

REFRIGERATION AND AIR CONDITIONING TECHNICIAN

NSQF LEVEL - 5

1st Year (Volume I of II)

TRADE THEORY

SECTOR: Capital Goods & Manufacturing



Directorate General of Training

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



**NATIONAL INSTRUCTIONAL
MEDIA INSTITUTE, CHENNAI**

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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, an autonomous body under Ministry of Skill Development & Entrepreneurship is entrusted with developing producing and disseminating Instructional Media Packages (IMPs) required for ITIs and other related institutions.

The institute has now come up with instructional material to suit the revised curriculum for **R&ACT 1st Year (Volume I of II) Trade Theory NSQF Level - 5 in Capital Goods & Manufacturing Sector** under annual 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

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.

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

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

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

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

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

Chennai - 600 032

**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 **R&ACT 1st Year (Volume I of II) NSQF (Level - 5)** under **Capital Goods & 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 Course of the R&ACT 1st Year (Volume I of II) Trade Theory NSQF Level - 5 in Capital Goods & Manufacturing . The contents are sequenced according to the practical exercise contained in NSQF LEVEL - 5 syllabus on Trade Theory 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.

Module 1	Fitting & Sheet Metal
Module 2	Electrical
Module 3	Electronics
Module 4	Welding
Module 5	Basic Refrigeration
Module 6	Refrigerator direct cool
Module 7	Frost free refrigerator/power of refrigerator

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 course. These exercises are designed to ensure that all the skills in compliance with NSQF LEVEL - 5 syllabus are covered.

The manual is divided into seven modules.

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

S.No	Learning Outcome	Lesson No
1	Awareness of trade related hazards and safety.	1.1.01 to 1.1.04
2	Produce fitting jobs as per drawing (Range of operation: marking, sawing filing, drilling reaming, taping and dieing etc.)	1.1.05 to 1.1.07
3	Produce sheet metal components (range of operation - marking, metal cutting bending, riveting and soldering etc.)	1.1.08 to 1.1.13
4	Aware of electrical safety. Join different wire, measure power, currents, volts and earth resistance etc. Connect single phase, 3 phase motors i.e star and delta connections.	1.2.14 to 1.2.21
5	Identify the electronic components and their colour code i.e transistor, capacitor, diode, amplifier, I.C and able to work soldering.	1.3.22 to 1.3.34
6	Perform gas welding, brazing, soldering observing related safety.	1.4.35 to 1.4.42
7	Identify RAC tools and equipments and recognise different parts of RAC system. Perform copper tube cutting, flaring swaging, brazing.	1.5.43&44 to 1.5.53
8	Test mechanical and electrical components. Perform leak test, vacuuming, gas charging, wiring and installation of refrigerator.	1.6.54 to 1.6.61 & 1.6.63 to 1.6.64
9	Perform door alignment, door gasket fitting, replace door switch.	1.6.62
10	Test compressor motor terminal, start compressor direct with relay and without relay, technique of flushing, leak testing, replacing capillary and filter drier, evacuating and gas charging.	1.6.65 to 1.6.73
11	Check components of frost free refrigerator (electrical / mechanical), wiring of frost free freeze and air distribution in refrigerator sector. Leak detection, evacuators and gas charging.	1.7.74

SYLLABUS

1st Year (Volume I of II)

Duration: Six Months

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
Professional Skill 25 hrs.; Professional Knowledge 07 hrs.	Identify trade related hazards and safety procedures following safety precautions.	1. Identify workshop & machineries. (06 hrs) 2. Demonstrate Safety precautions and First aid. (06 hrs) 3. Demonstrate fire fighting (03 hrs) 4. Demonstrate working at height using PPE's and identify the hazards and take personal safety precautions. (10 hrs)	Introduction to trade and related industries. General safety precautions and first aids, fire fighting equipments and electrical safety. History of Refrigeration and Air conditioning. Function, use and specifications of refrigeration tools, instruments and equipment. Grooming of technicians. (07 hrs)
Professional Skill 50 hrs.; Professional Knowledge 14 hrs.	Produce fitting jobs as per drawing (Range of operations: marking, sawing, filing, drilling, reaming, tapping and dieing etc.)	5. Identify general tools, instruments & equipments. Care and maintenance of tool, instruments and equipments. (10 hrs) 6. Perform flat filing, marking, punching and hack sawing to make a job as per drawing. (15 hrs)	Fitting Different types of Fitting hand tools, power tools, - their use. Function, construction, Specification & their application. Machineries and equipments used in fittings like drilling machines, grinding machines – types, specifications and care and maintenance. (07 Hrs)
		7. Perform flat filing, marking, punching, hack sawing, drilling, tapping, reaming, dieing to make a job as per drawing and check using precision measuring instruments Viz. Vernier calliper, Micrometer, etc. (25 hrs)	Fitting Precision measuring instruments – Function, construction, Specification & their application. (07 hrs)
Professional Skill 25 hrs.; Professional Knowledge 07 hrs.	Produce Sheet metal components (range of operation – marking, metal cutting, bending, riveting and soldering etc.)	8. Perform Sheet Cutting by straight snip as per drawing. (02 hrs) 9. Perform Sheet Cutting by bent snip as per drawing. (02 hrs) 10. Bend, fold and join metal sheets in different process. (03 hrs) 11. Join sheet metal by using rivet set and snap. (08 hrs) 12. Solder sheets of metal. (02 hrs) 13. Prepare a box or funnel with sheet metal as per drawing. (08 hrs)	Sheet Metal Function, construction, working, use, and application, specification of Sheet metal tools, instruments and equipment. Care and maintenance of tools. Types of sheet metal joints (cold and hot) and their use. Rivet & riveting their types and use. Solder and its composition. (07 hrs)
Professional Skill 50 hrs.; Professional Knowledge 14 hrs.	Identify electrical safety. Join different wire, measure power, currents, volts and earth resistance etc. Connect single phase, 3 phase motors i.e. star and delta connections.	14. Demonstrate Electrical safety precautions and First aid. (03 hrs) 15. Identify, use and maintain electrical tools. (03 hrs) 16. Prepare simple twist joints of wires. (03 hrs) 17. Prepare married joints of wires. (03 hrs)	Electrical Electrical terms such as AC and DC supply, Voltage, Current, Resistance, Power, Energy, Frequency etc. Safety precautions to be observed while working on electricity. Conductors and Insulators, Materials used as conductors. Series and parallel circuit, open circuit, short circuit, etc.

		18. Measure current, voltage, resistance, power' frequency, energy using analog and digital meter through a single phase circuit. (08 hrs) 19. Test insulation and earth resistance using Megger. (05 hrs)	Measuring Instruments such as voltmeter, ammeter, ohm meter, watt meter, energy meter and frequency meter. Earthing and its importance. Earth resistance. Insulation and continuity test (07 hrs)
		20. Star & Delta connection on a three phase motor and show line voltage, line current, phase voltage and phase current. (15 hrs) 21. Three phase power & power factor measurement. (10 hrs)	Inductors and capacitors. Effects of inductor and capacitors in an AC circuit. Inductive reactance, capacitive reactance, Impedance and power factor. Lagging and leading power factors. Single phase and Three phase supply system. Star and Delta connection and their comparison. Line voltage, Line current, Phase voltage and Phase current. Methods of improving power factor. (07 hrs)
Professional Skill 50 hrs.; Professional Knowledge 14 hrs.	Identify the electronic components and their colour code i.e. transistor, capacitor, diode, amplifier, I.C and able to work soldering.	22. Identify electronic components, tools & instrument. (05 hrs) 23. Colour coding of resistors. (03 hrs) 24. Verify Ohm's Law. (02 hrs) 25. Use voltmeter, ammeter and multimeter. (5 hrs) 26. Practice soldering & de soldering. (10 hrs)	Electronics Introduction to Electronics. Basic Principles of semiconductors, Principles and application of Diodes. Solder – its composition and paste. (07 hrs)
		27. Identify transistors, resistors, capacitors, diodes, S.C.R., U.J.T., amplifier and I.C. (03 hrs) 28. Construct and test full wave rectifier using diodes. (02 hrs) 29. Construct and test a bridge rectifier. (03 hrs) 30. Construct and test series voltage regulator circuit. (02 hrs.) 31. Construct and test power supply using fixed voltage regulator lcs. (05 hrs) 32. Identify and test SCR. (02 hrs) 33. Construct and test an electronic timer using UJT & SCR. (03 hrs) 34. Apply OP-AMP, photo transistor and test performance. (05 hrs)	Rectification, Zener diode as voltage regulator – transistors parameters- CB, CE, CC, configuration, amplification. SCR Photo diodes, photo transistors, multi – vibrator, CR & LR circuit. SCRs, UJTs, ICs. (07 hrs)
Professional Skill 50 hrs.; Professional Knowledge 14 hrs.	Perform gas welding, brazing, soldering observing related safety.	35. Identify gas welding equipments & accessories. (03 hrs) 36. Demonstrate safety precaution in handling of Oxy-acetylene cylinders, regulators etc. (03 hrs) 37. Setting up of AIR-LPG, O₂-LPG and O₂-C₂H₂ using can type portable flame set. (04 hrs) 38. Oxy-acetylene gas welding, brazing and cutting on thin sheet metal. (10 hrs) 39. Demonstrate Care & Safety of welding tools and equipments. Back fire arrester. (03 hrs)	Welding Introduction to basic principles of commonly used Welding processes, oxy fuel gas welding / cutting, brazing & soldering, nozzles, base metal and filler metal. Use of flux. Welding tools and equipment type specification and use. Safety method in welding. Method of gas welding, gas used and flames adjustment and pressure setting of O₂ and DA.

