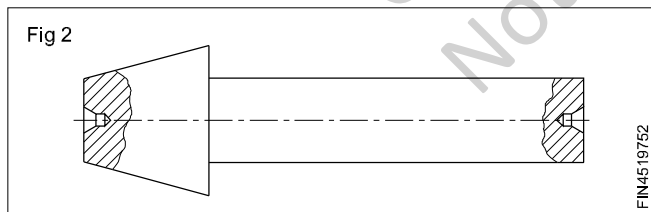
Types

There are two types of test mandrels.

Solid mandrels

Solid mandrels are available in different lengths.

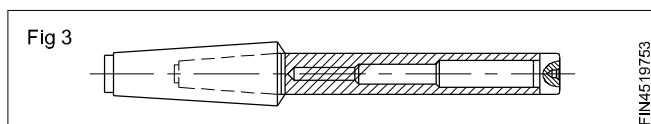
The diameter must be such that the sag is kept within the permissible limits. (Fig 2)



Hollow mandrel (Fig 3)

A hollow mandrel is made in order to reduce the weight of the mandrel. This avoids sag of the mandrel during inspection.

This mandrel also must be sized in between centre.

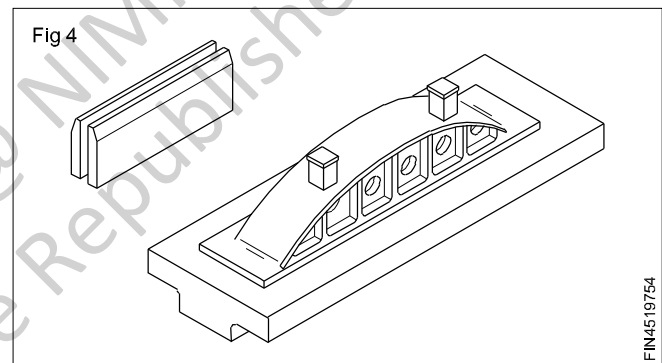


Size of mandrel

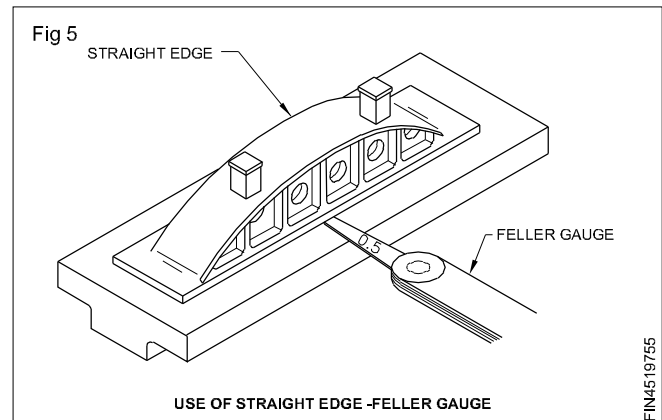
The measuring length of the cylindrical part of the mandrels depends on their purpose. The distance between the marks at the two ends of the cylindrical part represents the measuring length of the mandrel. It may be 75,150,200 300 or 500 mm. The diameter must be such that the sag is kept within permissible limits. In order to reduce the weight of the mandrel, it may be made hollow.

Straight edge

Straight edges are made for testing straightness. They are made of steel or cast iron and may be of 2 metres or 3 metres length. These should be heavy, well-ribbed and free of internal stresses. Their bearing surfaces should be as wide as possible. (Fig 4)

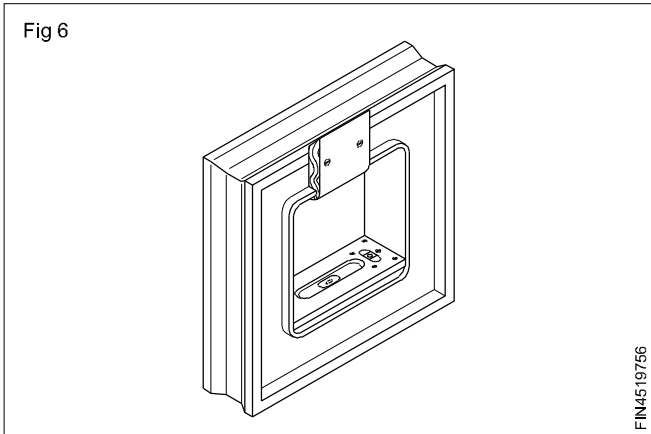


The application of a straight edge in testing the flatness of a surface is shown in Fig 5.

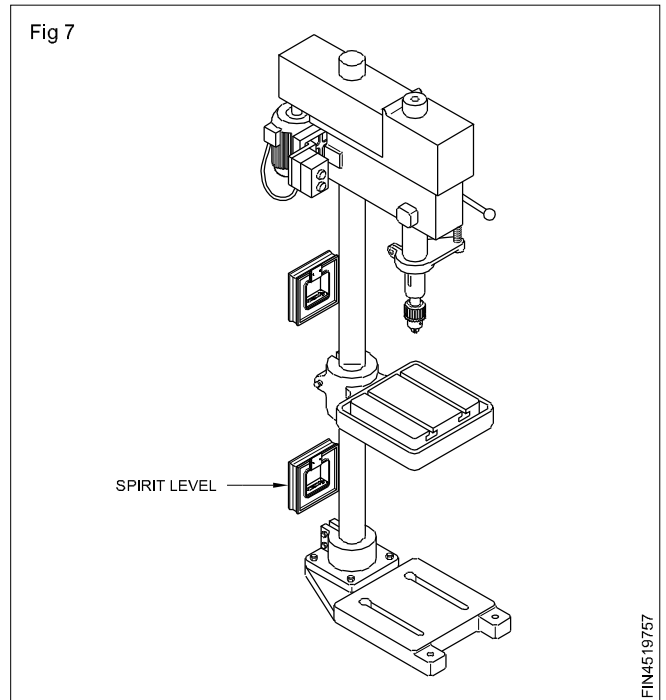


Block spirit level

A block spirit level is made of box sections with the faces accurately square or parallel. There are generally made of stress-free cast iron or steel and are used for checking the horizontal and vertical levels of a machine. (Fig 6)



The application of a block spirit level in testing a drilling machine is shown in Fig 7.



Ropes

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

- name the different types of ropes and their uses
- state the precautions to be observed while using ropes
- state the general inspection points for using ropes.

Ropes are made from individual fibres, spun together like string or yarn. Hemp, cotton, Manila, steel and synthetic wire are used in the manufacture of rope. Manila and hemp ropes are manufactured from the fibre of wild banana plants.

Ropes are manufactured in three or four strands. Manila and hemp ropes are used for light duty hoisting with a rope pulley block.

The following precautions should be observed while using the ropes.

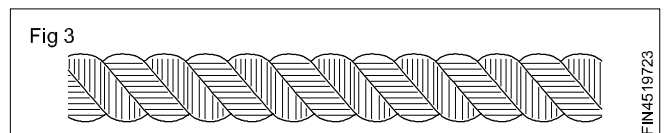
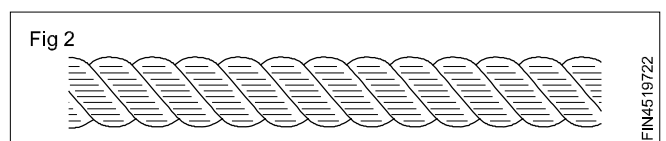
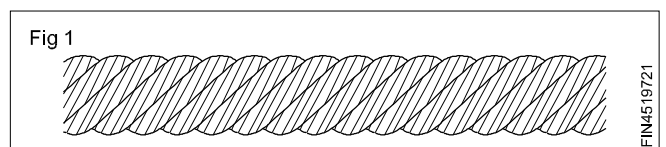
- Avoid running the rope over sharp edges.
- Ropes should be kept dry because moisture hastens their decay.
- Hang wet rope loosely in an area where it can dry before it is used.
- Avoid dragging of rope over concrete, gravel and other rough surfaces.
- Frozen rope should not be used until it is thawed.

Wire ropes

Wire ropes or cables are built up of strands of wire laid together in the direction of opposite twists which form the rope. Standard wire rope is made from strands encompassing a single core.

Wire ropes are used for heavy duty hoisting

When the wires and strands are twisted in the same direction the rope is known as 'Lang lay rope' (Fig 1) and when twisted in the opposite direction it is known as regular lay rope. (Fig 2) The combined lay rope is shown in Fig 3.



Rope inspection

- Inspect ropes frequently for damage.
- Surface inspection will reveal broken or worn out strands.
- For interior inspection twist the rope in the opposite direction to the way it was spun.

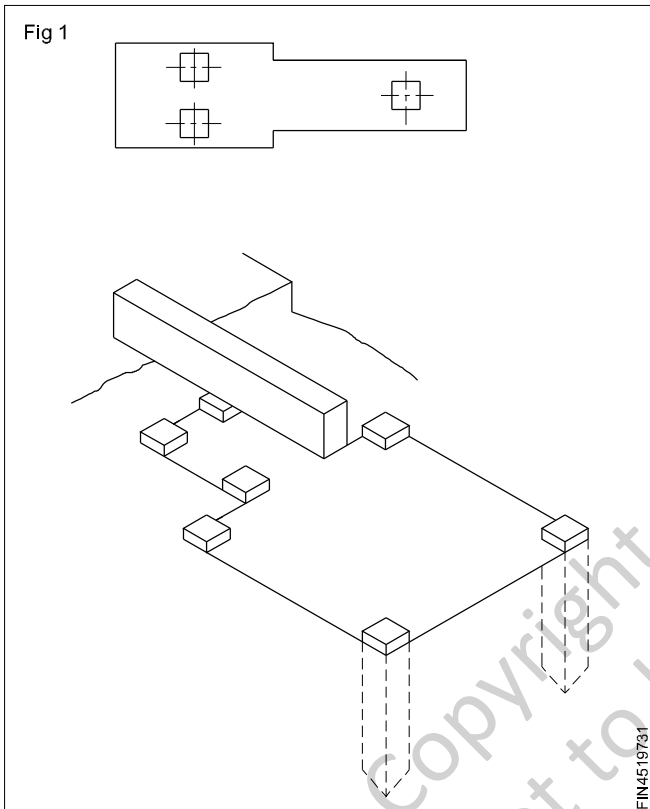
This will open up and separate the strands so that the interior fibres can be examined.