		40. Set Oxy-acetylene plant, use two stage regulator, adjustment of flame, gas pressure – O₂ and DA. (04 hrs) 41. Perform brazing between Cu to Cu and Cu to MS, Cu to aluminium pipes. (10 hrs) 42. Join metal plates by using gas welding (lap joint, butt joint, etc). (13hrs)	Difference between soldering and Brazing in terms of temperatures, filler materials, joint strengths and applications. Use of Oxy Acetylene, Oxy LPG, Air LPG and two stage regulator for brazing/soldering. Description of back fire arrester. (14 Hrs)
Professional Skill 100Hrs.; Professional Knowledge 28Hrs.	Identify RAC tools and equipments and recognize different parts of RAC system. Perform copper tube cutting, flaring, swaging, brazing.	Basic Refrigeration 43. Identify & use of general hand tools, instruments & equipments used in refrigeration work. (12 hrs) 44. Identify & use of special tools, instruments & equipments used in refrigeration work. (13 hrs)	Basic Refrigeration Basic principle of refrigeration, working, use, specifications of refrigeration tools, instruments and equipment. Fundamentals of Refrigeration, units and measurements, Pressure & its Measurements. Thermodynamics law. (07 Hrs)
		45. Identify various refrigeration equipments and components of vapour compression system like compressor, condenser, expansion device and evaporator. Identify and Check vapour absorption refrigeration cycle (VARC) (12 hrs) 46. Unroll, cut and bend soft copper tubes. (04 hrs) 47. Swage and make a brazed joint on copper tubing. (10 hrs) 48. Make flare joints and test them with flare fittings. (10 hrs) 49. Pinch off copper tubing. (04 hrs) 50. Use lock ring tool and various fittings of locking for servicing of appliances (10 hrs) 51. Brazing of Cu to Cu, Cu to steel, Cu to brass using AIR LPG suitable in RAC machine. (07 hrs) 52. Brazing of Cu to Cu, Cu to steel, Cu to brass using OxyLPG. (07 hrs) 53. Brazing of Cu to Cu, Cu to steel, Cu to brass using Oxy Acetylene. (11 hrs)	Science related to refrigeration, work, power, energy, force, Heat and Temperature, Different temperature scales, Thermometers, Units of heat, sensible heat, latent heat, super heating and sub-cooling, saturation temperature pressure, types, units. Types of Refrigeration systems, including Vapour absorption refrigeration cycle (VARC), water - combination. Study the construction and working of vapor compression cycle, low side & high side of vapour compression system. Applications of vapour compression cycle. Coefficient of Performance (COP), Ton of Refrigeration. (14 Hrs) Construction and working of V.C Cycle, fundamental operations, sub cooling and super heating. Study of Ph, Ts, Pv diagram. (07 Hrs)
Professional Skill 25Hrs.; Professional Knowledge 07 Hrs.	Test mechanical & electrical components. Perform leak test, vacuuming, gas charging, wiring & installation of refrigerator.	54. Identify electrical and mechanical components of refrigerator. (03 hrs) 55. Check and replace electrical components of refrigerators. (04 hrs) 56. Leak test, evacuation, gas charging in refrigerators. (08 hrs) 57. Wiring circuit of refrigerator. (08 hrs) 58. Installation of refrigerator. (02 hrs)	Refrigerator (Direct cool) Function, construction, working of single door direct cool refrigerator, specifications, trouble shooting, care and maintenance. Requirement of Vacuum and level of vacuum. (07 Hrs)

Professional Skill 25 Hrs.; Professional Knowledge 07 Hrs.	Perform door alignment, door gasket fitting, replace door switch.	Refrigerator (Direct cool) 59. Identify electrical components of direct cool refrigerator. (05 hrs) 60. Identify mechanical components of direct cool refrigerator. (05 hrs) 61. Installation of refrigerator. (02 hrs) 62. Checking door alignment, adjustment of door switch operation & replacing of gaskets. (03 hrs) 63. Tracing the mechanical components of refrigerator. (03 hrs) 64. Check, Find Fault and test the electrical and other system components of refrigerator. (07 hrs)	Refrigerator (Direct cool) Study the construction & working of direct cool Refrigerator. Study the electrical components of refrigerator. Study the mechanical components of refrigerator and their types. Study the heat exchanger, door gaskets, Heat Insulation materials. Care and maintenance of refrigerator. (07 Hrs)
Professional Skill 25 Hrs.; Professional Knowledge 07 Hrs.	Test compressor motor terminal, start compressor Direct with relay & without relay, technique of flushing, leak testing, replacing capillary & filter drier, evacuation & gas charging.	65. Testing of compressor. (02 hrs) 66. Identification of motor terminals. (02 hrs) 67. Start of compressor with and without relay. (03 hrs) 68. Test performance of direct start refrigerator. (02 hrs) 69. Cleaning and flushing of evaporator and condenser with dry nitrogen. (02 hrs) 70. Replacement of capillary tube and drier. (02 hrs) 71. Installation of gauge manifold in the system. (02 hrs) 72. Leak testing, evacuation and gas charging in refrigerator. (05 hrs) 73. Check electrical wiring of refrigerator. (05 hrs)	Importance of flushing in evaporator and condenser, use of dry nitrogen for flushing, necessity of replacing capillary and drier. Evacuation, leak testing, gas charging method in refrigerator, Refrigerants used in Refrigerators and its properties. Desiccant drying agent. (07 Hrs)
Professional Skill 50 Hrs.; Professional Knowledge 14 Hrs.	Check components of frost free refrigerator (electrical / mechanical), wiring of frost free freezer & air distribution in refrigerator sector. Leak detection, evacuation & gas charging.	74. Tracing electrical circuit of Frost Free refrigerator. (07 hrs) 75. Checking, fault finding and testing of electrical accessories like thermostat, timer, defrost heaters, bi-metal, air louvers etc. and other system components. (10 hrs) 76. Checking air distribution system. (03 hrs) 77. Servicing of refrigerator. (03 hrs) 78. Testing the performance of refrigerator. (02 hrs)	Frost Free Refrigerator Study the construction and working of Frost Free (2 or 3 door) Refrigerator parts particularly, the forced draft cooling, Air Duct circuit, temperature control in Freezer & cabinet of Refrigerator, air flapper / louver used in refrigerator section, automatic defrost system. Study of Electrical accessories & their functions (Timer, Heater, Bimetal, Relay, OLP, T/S etc.) Refrigerator cabinet volume calculation. (07 Hrs)
		79. Identify three and four door no frost refrigerator. (07 hrs) 80. Stripping of components. (07 hrs) 81. Tracing electric circuit. (03 hrs) 82. Testing components. (03 hrs) 83. Leak testing, evacuation, gas charging. (05 hrs)	Refrigerator (Inverter Technology) Study the construction and its working of two and three door frost free refrigerator. Care and maintenance, installation method. (07 hrs)

Introduction about training scheme & trade

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

- explain above NCVT
- explain above various vocational training programme
- explain about refrigeration and airconditioning
- explain about qualities of good mechanic
- explain the history of refrigeration.