Wooden block

The position of the foundation is first determined, marked off and wooden pegs are driven if it is in the soil. (Fig 1)

The size of excavation is drawn with chalk if it is on a concrete floor.

Excavating the hole should be done as neatly as possible but should the soil persist in falling into the hole it may be advisable to shore this up by the use of shuttering. The excavation should be made a few millimetres deeper than the required foundation depth. The bottom surface is well rammed prior to and after placing a layer of clean bottoming stones or broken bricks.



Wooden template

A wooden template is formed as shown in Fig 2 to represent the base of the machine and to support bolts over the excavation as shown. The combined thickness of the template frame A and blocks B should equal the thickness of the foot of the machine as shown. These boxes are formed of light timber and are suitably nailed for easy removal later.

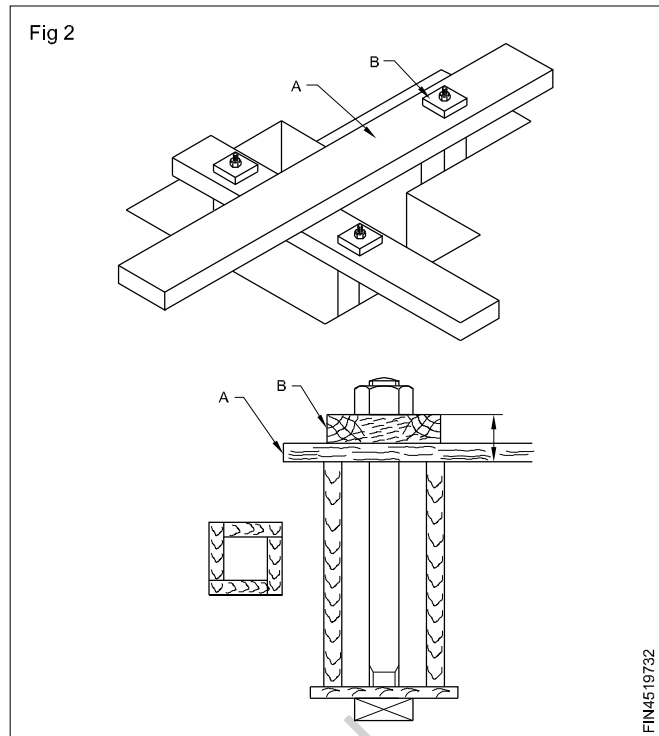
Pulley block

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

- describe of pulley block
- use of pulley block.

Pulley block (Fig 1)

Pulley block is a system of two or more pulleys with a rope or cable threaded between them, usually used to lift heavy loads. The pulleys are assembled together to form blocks



Wooden forms

Wooden forms for concrete foundations are made and placed over the excavation.

Bracing the wooden form

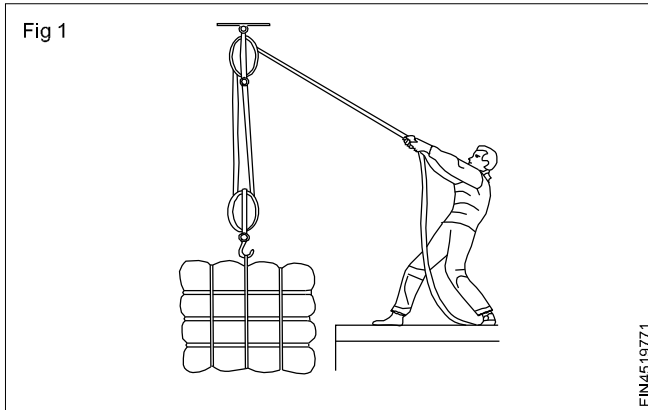
After placing the wooden form in position in the excavation, it is firmly braced from the outside so as to withstand the pressure of the concrete and prevent any movement when the concrete is being poured.

Concrete

Should be prepared from clean cement on a wooden surface. Proportions for the mixture vary. A good average mixture is 1:2:4. ie 1 part cement, 2 parts sand and 4 parts stone. This is mixed thrice when dry and thrice after wetting and is immediately placed on the excavated area after a good spraying with water on the excavated area.

The foundation should be given a day atleast to set before the template is removed.

and then blocks are paired so that one is fixed and one moves with the load. The rope is threaded through the pulleys to provide mechanical advantage that amplifies the force applied to the rope.



A block is a set of pulleys or “Sheaves” mounted on a single frame. An assembly of blocks with a rope threaded through the pulleys is called tackle. A block and tackle system amplifies the tension force in the rope to lift heavy loads. They are common on boats and sailing ships, where tasks are often performed manually.

Plumb bob

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

- state the construction of plumb bob
- state the use of plumb bob.

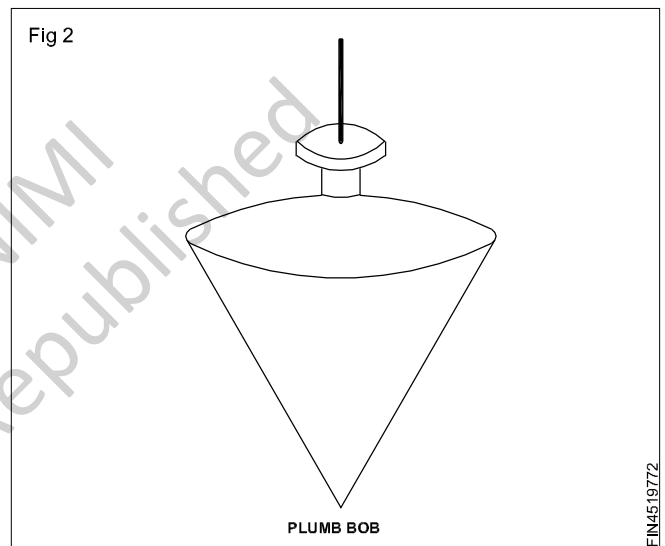
The plumb bob (Fig 1)

The plumb bob employs the law of gravity to establish. A string, suspended with a weight at the bottom will be both vertical and perpendicular to any level plane through which it passes. In a sense, the plumb bob is the vertical of the line level.

The plumb consists of a specially designed weight and coarse string made of twisted cotton or nylon threads. At end of the string weight is affixed. Precisely machined and balanced bobs have point tips and can be made of brass, steel or other materials

How to use a plumb bob

To use the plumb bob, the string is fixed at the point to be plumbed. The weight, or bob, is then allowed, to swing freely, when it stops, the point of the bob is precisely below the point at which the string is fixed above.



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.

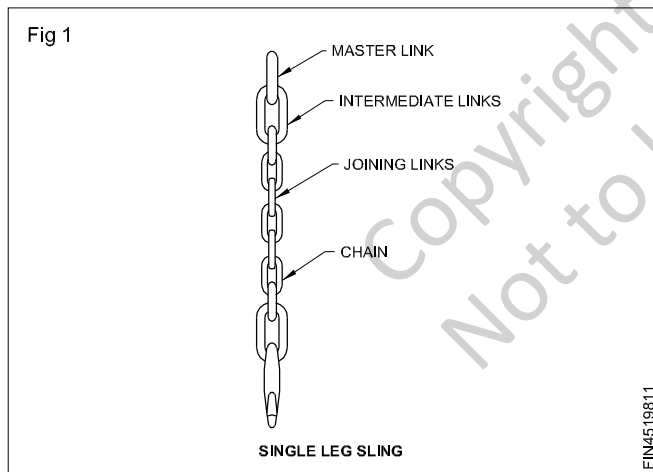
Slings are made with fibre rope, (manila, sisal, nylon, terylene and polypropylene) chain, wire rope etc. Other appliances like hooks, eye bolts, shackles, lifting clamps etc are used to make or sling considering the type of the load.

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

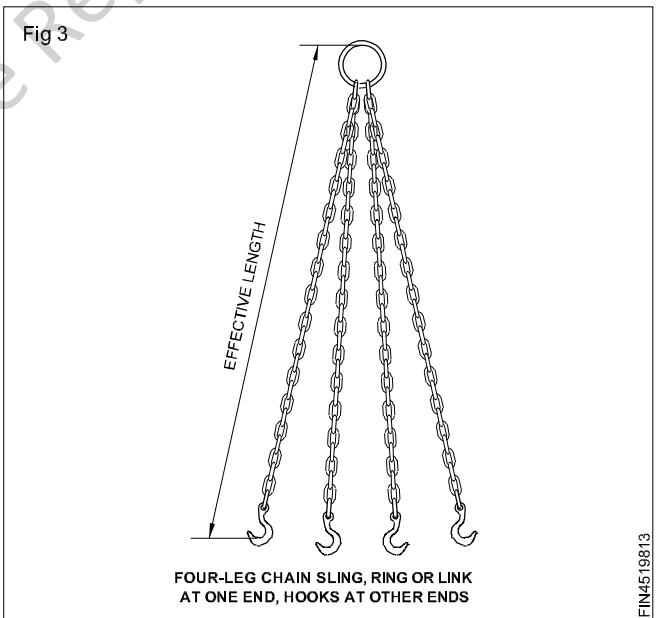
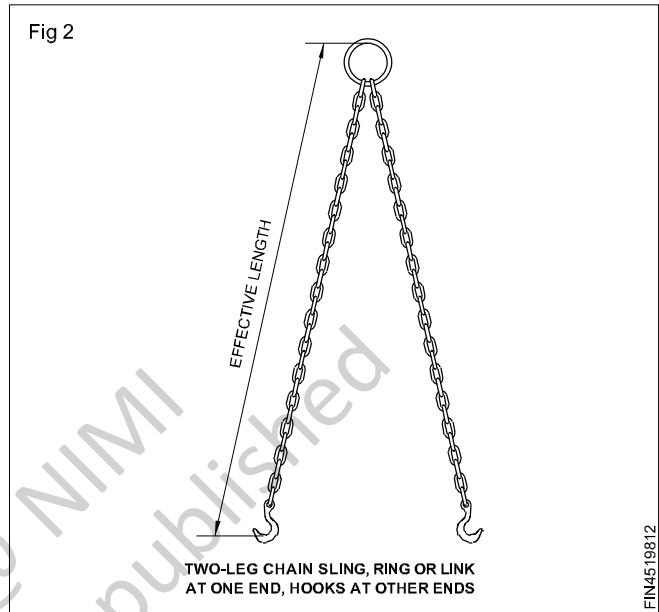
- Single leg chain (Fig 1)



- Double leg chain (Fig 2)
- Four leg chain (Fig 3)
- Endless chain (Fig 4)

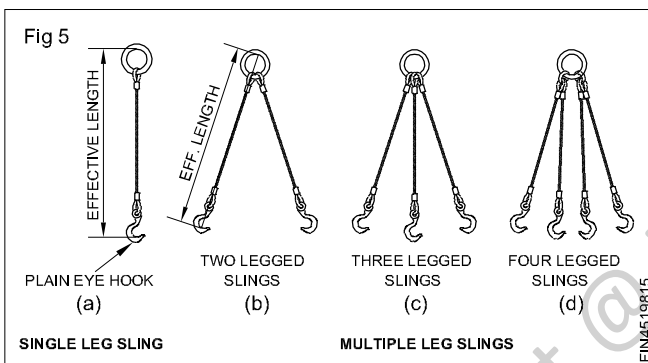
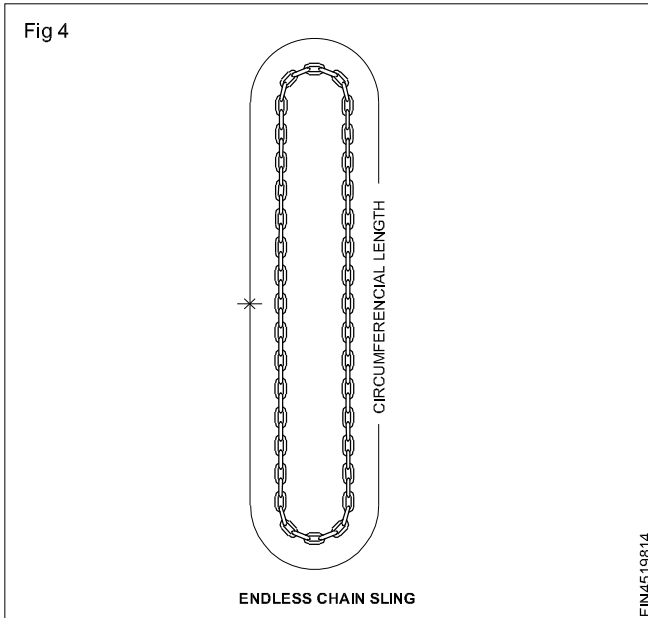
A chain will have the following components (Fig 1)

- Master link.
- Intermediate link.
- Joining link.
- Chain hook.

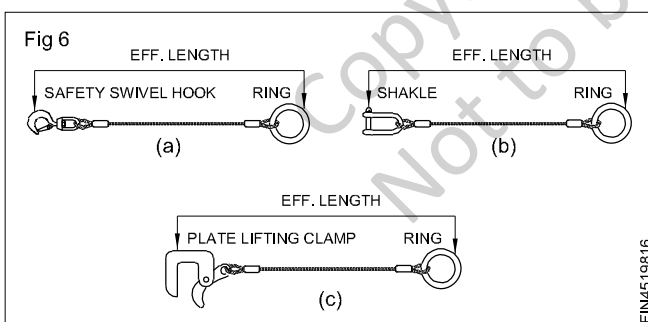


Wire rope sling

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.



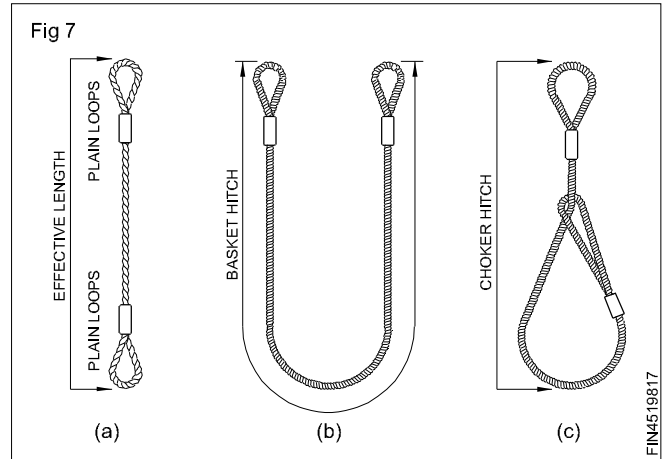
A few other slings like sling with safety swivel hook, Dee shackle and plate lifting clamp with effective length are shown in Fig (6a, b and c) respectively.



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.

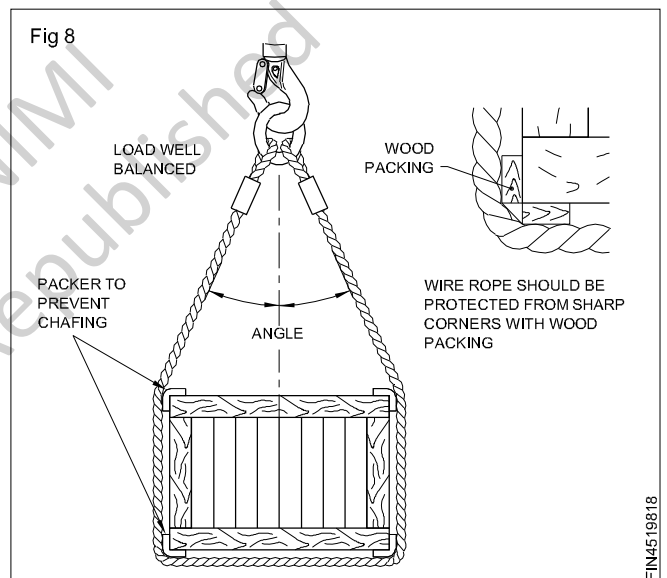
The following points are to be noticed and followed strictly.

- 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.
- Check the condition of the sling and consider the load carrying capacity of the sling.



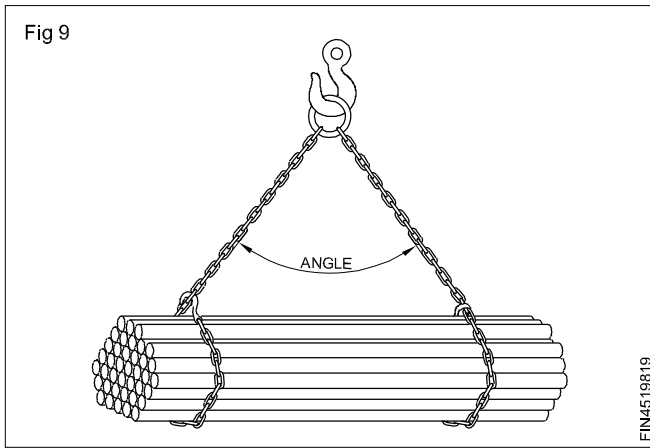
- Fibre rope get spoiled due to heat and in presence of toxic liquid and fumes. However, polypropylene ropes offer goods resistance to water chemicals and alkalis. They are stronger, reliable and durable comparing to other fibre ropes.

- Always prepare the sling to keep the load in well balanced condition.



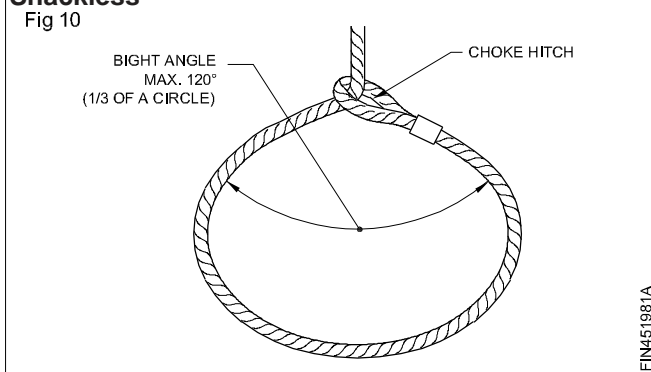
- Prepare a sling for the load within permissible angle as in Fig.9 ($30^\circ, 90^\circ, 120^\circ$). Lesser the angle load carrying capacity of the slings is more. When the angle exceeds 120° , the load carrying capacity of the sling is reduced to half.

- 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 right angle should not exceed 120° . (Fig 10)



- Always keep yourself away from the suspended load.
- After completion of the work always return the hook fasten to the master ring.

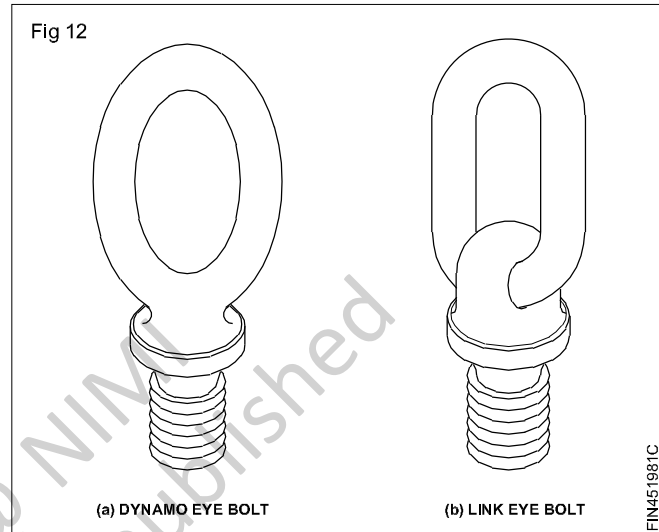
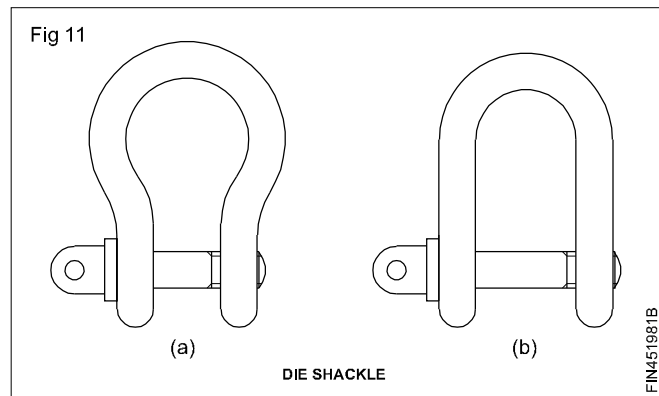
Shackless



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.