We are the citizen of peaceful nation, our policy and economy is based on the method of peace itself. We all know we got the political freedom by fighting for number of years

At present we want to win the economical freedom, further we should develop a balanced economy and promote.

During second world war there was a high demand of technicians in defense services. In order to meet the sudden demand of technicians, in the year 1940 GOVT of India started the war TECHNICIAN TRAINING SCHEME.

We got the Independence on 15th August 1947. After the independence many of new factories have been expanded. Day by day production capacity increased in the country. To meet this demands there was a requirement of man power, not only a man power some industries of our country needed huge number of well doing SKILLED CRAFTSMEN so, in the year 1950 Govt. of India started the CRAFTSMEN SKILLED SCHEME on national basis. Latest to ensure the regular supply of skilled man power Govt. of India introduced number of various training schemes with the control of directorate general of employment and training (DGET) under the ministry of labour. Now it is DGT. The state Govt. are responsible for the administration and implementation of training scheme in industrial training institutes (ITI).

National council for a vocation training (NCVT)

In the year 1956 NCVT was set up by GOVT of India to maintain the uniformity in the standard of training in all the country.

It is an advisory body which will conduct the all INDIA TRADE TSET at the end of the course and this will award the **National Trade Certificates (NTC)** for the successful candidates.

Various vocational training programme

- 1 Craftsman training scheme
- 2 Apprenticeship training scheme
- 3 Foreman training scheme
- 4 Craft instructor training programme
- 5 Advanced vocational training scheme etc...

Craftsmen training scheme

Craftsmen training scheme was introduced in 1950 the year with following objectives.

- A To ensure a steady flow of skilled workers in different trades for industry.
- B To reduce unemployment among the educated youth & to equipping them for suitable industrial employment.
- C To raise the quality and quantity of industry production by systematic training of workers.

It is a basic skill training program under this scheme training is provided in 32 engineering trades and 44 non engineering trades to the youth in the age group of 15-25 years. The duration of the courses varies from 1 to 2 years minimum educational qualification is SSLC of equivalent and +2 for some trades.

Apprenticeship training scheme

Apprenticeship training scheme was introduced by the GOVT. of India the apprenticeship act was implemented in 1961 and it came into force with effect from 1/03/1962 and which was passed in Rajyasabha in 1971.

The objectives of this scheme is to

- A To impact on the job training to the youth and to expose them into actual work environment of industry to meet the industrial needs.
- B To work on the production jobs thereby to gain confidence.

Mechanic refrigeration & air conditioning

Mechanic

A person who has thorough knowledge of.....

- Different types of equipment, Accessories and material used in the trade and their working.
- Identify the possible troubles, their causes and their remedy.
- Manipulate and handle the tools, equipments & materials, and chemicals used for manufacturing, installing, Maintaining, servicing, repairing in the trade.
- Independently diagnose troubles and carry out repairs.
- Adopting safety precautions and first aid and many more.

Refrigeration

Refrigeration is the method of producing cold or refrigeration is an artificial method of removing heat.

More specifically refrigeration may be defined as that the branch of science, which deals with process of reducing and maintaining their temperature of the space or product below the temperature of the surrounding.

Air conditioning

Air conditioning is the simultaneous control of the following four factors.

- 1 Temperature
- 2 Humidity
- 3 Air motion
- 4 Purity of air

Temperature

Human body feels comfortable when air is at 22° C. If the outside air is hot the air conditioning system should reduce the temperature by removing heat and if the outside air is cold it should increase the temperature, maintain desired temperature in all conditions.

Humidity

The moisture contents of air should be increased or decreased to suit the requirement in the conditioning space. The human body feels comfortable when the humidity is between 40 to 60%.

Air motion

Air should be maintained at proper velocity in the conditioned space for proper distribution to feel comfortable.

Purity of air

For human comfort air should be free from dust and other impurities, therefore air should be filtered cleaned and purified before allowing into the conditional space.

Qualities of good mechanic

A good mechanic should have the following qualities.

1 Educational qualification

- a Should have a government -recognized diploma or certificate.
- b Must have undergone through practical training.

2 Mastery over his/her trade

Should have through knowledge of

- Various types of function and correct usage of tools, instruments, equipments and accessories.
- Behavior of gases and chemical used in the trade.
- Major hazards like explosion. Fire and effects of gases.
- Proper use of fire extinguishers.
- Electricity and its behavior.
- Safety precaution and first aid.
- Possible troubles that may latest development in the trade.

3 Personality characteristics

- Should maintain sound health and good physique.
- Should wear proper dress suitable to his work.
- a **Alertness:** Ability to aware of things happening around.
- b **Wisdom:** Combination of knowledge and experience.
- c **Human Relation:**
 - Impartiality
 - Patience
 - Courtesy
 - Loyalty
 - Self control

Development of refrigeration

Modern refrigeration has much application. The first and probably still the most important of food.

Most food kept at room temperature spoil rapidly. This is due to the rapid growth of bacteria. At common refrigeration temperatures of about 39°F (4°C), bacteria growth quite slowly. Food at this temperature will keep much longer. Refrigeration preserves food by keeping it in cold. Other important uses of refrigeration include air conditioning, beverage cooling, and humidity control. Many manufacturing process also use refrigeration.

The refrigeration industry became important commercially during the 18th century. Early refrigeration was obtained by use of ice. Ice from lakes and ponds was cut and stored in the winter in insulated store rooms for summer use.

The use of natural ice required building insulated container or iceboxes.

Ice was first made artificially about 1820 as an experiment. Jacob Perkins, an American engineer invented the machine which led to our modern compression systems. Michael Faraday discovered the principles for the absorption type of refrigeration as early in 1824. It was not actually built until 1855 by a German engineer.

During 1890, a warm winter resulted in shortage of natural ice. This help start the mechanical ice making industry.

Mechanical domestic refrigeration first appeared about 1910. J.M. Larsen produced a manually produced household machine in 1913. By 1918 kelvinator produced the first automatic refrigerator for the American market. They sold 67 machines that year.

The first of the sealed or "hermetic" automatic refrigeration units was introduced by General Electricity in 1928. It was named the Monitor Top.

Beginning with 1920, domestic refrigeration became an important in industry. The Electrolux, which was an automatic domestic absorption unit, appeared in 1937.

Fast freezing to preserve food for extended periods was developed about 1923. This marked the beginning of modern frozen foods industry. Automatic refrigeration unit, for the comfort cooling parts of air conditioning appeared in 1927.

Mechanical refrigeration systems were first connected to heating plants to provide summer cooling in the late 1920s. by 1940, practically all domestic units were of the hermetic type. Commercial units had also been successfully made and used. These units were capable of refrigerating large commercial food storage systems. They could provide comfort cooling of large auditoriums. That could also produce low temperatures used in may commercial operations.

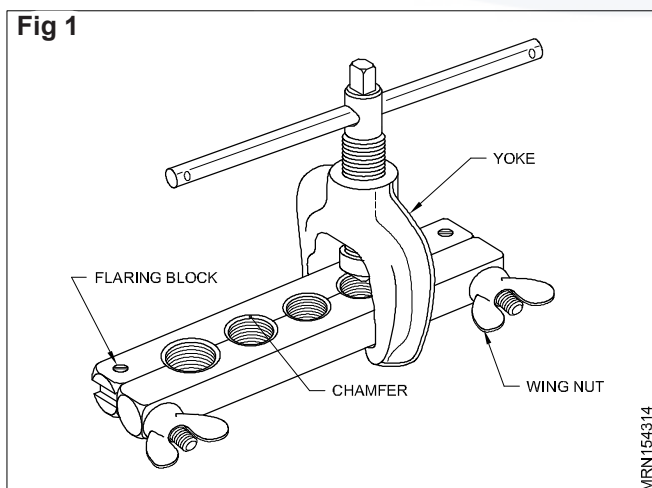
In 1935, Frederick McKinley Jones produced an automatic refrigeration system for lonhaul trucks. From a small, slow start in the late 1930d, air conditioning of automobiles has also grown rapidly.

Starting in the 1960s, the home air conditioning market experienced tremendous growth. Energy was in expensive, and therefore, simple air conditioning became common in many homes. Solar energy and other alternative energy sources became additional sources for powering heating and cooling system.