Slings 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 recommended in eye hook with safety catch (Fig 13b) for general handling purposes. Swivel spring safety hook (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.

Tensioning screws

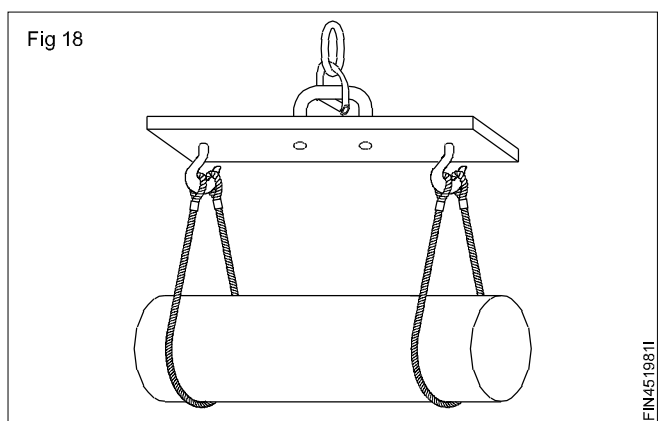
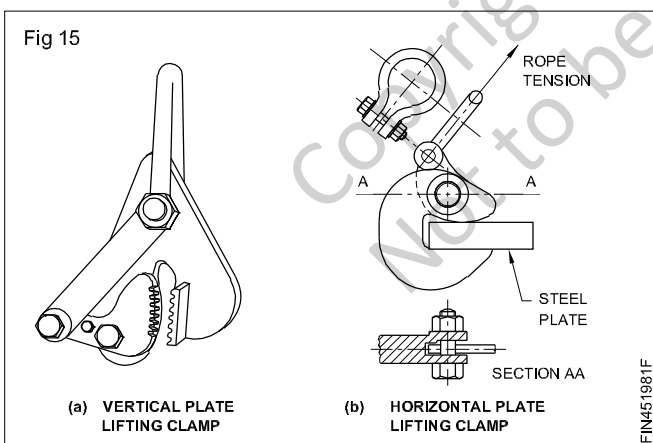
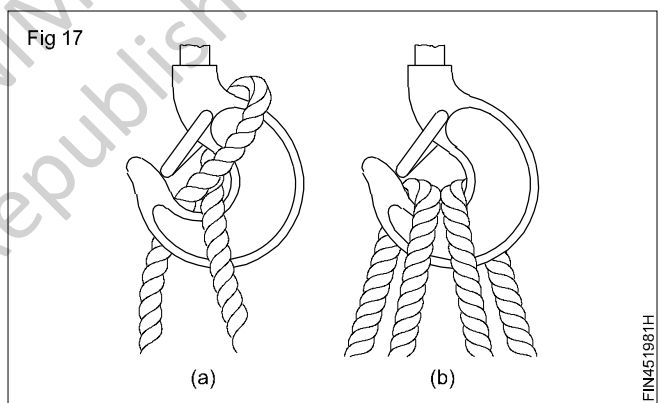
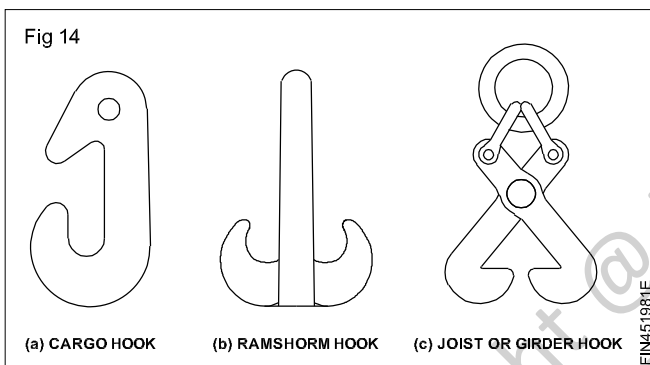
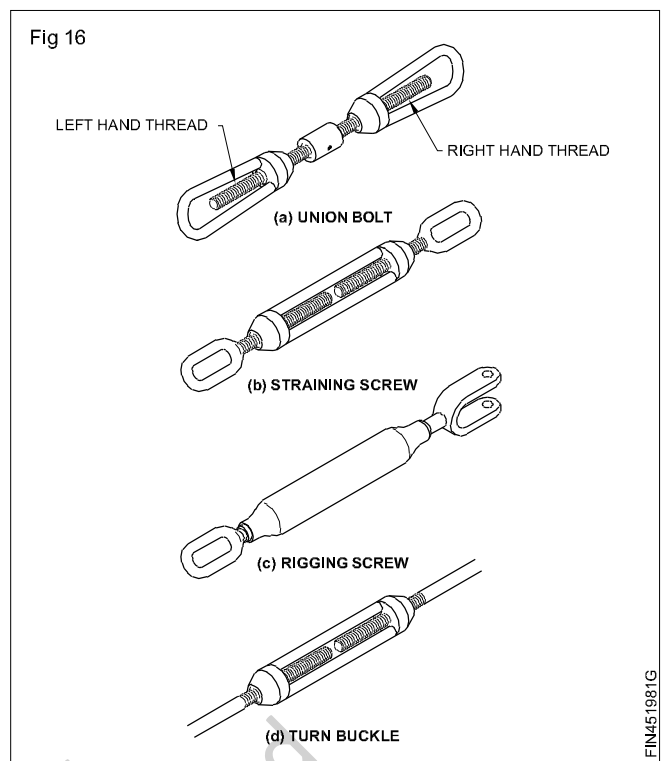
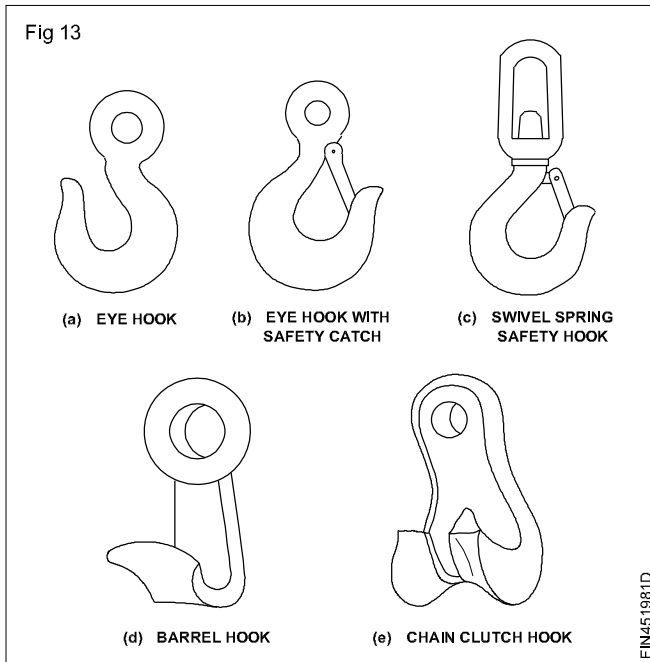
These screws or bolts are used in a situation where adjustment in tension is essential.

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.

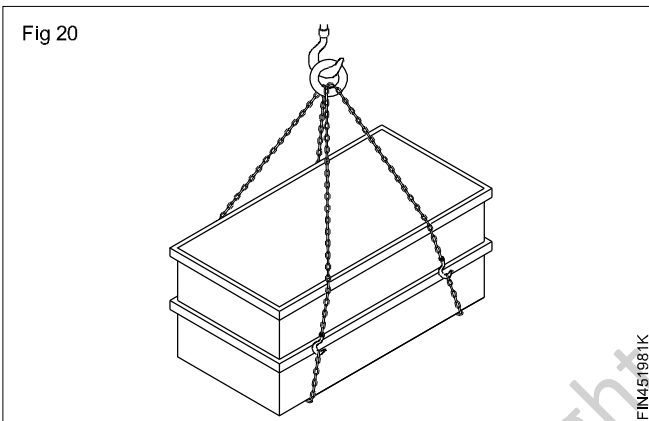
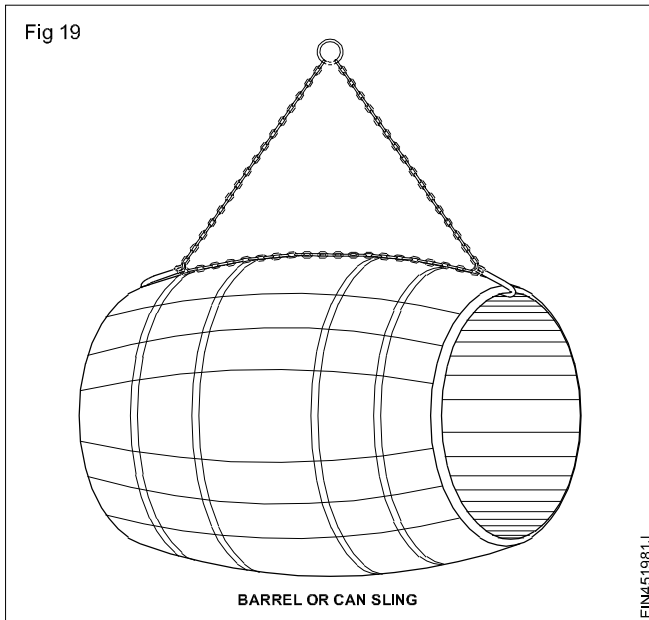


Method of slinging

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.