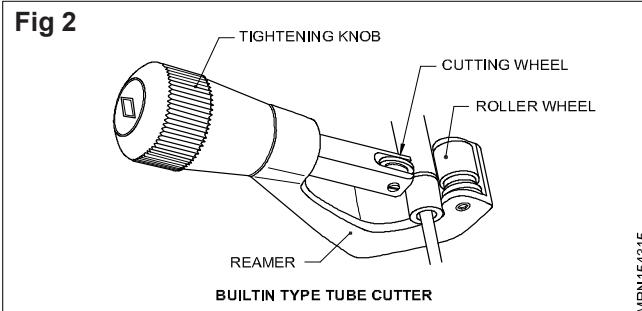
Due to tremendous growth in technology, by 1990 all areas of refrigeration and air conditioning were using microprocessor control systems. The purpose of this system is to increase reliability and efficiency of the heating and cooling units. By 1990, the automobile air conditioner became as standard as the automatic transmission.

Flaring tool with yoke (Fig 1) : It is used for making of different sizes of flares of copper tubes. It has two parts.

Flaring block and yoke. Flaring block consists of two parts in which forming holes of different size or tubing. These parts are clamped together with using nut and bolts. The face of each hole is cut out 45° angle sheet. To produce a flare die or cone in yoke rotate against the flare sheet.

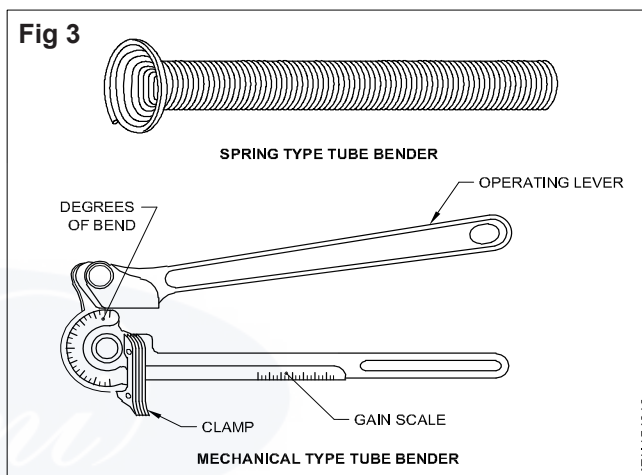


Tube cutter (Fig 2) : Small diameter annealed (soft) copper tubes are used in most refrigeration work. Tube cutter is used to cut these tubes. It consists of a 'V' block against which the tube rests and an adjustable round blade of carbon steel which cuts the tube. After placing the tube in 'V' block blade is adjusted and tube cutter is revolved the tube and cut the tube. Some tube cutters are equipped with a Reamer for removing the burr at the cutting end of the tube. Its size depends upon the maximum diameter of the tube which it can cut.



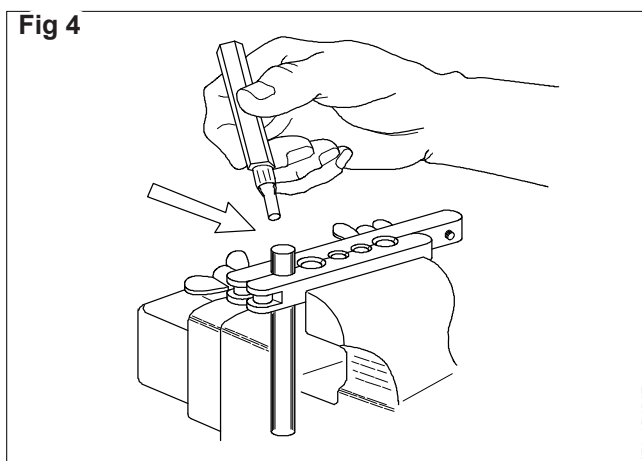
Pipe bending tool (Fig 3) : There are External coil spring bending tools where the external spring is designed to be used near the ends of tubes.

A lever type tube bender is used to form bends neatly and accurately with out buckling the tubing. These tools will form bends up to 180° in the continuous operation. The forming wheel is calibrated to show the degree of bend attained. Each of these tools is used with one size of bending.



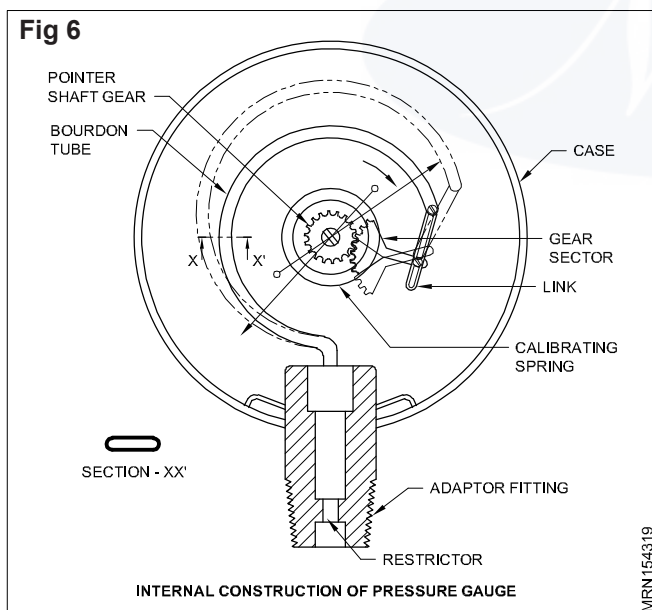
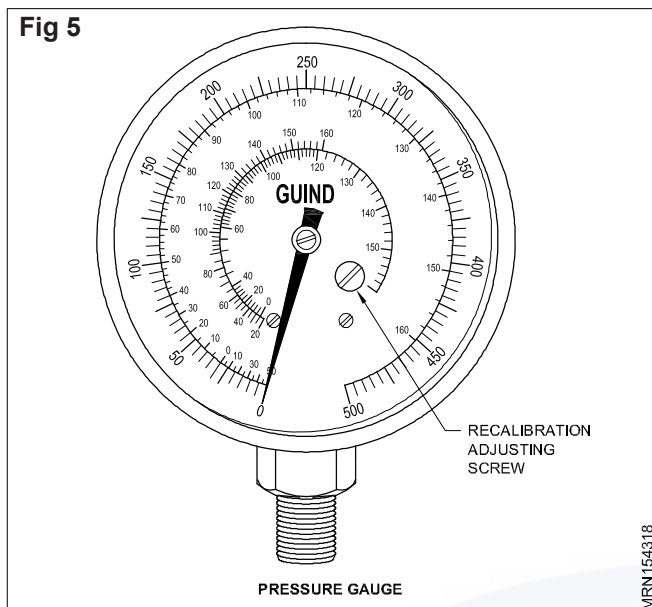
Swaging tools (Fig 4) : Swaging is a means of shaping copper tubing so that operation is accomplished with a punch type or screw type swaging tool. The tubing is clamped into the flaring block and the specially designed punch is hammered into the tubing, swaging or expanding the end. So that it will fit over the end of another piece of tubing.

Pinching tools: It is used for sealing or closing the diameter of copper tubes. It consists of two bars forming jaws and holes of various sizes and are clamped together with using nuts and bolts. The tube is pinched off both the two jaws.



Pressure gauges (Figs 5 & 6) : It is used to check the pressure of the refrigerant in refrigeration unit. There are high pressure vacuum and compound gauges.

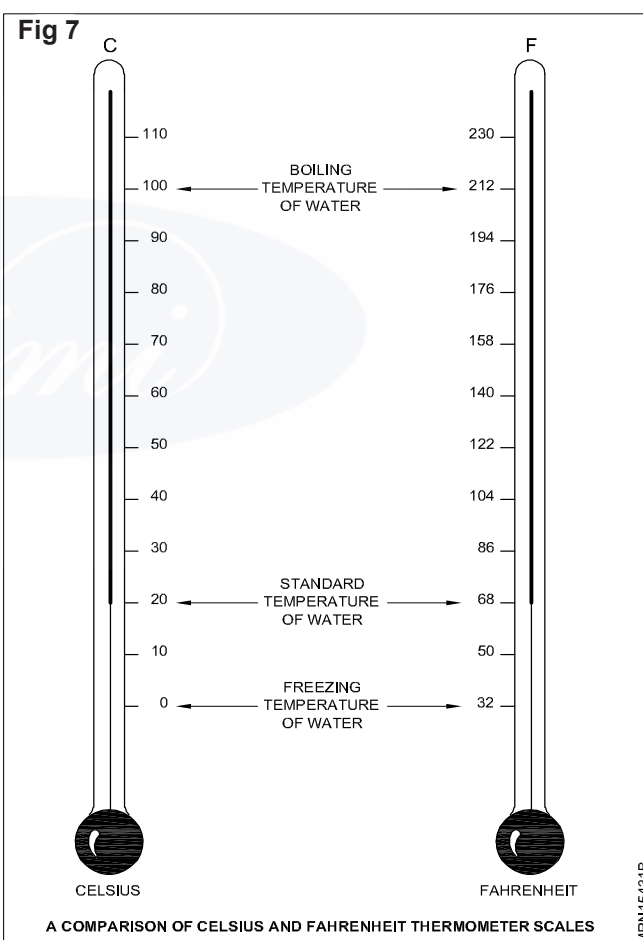
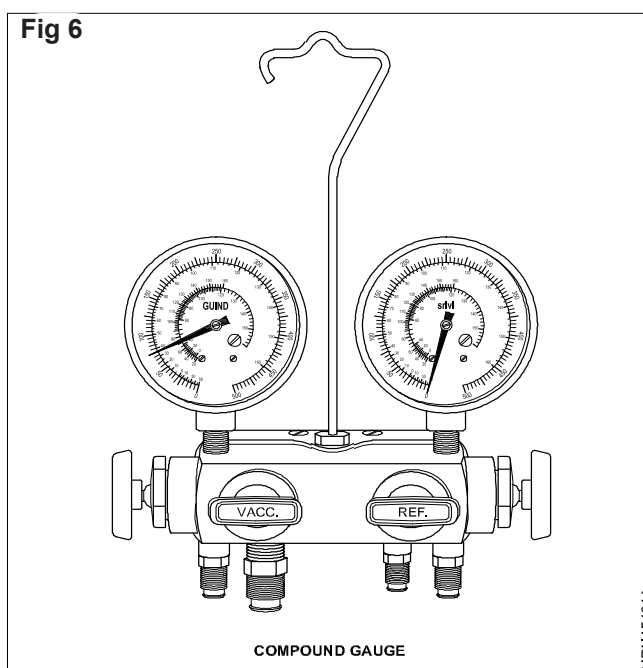
A pressure rise in Bourdon tube makes it tend to straighten. This movement will pull on the link, which will turn the gear sector counter clockwise. The pointer shaft will then turn clockwise to move the needle. Most popular gauges have a 2½" dial and are connected into refrigeration system with 1/8" male pipe thread.



Compound gauge (Fig 7) : It measure both pressure and vacuum. It is usually calibrated from 0 to 30 Hg and from 0 to 200 PSIG.

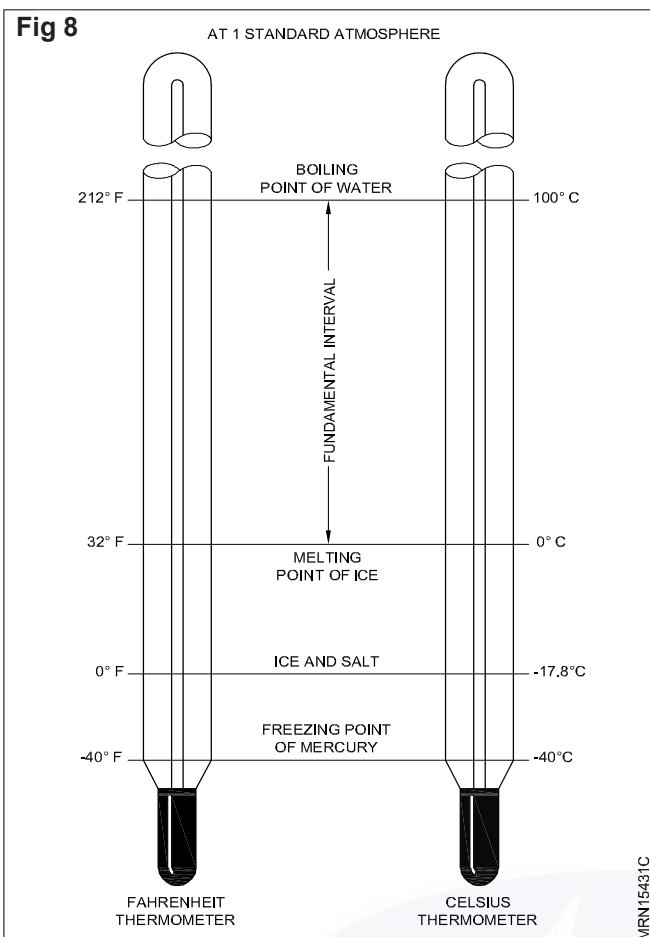
Thermometer (Fig 8) : The most common Thermometer scales are Celsius or Centigrade scale, and Fahrenheit. The two temperature determine the calibration of Thermometer.

- the temperature of melting ice
- the temperature of boiling point



On Centigrade Thermometer the temperature of melting ice or the freezing temperature of water is 0°C. The temperature of boiling water is 100°C. There are 100 spaces or degrees on the scale between freezing and boiling.

On Fahrenheit Thermometer, the temperature of melting ice or freezing temperature of water is 32°F. The temperature of boiling water is 212°F. This provide 180 spaces or degrees between the freezing and boiling temperature. (Fig 9).



Leak detects

Soap bubble method: Clean all the joints with piece of dry cloth and soap solution is applied around all joints and supported place and leakage place given out bubbles.

Halide torch method: In thin carbon element is heated by hydrocarbon flame in the Halide torch. The rubber tube in the torch extracts air on the element when flame burn. To find leak this tube is slowly moved on outside joint of the system, fittings at that slightest change in colour. If the flame colour become a very pint green, a small leak is indicated.

This flame will be green when large leak are encountered.

Electronic detector: The latest and most sensitive leak detector is an electrically operated electronic leak detector. It consists of control unit and probe.

The control unit incorporates an amplifier, a halogen sensitive element and air pump. The probe consists of plastic nozzle with transparent tip and a lamp. The probe is connected to the control unit with flexible tube and electric wires for a lamp.

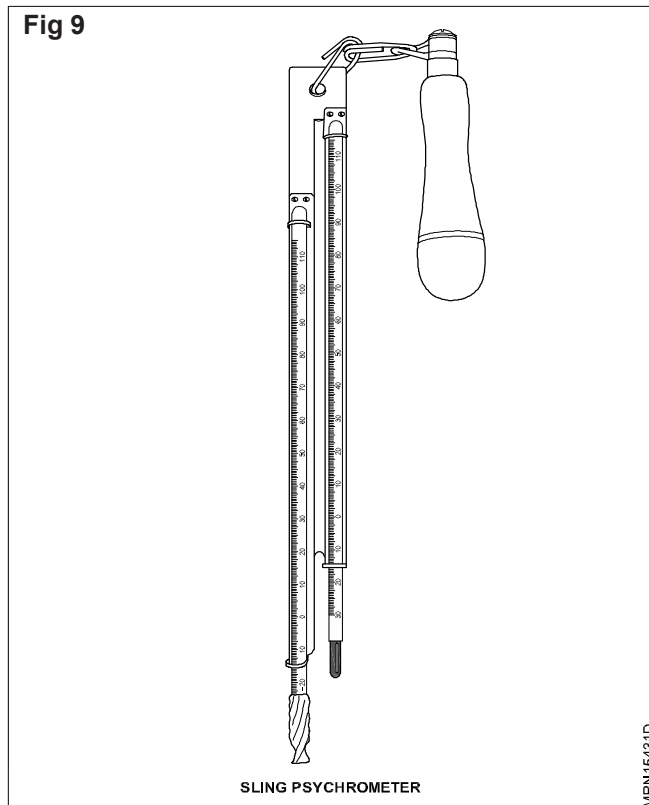
Tachometer, vacuum pump and air compressor

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

- explain the necessary part, function and application of tachometer
- explain the necessary part, and function of vacuum pump
- explain the necessary part, and function of air compressor.