Slinging methods

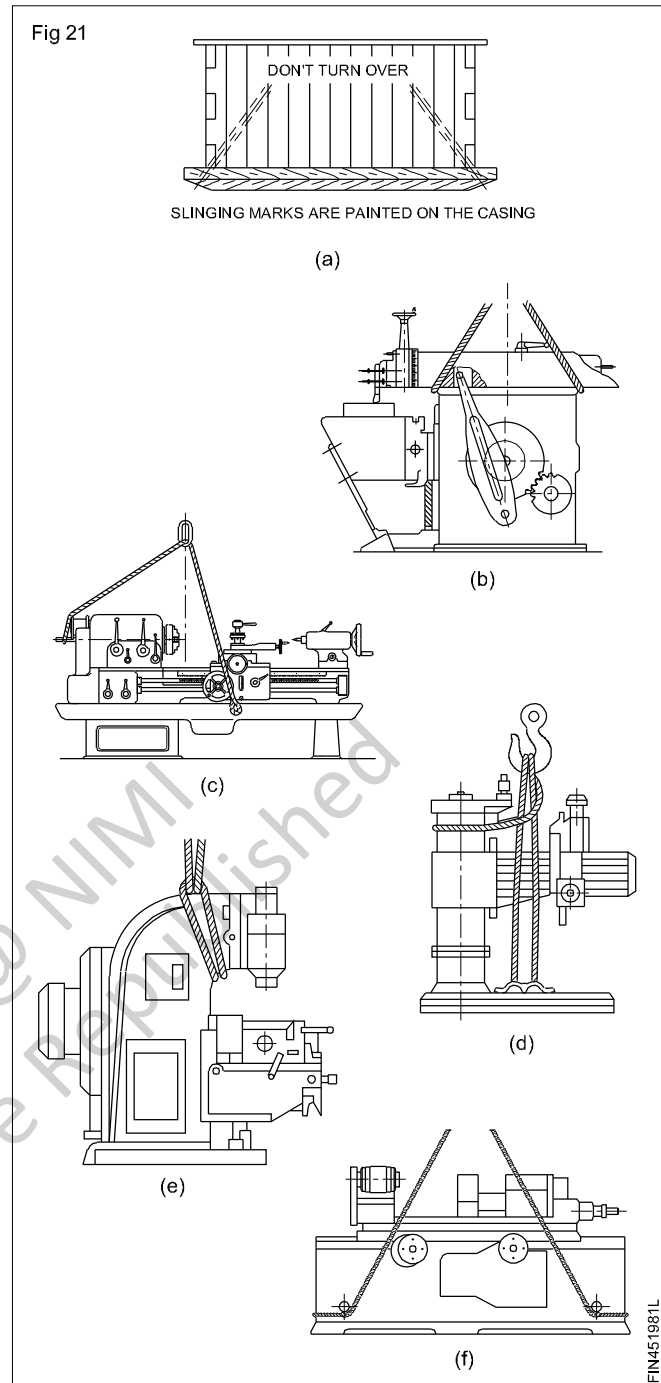
Wooden casing arrives at the purchaser's premises with sling marks as shown in Fig 21. The casing should be unpacked and suitable slings are made to shift to the place of installation.

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 methods of slinging shaper, lathe, radial drilling machine, vertical milling and universal cylindrical grinder are shown in Fig 21 respectively.

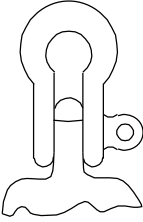
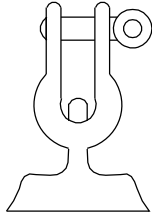
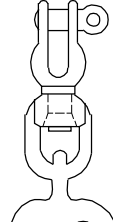
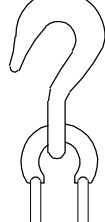
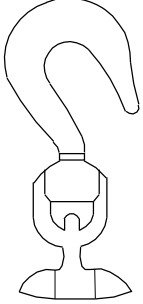
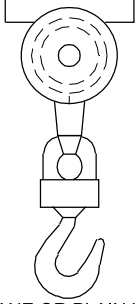
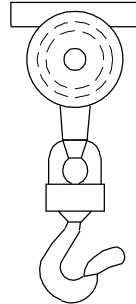
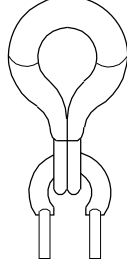
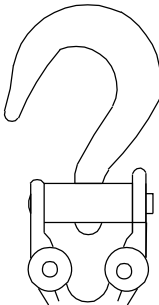
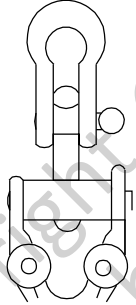
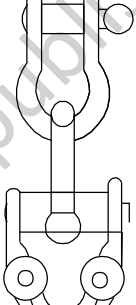
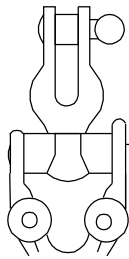

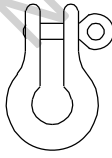
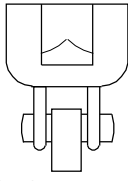
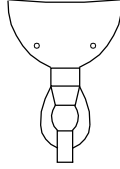
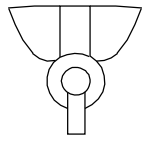



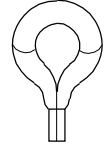
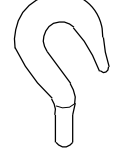
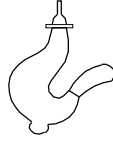
Rigging Theory

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.



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

					
LOOSE FRONT REGULAR SHACKLE	LOOSE FRONT UPSET SHACKLE	UPSET SWIVEL SHACKLE IN LOOSE SIDE SINGLE HOOK	LOOSE SWIVEL LINK		
					
SINGLE SWIVEL HOOK IN LOOSE SWIVEL LINK	CRANE OR PLAIN HOOK ANTITOPPING BLOCK WITH LOOSE DISK BEARING SWIVEL HOOK	RELEASING HOOK	LOOSE SIDE SISTER HOOK		
					
STIFF SINGLE SWIVEL HOOK	REGULAR OR UPSET SHACKLE IN LOOSE SWIVEL	STIFF UPSET SWIVEL SHACKLE	STIFF UPSET SWIVEL SHACKLE		
					
REGULAR SHACKLE	UPSET SHACKLE	SINGLE AND TRIPLE WOOD BLOCK BECKET	DOUBLE WOOD BLOCK BECKET	SINGLE, DOUBLE AND TRIPLE METAL BLOCK BECKET	
					
FRONT SINGLE SHACKLE	SIDE SINGLE HOOK	FRONT SISTER HOOKS	SIDE SISTER HOOKS	SWIVEL HOOK	RELEASING HOOK

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Fork lift and pallet truck

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

- tell about fork lift (stacker)
- mention handling load by hand pallet truck
- state advantages of moving load by stracker and pallet truck.

The fork lift is a small 4-wheel vehicle with diesel/petrol/ electrically powered engine. Heavy counter weight are fitted to the rear of the units. There are two lifting fork or arms in front of the machine which are adjustable to carry the load. They are available in various designs and capacities for shifting and stacking load in different positions.

Types

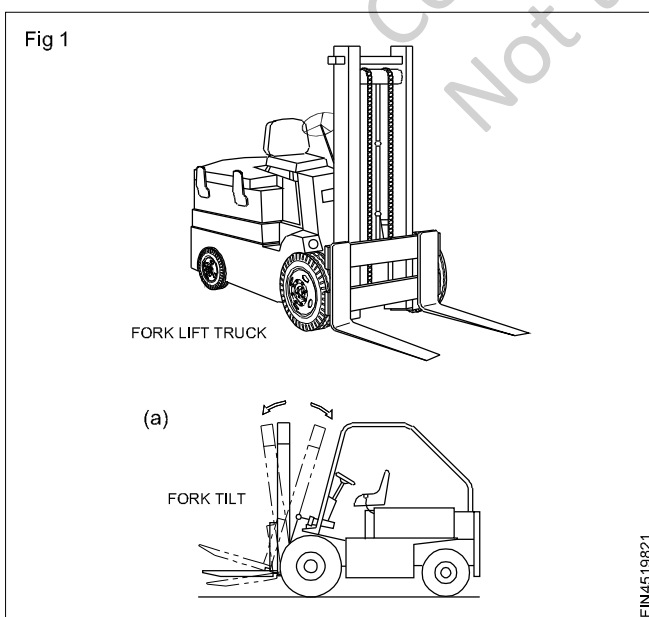
- 1) Diesel automotive fork lifter.
- 2) Battery powered fork lift stacker.
- 3) Hydraulic stacker.
- 4) Mechanical stacker.
- 5) Hand pallet truck.

1 Diesel automotive fork lifter (Fig 1)

This diesel powered truck is driven by a driver to carry loads to considerable distances to and from the shop floor/yards to work place or for storage capacity 2 tonne to 10 tonne lift 2 meter height (common).

Fork unit can be hydraulically fitted, upto 15 degrees inward or outward and lifted to desired level. (Fig 1a)

This works very efficiently to move loads faster even on rough roads. Suitably used in harbour work, in industries, ware houses. transportation between lorry and railway terminals etc.

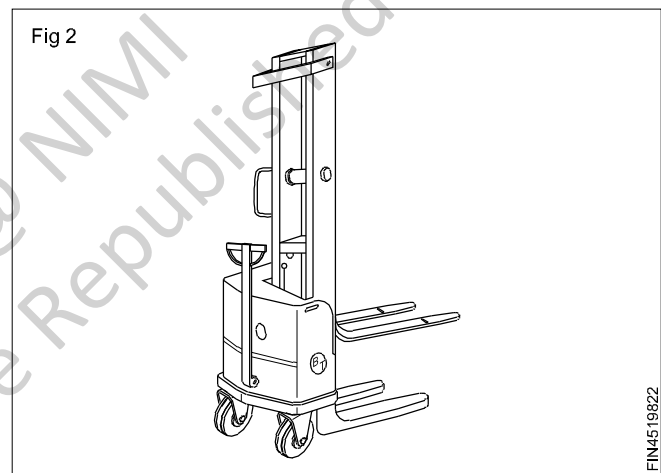


Maintenance

- Engine oil and hydraulic oils are to be changed periodically.
- Check for leakage in hydraulic cylinders.
- Cleaning and lubrication should be done to all motion parts including counter weight chain.