Tachometer (Fig 1)

Necessary part



To test the leaks, the probe is moved slowly along a tube or component around which leak is suspected. A signal is generated which causes the lamp in the probe to light, thus refrigerant leak is indicated and located.

Gauge manifold: These are arranged for one suction and one discharge gauge. Either three or four flared connections for lines from the vacuum pump, refrigerant cylinder and appliance are to be tested.

Sling psychrometer: Relative humidity is measured by an Instrument known as the Sling Psychrometer. This instrument consists of two ordinary Thermometer; securely fastened in a frame which is attached by chain. By means of this chain the instrument can be rapidly whirled around so that it comes in contact with maximum amount of air. Around the bulb of one Thermometer is a wick cloth which dampered with water when taking a reading.

The theory of the instrument is simply that the evaporation of moisture from the bulbs of the wet thermometer causes it to read lower than the one which is dry.

The rate of evaporation depends directly on the amount of moisture in the air at the time the test is made. The difference in the readings of the two thermometer enables one to find the relative humidity.

- | | | |
|------------------------|---|----------------|
| – Head spindle | – | Speed selector |
| – Pointer lock Sbutton | – | Speed scales |

Function of Tachometer

Measurement of speed: Speed is defined as a scalar quantity. Electricians must know how to measure the speed of rotating electrical machines. The speed of rotating machines is measured in two ways.

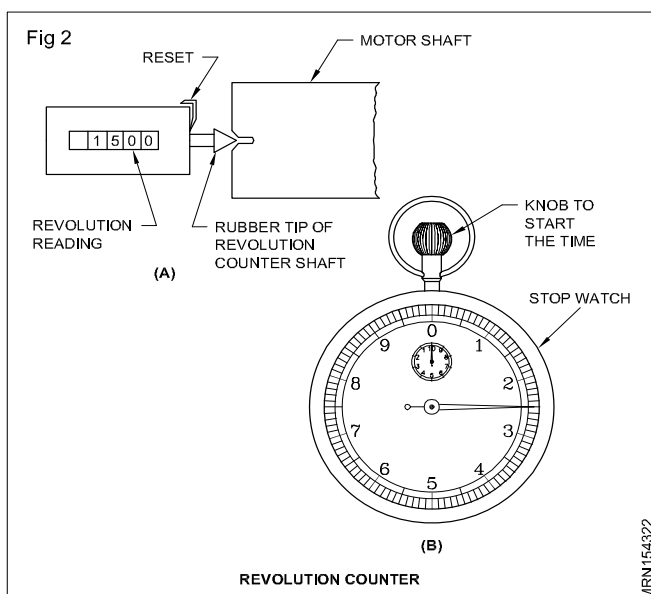
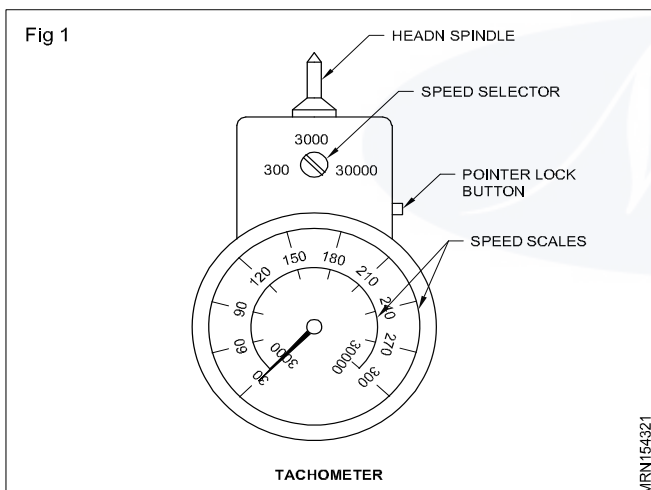
- Direct method (contact method)
- Indirect (non-contact) method

In practice both the methods are being used by electricians.

In the direct method two types of instruments as stated below are used for measuring speeds.

- Revolution counter and stop watch
- Tachometer

Revolution counters: Revolution counters are of two types; one is a dial type counter which is an earlier version and has become obsolete (Fig 1). The other type is a digital counter which is shown in (Fig 2). The spindle of the counter which is provided with a conical rubber bush is placed in the countersunk portion of the machine shaft for measuring speed. The revolution counter counts the number of revolutions as long as its rubber brush is in contact with the shaft. To get the revolution per minute, it is necessary to have a timing device.



Hence to measure the speed of the rotating shaft with the revolution counter, a stop watch is also necessary. Just when the rotation of the shaft speed is transferred through friction to the counter, the stop watch begins to tick. Both the revolution counter and the stop watch are stopped at the same time and the number of revolutions indicated in the counter per minute gives the speed of the shaft in r.p.m. The accuracy of this method is not very great, as human reflexes are involved.

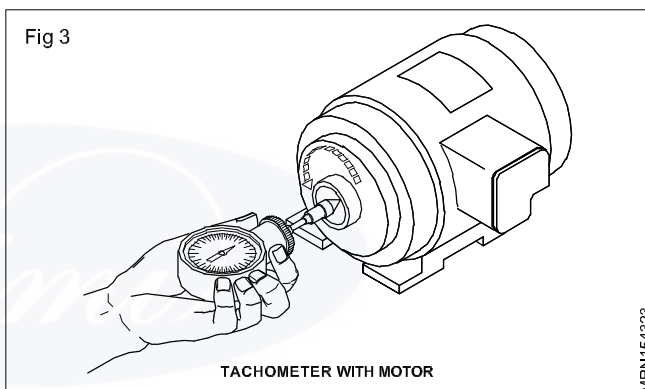
The second instrument used for direct measurement of speed is a tachometer as shown in (Fig 3). The speed is directly shown by a needle over a calibrated dial.

The tachometer is used in the same way as that of the revolution counter except that a stop watch is not required.

Applications: Tachometers are of two types

- Analog type
- Digital type

Both are employed to measure the speed of the compressor motor, pump motor, fan motor and other revolving parts. Knowing the RPM of the motor we can easily judge the efficiency of the motor.



Parts and function of vacuum pump (Fig 4)

- vacuum pump
- vacuum hose

Function of vacuum pump: Conventional and high vacuum type have been discussed earlier and both are available in portable sets suitable for site work. Not that high vacuum models use a special high quality paraffin based oil. Its vapour pressure at 37.7°C (100°F) is no more than 0.005 mm (5 micron) and a vacuum pump cannot pull a total absolute pressure less than the vapour pressure of its sealing oil.

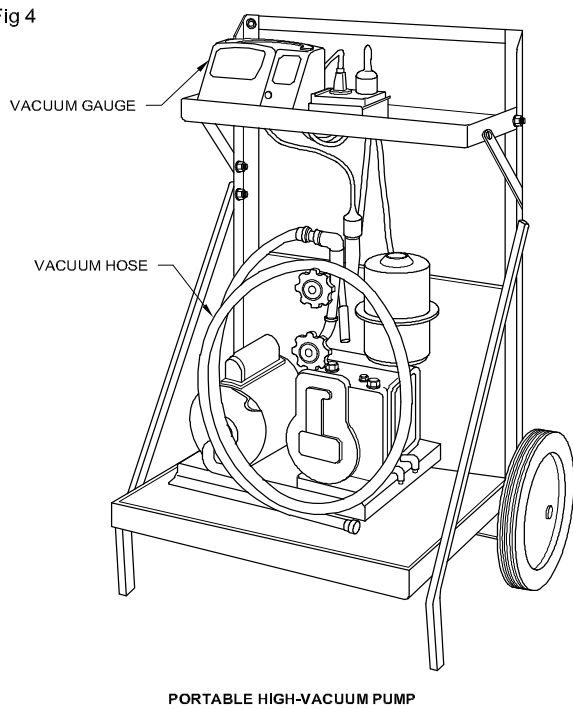
High vacuum gauges: These are the electronic type as shown in (Fig 5). The range covered should be 20 mm to zero enabling unit pressure to be watched through out the dehydration process which starts at approx. 21°C (70°F).

Application: The vacuum pump is used in our refrigeration system every unit before gas charging vaccumizing of system. After vacuum we charge gas in system.

Parts of air compressor

- vacuum gauge
- vacuum hose

Fig 4



MRN154324

Compressor: Sucks air from the outside (atmosphere) compresses and fills up the reservoir at a higher pressure.

Pressure gauge: It shows the pressure of the stored air in the reservoir

Safety device: It is a safety device for the reservoir. A release pressure valve is provided to protect the air reservoir from bursting. When the air pressure in the reservoir exceeds the specified limit the safety valve opens and releases the excess pressure.

Drain plug: The moisture in the air when compressed condenses into water and this will accumulate in the reservoir. It must be drained through the drain plug periodically to prevent corrosion of the tank.

Care and maintenance: The recommended grade of oil should be used.

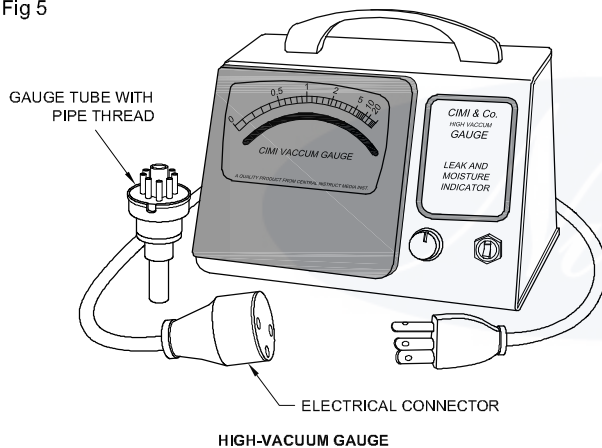
The level of the oil should be maintained at specified mark shown on the dip stick.

Ensure that the belt guards are fitted properly. Ensure that the drive belts are in good condition and their tension is correct.

Application of air compressor

- It is used to test the leakage by building up pressure
- It is used to flush the refrigeration A/C systems
- Also use in choke system we clear to the pressure of system
- In a spray painting a unit cabinet uses air compressor.

Fig 5



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Function of air compressor (Fig 6)

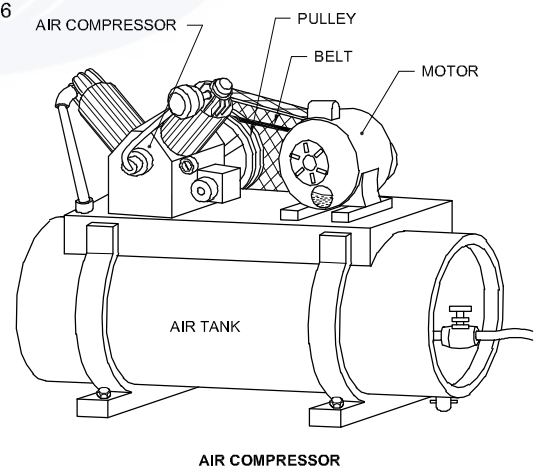
Air compressor: An air compressor is used for various purposes in auto garages like washing, greasing and cleaning of the vehicle and the auto parts and inflate tyres.

Compressor main parts

Reservoir: A tank for storage of air

Motor: Drives the engine (compressor)

Fig 6



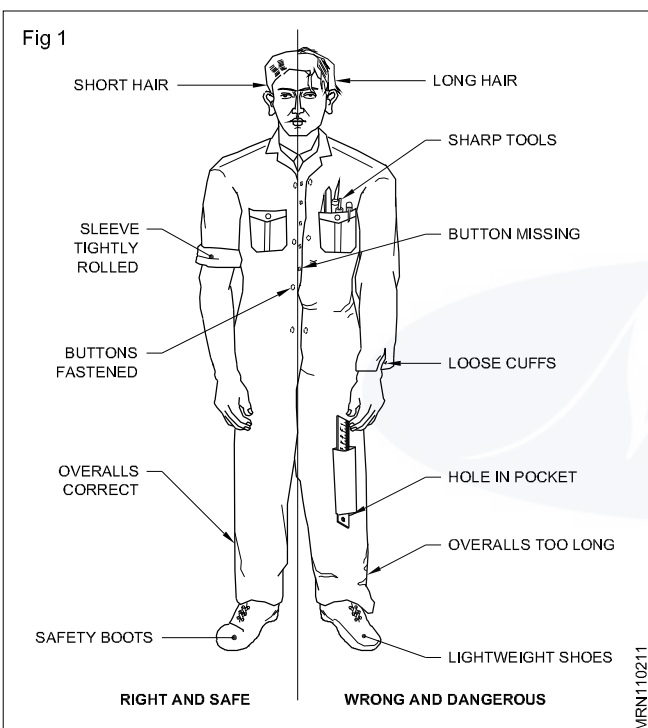
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Safety & Guidelines for good shop floor maintenance

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

- **state the importance of safety**
- **list out and explain the safety precautions to be observed in a work shop**
- **list the benefits of a shop floor maintenance**
- **state what is 5S**
- **list the benefits of 5S.**

Generally accidents do not happen; they are caused. Most accidents are avoidable. A good craftsman, having a knowledge of various safety precautions, can avoid accidents to himself and to his fellow workers and protect the equipment from any damage. To achieve this, it is essential that every person should follow safety procedure. (Fig 1)



Safety in a workshop can be broadly classified into 3 categories.

- General safety
- Personal safety
- Machine safety

General safety

- 1 Keep the floor and gangways clean and clear.
- 2 Move with care in the workshop, do not run.
- 3 Don't leave the machine which is in motion.
- 4 Don't touch or handle any equipment/ machine unless authorised to do so.
- 5 Don't walk under suspended loads.
- 6 Don't cut practical jokes while on work.

- 7 Use the correct tools for the job.
- 8 Keep the tools at their proper place.
- 9 Wipe out split oil immediately.
- 10 Replace worn out or damaged tools immediately.
- 11 Never direct compressed air at yourself or at your co-worker.
- 12 Ensure adequate light in the workshop.
- 13 Clean the machine only when it is not in motion.
- 14 Sweep away the metal cuttings.
- 15 Know everything about the machine before you start it.

Personal safety

- 1 Wear a one piece overall or boiler suit.
- 2 Keep the overall buttons fastened.
- 3 Don't use ties and scarves.
- 4 Roll up the sleeves tightly above the elbow.
- 5 Wear safety shoes or boots or chain.
- 6 Cut the hair short.
- 7 Don't wear a ring, watch or chain.
- 8 Never lean on the machine.
- 9 Don't clean hands in the coolant fluid.
- 10 Don't remove guards when the machine is in motion.
- 11 Don't use cracked or chipped tools.
- 12 Don't start the machine until
 - the work piece is securely mounted
 - the feed machinery is in the neutral
 - the work area is clear.
- 13 Don't adjust clamps or holding devices while the machine is in motion.
- 14 Never touch the electrical equipment with wet hands.
- 15 Don't use any faulty electrical equipment.
- 16 Ensure that electrical connections are made by an authorised electrician only.
- 17 Concentrate on your work. Have a calm attitude.
- 18 Do things in a methodical way.

- 19 Don't engage yourself in conversation with others while concentrating on your job.
- 20 Don't distract the attention of others.
- 21 Don't try to stop a running machine with hands.

Machine safety

- 1 Switch off the machine immediately if something goes wrong.
- 2 Keep the machine clean.
- 3 Replace any worn out or damaged accessories, holding devices, nuts, bolts etc as soon as possible.
- 4 Do not attempt operating the machine until you know how to operate it properly.
- 5 Do not adjust tool or the work piece unless the power is off.
- 6 Stop the machine before changing the speed.
- 7 Disengage the automatic feeds before switching off.
- 8 Check the oil level before starting the machine.
- 9 Never start a machine unless all the safety guards are in position.
- 10 Take measurements only after stopping the machine.
- 11 Use wooden planks over the bed while loading and unloading heavy jobs.
- 12 Safety is a concept, understand it. Safety is a habit, cultivate it.

Benefits of a shop floor maintenance

Some of the benefits which may be derived from the utilization of a good Shop Floor Maintenance are as follows:

- Improved Productivity
- Improved operator efficiencies.
- Improved support operations such as replenishment moves and transportation of work in process and finished goods.
- Reduction of scrap
- Better control of your manufacturing process
- More timely information to assist shop floor supervisors in managing their assigned production responsibilities.

- Reduction of down time due to better machine and tool monitoring.
- Better control of Work In Progress inventory, what is and where it is improved on time schedule performance.