2 Battery powered fork lift stacker (Fig 2)

Powered fork lift stackers are compact in design and used to carry load mainly indoor within narrow space for shifting and stacking even to higher levels. The operator walks beside the truck to steer it. Lifting is done hydraulically.



They are commonly used in workshops, warehouse , rail containers, wagons etc. capacity 500 kg-2000 kg. Lift upto 5 meter commonly used.

Maintenance

- All motion parts are to be cleaned and lubricated periodically
- Hydraulic oil should be changed (Servo System 57/ 68 as recommended) once in two years.
- Oil seals are to be changed in case of leakage.
- Distilled water should be poured in the battery as and when the level goes down.
- Battery should be charged periodically.

3 Manually operated hydraulic stacker (Fig 3)

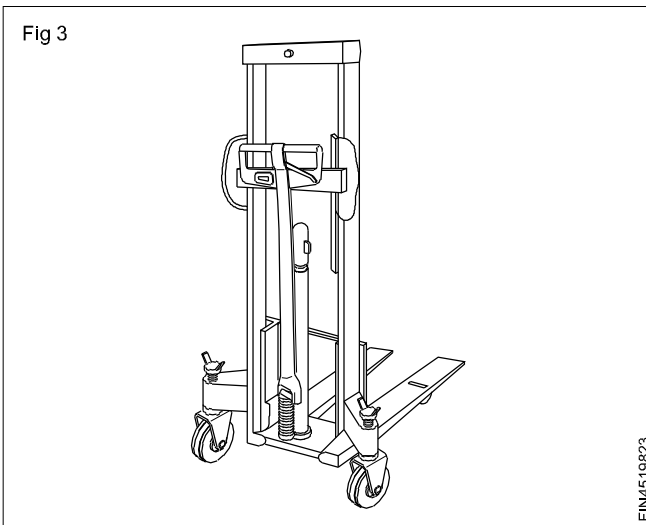
This type of stacker is used commonly as they are cheaper and can be easily handled manually for shifting and stacking load in a limited space.

Capacity- 500 Kg to 2000 Kg.

Lift upto 5 meter.

Beneficially used in light industries, ware house etc for loading, unloading and stacking.

Maintenance



- Clean and lubricate all motion parts.
- Change hydraulic oil once in two years (servosystem 57 or 68 as recommended to be used)
- Replace oil seal for oil leakage.

Mechanical stacker (Fig 4)

This type of stacker is mechanically handled for moving, lifting and stacking load. These can be operated in a limited space so they are used in small scale industries.

Capacity 500 Kg.

Lift upto 2 meter.

Maintenance



- Clean and lubricate all motion parts periodically.

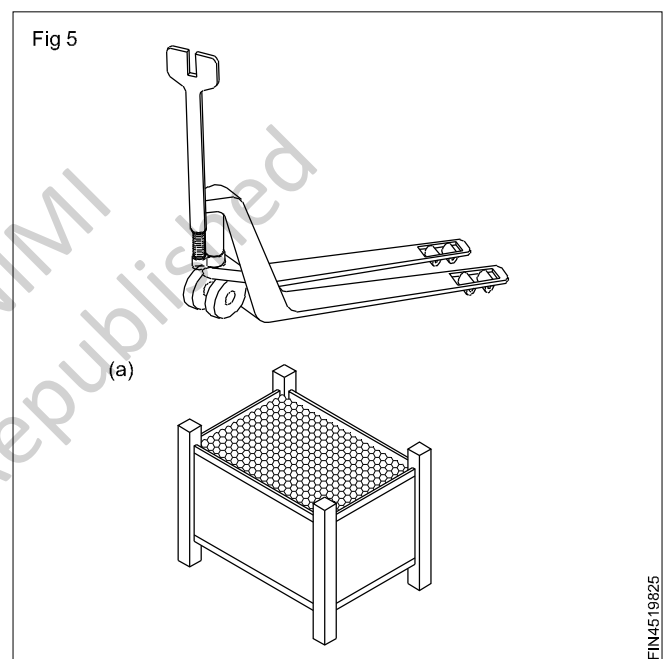
Hand pallet truck (Fig 5)

Pallet trucks are basically used for carrying pallet bins (Fig 5a) and other loads on floors, warehouses with high rate of turn over even bulky goods.

Capacity 500 kg to 2000 kg.

Maintenance

- Change hydraulic oil once in two years (servosystem oil 57 or 68 as recommended). Topup oil periodically wherever required.
- Replace oil seals in case of oil leakage.
- Clean and lubricate other motion parts periodically.



Types of cranes

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

- State basic function of crane
- mention the types of crane
- describe the application of various cranes
- state the highlights on troubleshooting
- narrate the safety on overhead crane repair.

Basic function of crane

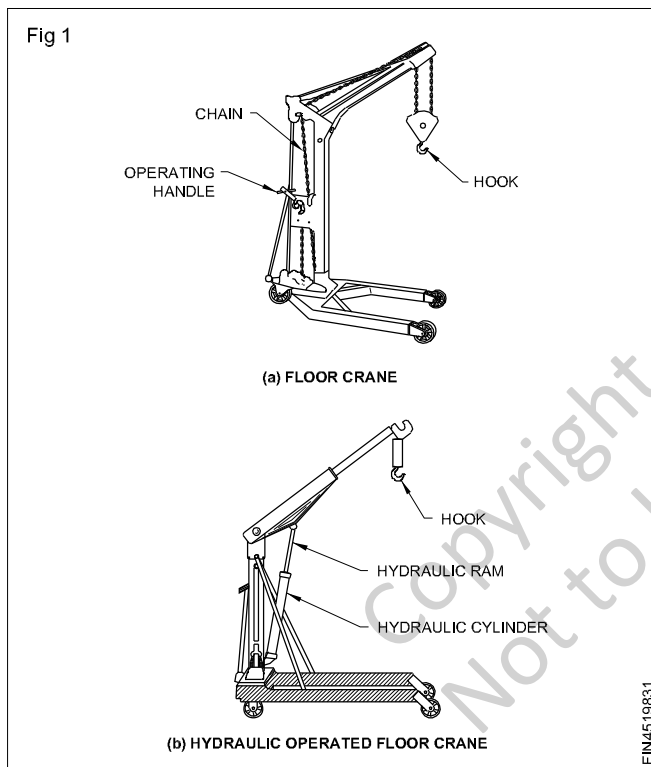
Crane is made up of sturdy structural member of steel, which are used in Industries, Port trust etc to shift the heavy materials from one place to another place for subsequent operation, assembly etc. The shape and its construction varies with application and types. There are many types of cranes are available.

Types

- Floor cranes
- Jib cranes
- Derrick cranes
- Overhead cranes
- Gantry cranes
- Travelling cranes.

Floor cranes (Fig 1a & b)

Hand operated floor cranes are used for handling light loads (up to 2000 Kg.) on the shop floor.



Hydraulic floor cranes are also used for lifting and shifting loads. The boom of the crane is moved up and down approximately 30° hydraulically. The boom can be extended to work for a longer reach. As the boom extends the loads carrying capacity decreases. Capacity ranges from 1000 Kg to 5000 Kg.

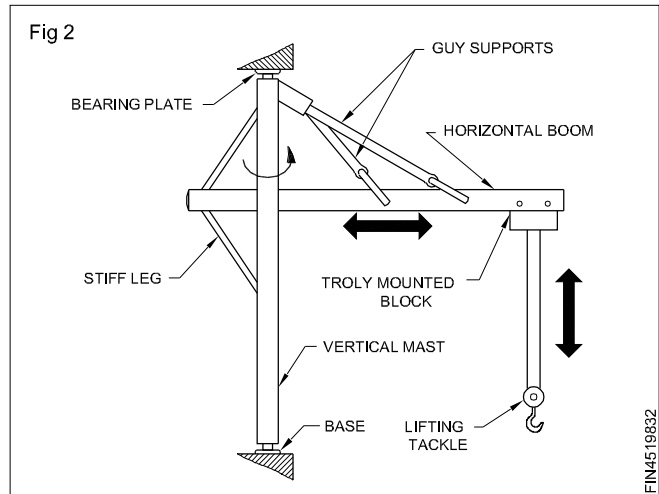
These floor cranes are mounted on wheels and can be moved from one place to another by pushing.

Fig 2 shows simple jib crane mounted on the strong base and supported by bearing plate at the top. The jib also called boom is supported by vertical mast with guy support at the front and stiff legs at the rear.

There are three possible movements of load i.e.

- a Raise or lower the load

- b Horizontal movement of load between mast and end of boom
- c 360° rotation of mast on its axis (slewing).



Pillar jib crane

Fig 3 show simple jib crane. The bottom is fastened to the mast about two-thirds of the way from the base. The rear end of the boom extends beyond the mast. Boom is supported by guys from the top of the mast to provide additional support. The lifting tackle on the boom hangs from a trolley-mounted block, which slides along the length of the boom to shift the load at any position. The load can be rotated within a radius from mast.

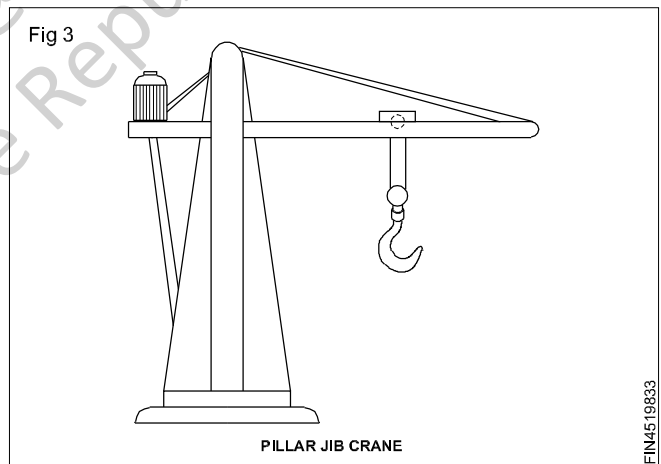


Fig 4 shows the bracket jib crane used for light load.

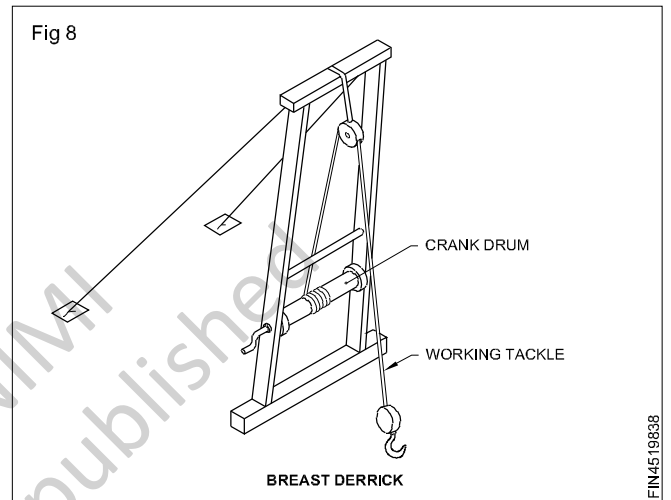
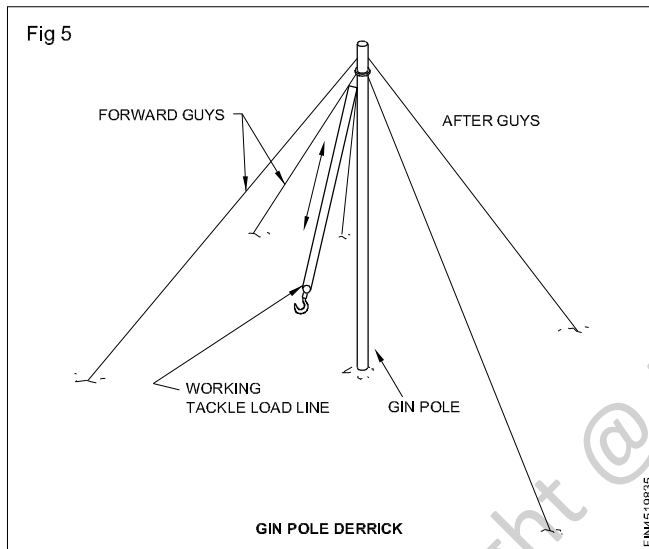
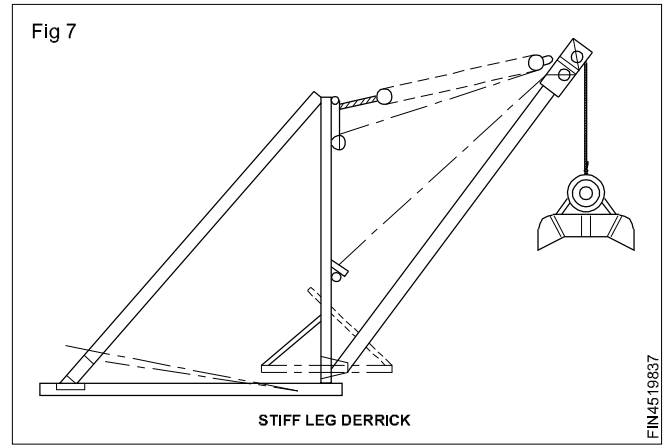
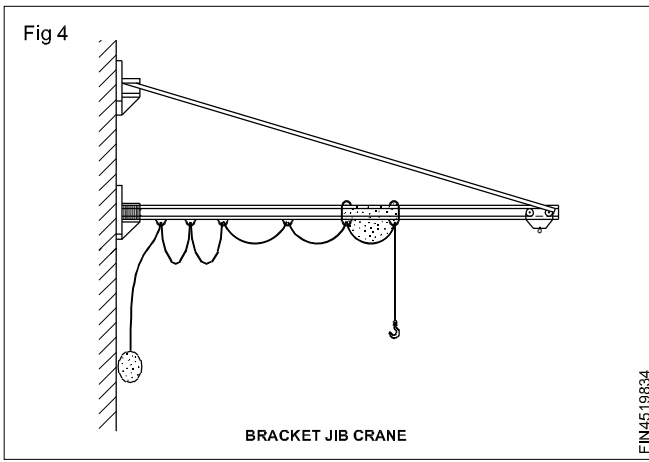
Derricks cranes

Gin pole derrick crane (Fig 5)

Gin pole derrick one single pole units with one end firmly secured at the base to prevent movement. It is used as a temporary hoist to raise and lower a number of light loads. In setting up a gin pole, use atleast two after guys to provide support for the working end of the pole.

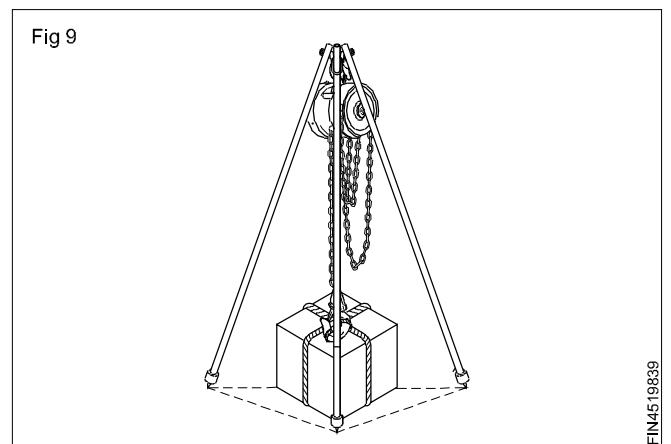
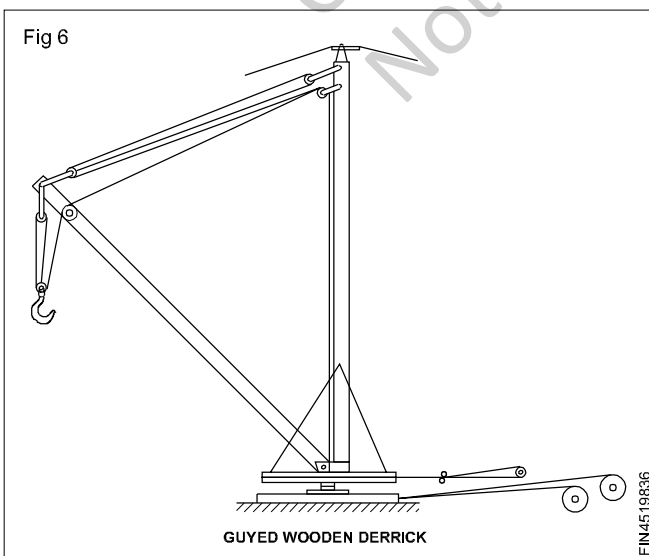
Guyed derrick crane (Fig 6)

The derricks are made of steel or wood. Derrick made of steel are mostly used. The derrick or boom is supported with mast. Mast and boom are either hand operated or power operated. The boom is rotate through



Tripod with chain pulley block

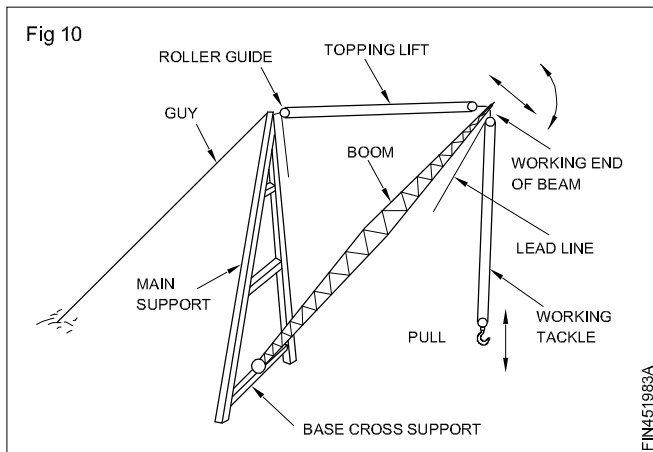
Each leg of the tripod is having a hole at its top end to fix up a stout bolt through 'u' shaped shackle. This bolt and shackle holds the tripod legs together at the top end and the chain pulley block can be hooked into the shackle. A nuts is screwed into the threaded end of the bolt which is riveted slightly to prevent unscrewing and coming out of nut. The bolt is kept a little loose adjust the position of three legs. (Fig 9)



Frame derrick crane

A 'frame derrick' gets its name from the shape of its main support. The main support, as shown in Fig 10 is triangular, with the base resting on the ground or floor.

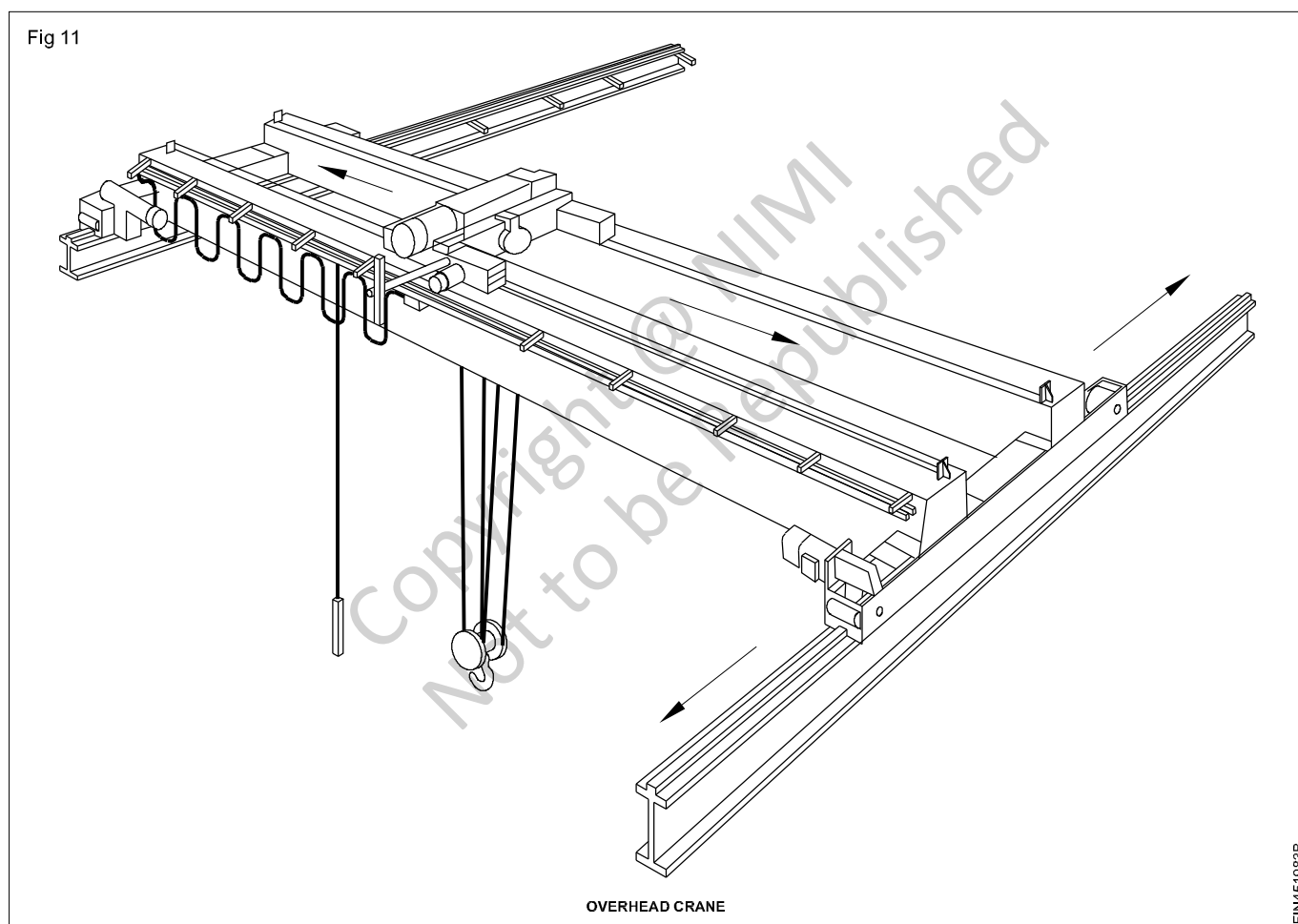
Fig 7 & 8 shows stiff leg derrick and breast derrick cranes used for material handling.



For light load frames are made of wood and for heavy duty frames are made from steel. Frames are mounted in position that prevents the base from moving or shifting under load. To operate a framed derrick, the boom or moving section, connects to a cross support at the base of the frame up-right support. The working end of the boom carries the upper block for raising the load.

Overhead crane (Fig 11)

An overhead travelling crane consists of a bridge constructed from one or several girders supporting a travelling hoist. Electrically operated overhead crane is called in short EOT crane. They are used in workshop engine rooms and in open yards to move materials to a considerable distance in fabrication and assembly works. The capacity of the crane varies from 1 tonne (light duty) to 5 tonne (heavy duty) and above depends upon the application.



For assembling and dismantling of bulk component like diesel locomotive, carriage wagon etc. during periodical over hauling two cranes of equal capacity being used. Each crane is operated by individual certified operator. Both the operators should follow same signal at a time from the rigger. The operators sit in a cabin provided for them.

The crane normally having three individual drive are called.

- long travel
- cross travel
- hoisting

Each travel consists of individual motor drive coupled with reduction gear box. Heavy duty crane are provided with two hoisting one meant for higher load called main

hoist and another one for light load called auxiliary hoist. The capacity of the crane is written on the structural member of the crane visibly is called safe working load (SWL).

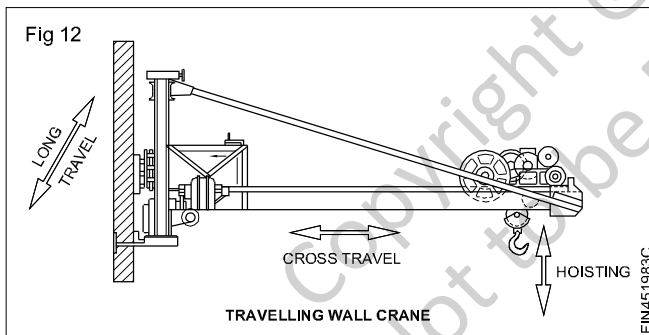
While lifting the load by crane the load do not exceed safe working load of a crane at any circumstances.

They are standard signals that every crane operator should follow while handling the load to control the crane.

While lifting load by using chain having more than one legs, ensure all the legs should have equal length.

While lifting load the structural member of the crane subjected to deflection from its position. The permissible deflection is 1mm for each 900 mm span measured at midpoint of the span by keeping the load at the centre. A crane having 9 meters span i.e. distance between two rails of long travel, the permissible deflection is 10mm.

Travelling wall crane also used in assembly shop. The long travel wheels runs on rails mounted on wheels. Fig 12 shows travelling wall crane.



Gantry crane (Fig 13)

Most gantry cranes are much larger than over head travelling cranes. It is used outside of the buildings. Gantry cranes also move on tracks, but their tracks are on the ground rather than suspended overhead. Trolleys are mounted on two upright structures separated by the connecting bridge.

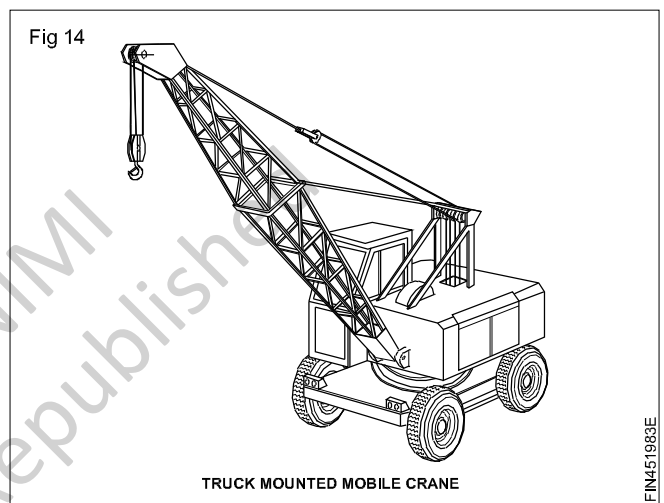
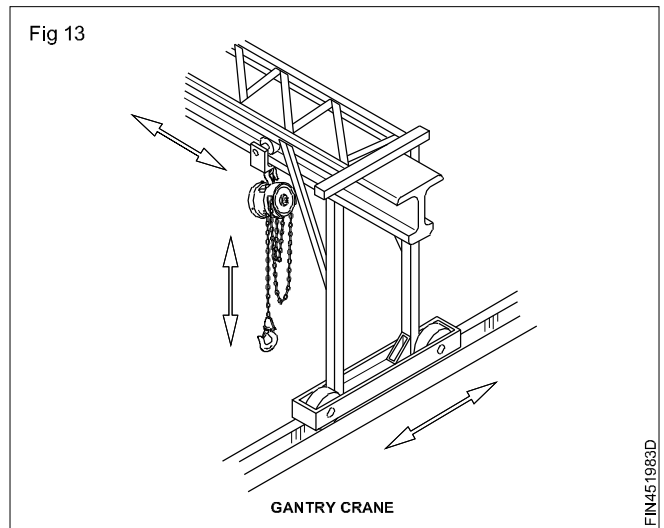
Trolley wheels support the gantry. The gantry's load movement capabilities are the same as those of the travelling crane.

Trucks mounted mobile crane (Fig 14)

There are locomotive cranes, truck-mounted cranes which are also used for lifting and moving the loads.

These crane can be used in remote places.

Problem - "The crane is not working when switched on".



When attending any repair on the overhead crane wear helmet and safety belt. The safety belt to be tied with structural member while attending repair to avoid accident by slipping.

Precautions in the removal and replacement of heavy parts

People who install or dismantle machinery and equipment could:

- Work in isolation
- Work on machinery and equipment at heights, or over machinery and equipment to connect services, such as electricity, air or water
- Work in low light, or with bright directional light
- access machinery and equipment from the top, sides or underneath
- Work with or near cranes, forklifts or rigging to lift machinery and equipment
- work in confined spaces
- use power tools, welders, extension leads, which present electrical hazards if damaged or wet.

People operating machinery and equipment could:

- be required to place their hands close to the mechanism of the machinery and equipment that does the work, and may be injured if caught or trapped by moving parts
- be exposed to constant harmful noise, radiated, energy or fumes being emitted from the machinery and equipment being operated, or are close to
- inadvertently bump or knock poorly placed control levers or buttons
- be required to make adjustments to the mechanism of machinery and equipment while the machine is in motion
- be required to clear away scrap
- make minor adjustments, or reach into the moving mechanism of the machinery and equipment being operated.

People providing maintenance or repair services could:

- work alone
- work on machinery and equipment at height, or over machinery and equipment to connect services, such as electricity, air or water
- access machinery and equipment from the rear or sides
- be required to enter confined spaces of larger machinery and equipment

- be trapped by the mechanism of the machinery and equipment through poor isolation of energy sources or stored energy, such as spring-loaded or counter-balance mechanisms, compressed air or fluids, or parts held in position by hydraulics or pneumatic (air) rams
- Move heavy parts when changing the set up of machinery and equipment, or repairing failed parts, such as electric motors or gear box assemblies
- disable or remove normal safety systems to access the mechanisms of machinery and equipment.

People providing cleaning services could:

- work alone
- access machinery and equipment from the rear or sides, or in unexpected ways
- climb on machinery and equipment
- enter confined spaces, or larger machinery and equipment
- become trapped by the mechanism of the machinery and equipment through poor isolation of energy sources or stored energy, such as spring - loaded or counter - balance mechanisms, compressed air or fluids, or parts held in position by hydraulics or pneumatic (air) rams
- work with chemicals
- operate electrical equipment in wet areas.