5S Concept

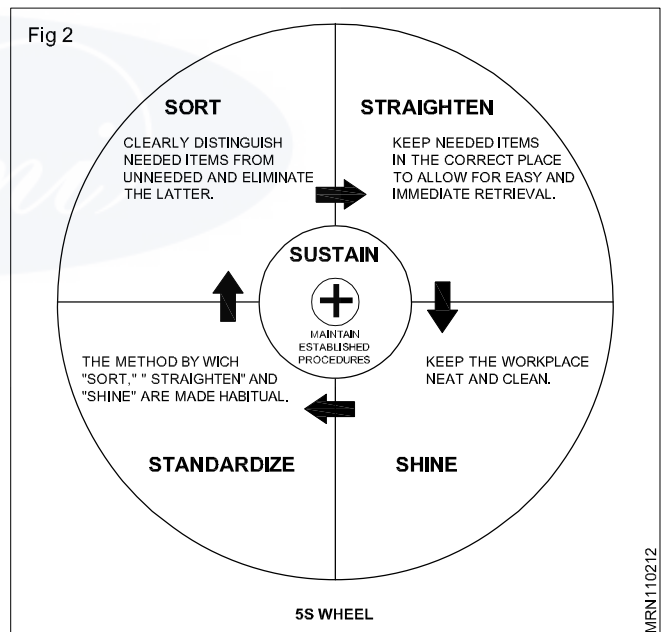
5S is a Japanese methodology for works place organisation. In Japanese it stands for

- 1 **Seiri (SORT),**
- 2 **Seiton (SET)**
- 3 **Seiso (SHINE)**
- 4 **Seiketsu (STANDARDIZE)**
- 5 **Shitsuke (SUSTAIN).**

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

The Benefits of the 5s system

- Increases in productivity
- Increases in quality
- Reduction in cost



Safety practice - fire extinguishers

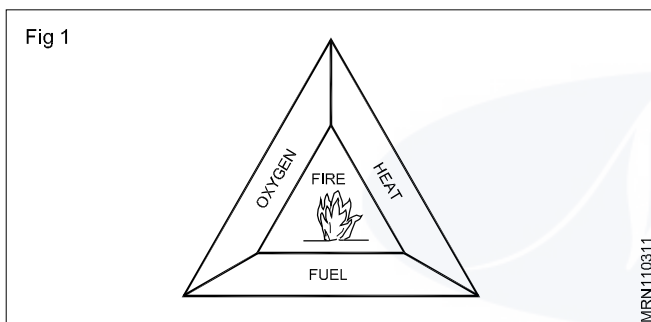
Objectives: At the end of this lesson you shall be able to

- state the effects of a fire breakout
- state the conditions required for combustion relevant to fire prevention
- state the general precautionary measures to be taken for fire prevention
- distinguish different types of fire extinguishers
- determine the correct type of fire extinguisher to be used based on the class of fire
- describe the general procedure to be adopted in the event of a fire.

Fire is the burning of combustible material. A fire in an unwanted place and on an unwanted occasion and in uncontrollable quantity can cause damage or destroy property and materials.

Fires injure people, and sometimes, cause loss of life. Hence, every effort must be made to prevent fire. When a fire outbreak is discovered, it must be controlled and extinguished by immediate correct action.

Is it possible to prevent fire? Yes, by eliminating anyone of the three factors that cause fire. (Fig 1)



The factors that must be present in combination for a fire to continue to burn are as follows.

Fuel	Any substance, liquid, solid, or gas will burn if given oxygen and high enough temperature.
Heat	Every fuel will begin to burn at a certain temperature. Solids and liquids give off vapour when heated and it is this vapour which ignites. Some liquids give off vapour even at normal room temperature say 15°C, eg. petrol.
Oxygen	Usually it exists in sufficient quantity in air to keep a fire burning.

EXTINGUISHING OF FIRES

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

- Starving the fire of fuel by removing the fuel in the vicinity of fire.
- Smothering - i.e. by isolating the fire from the supply of oxygen by blanketing it with foam, sand etc.
- Cooling - i.e. by using water to lower the temperature..

Preventing fires

Most of the fires could be prevented with more care and by following some rules of simple common sense.

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

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

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

Highly flammable liquids and petroleum mixtures (Thinner, Adhesive solutions, Solvents, Kerosene, Spirit, LPG Gas etc.) should be stored in a separate place called the flammable material storage area.

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

Classification of fires and recommended extinguishing agents.

Fires are classified into four types in terms of the nature of fuel.

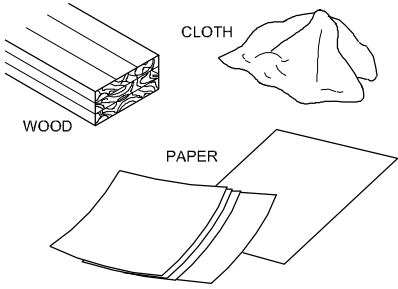
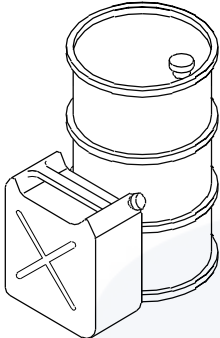
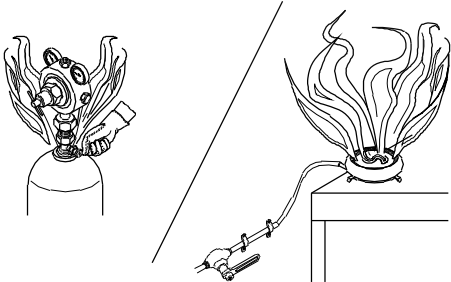
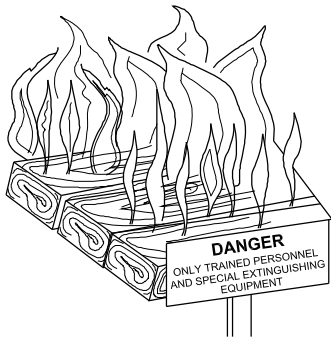
- Class A Fire
- Class B Fire
- Class C Fire
- Class D Fire

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

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

It is important to know the right type of agent for a particular type of fire; using the wrong one can make things worse.

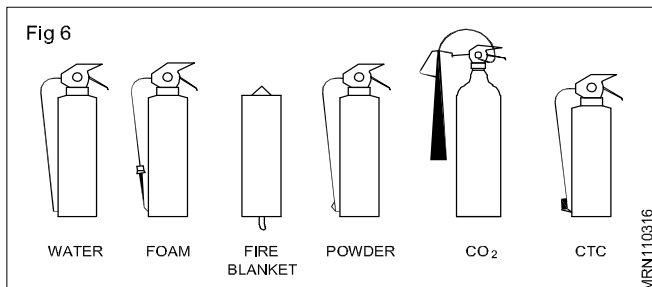
There is no classification for 'electrical fires' as such, since these are only fires in materials where electricity is present.

Fuel	Extinguishing
CLASS 'A' Fire Wood, paper, cloth etc. Solid materials. 	Most effective i.e. cooling with water. Jets of water should be sprayed on the base of the fire and then gradually upwards.
CLASS 'B' Fire Flammable liquids & liquifiable solids 	Should be smothered. The aim is to cover the entire surface of the burning liquid. This has the effect of cutting off the supply of oxygen to the fire. Water should never be used on burning liquids. Foam, dry powder or CO₂ may be used on this type of fire.
CLASS 'C' Fire Gas and liquified gas 	Extreme caution is necessary in dealing with liquified gases. There is a risk of explosion and sudden spreading of fire in the entire vicinity. If an appliance fed from a cylinder catches fire - shut off the supply of gas. The safest course is to raise an alarm and leave the fire to be dealt with by trained personnel. Dry powder extinguishers are used on this type of fire. Special powders have now been developed which are capable of controlling and/ or extinguishing this type of fire.
CLASS 'D' Fire Involving metals 	The standard range of fire extinguishing agents is inadequate or dangerous when dealing with metal fires. Fire on electrical equipment. Carbon dioxide, dry powder and vapourising liquid (CTC) extinguishers can be used to deal with fires in electrical equipment. Foam or liquid (e.g. Water) extinguishers must not be used on electrical equipment under any circumstances.

Types of fire extinguishers

A fire extinguisher, flame extinguisher or simply extinguisher is an active fire protection device used to extinguish or control small fires, often in emergency situation. It is not intended for use on an out of control fire.

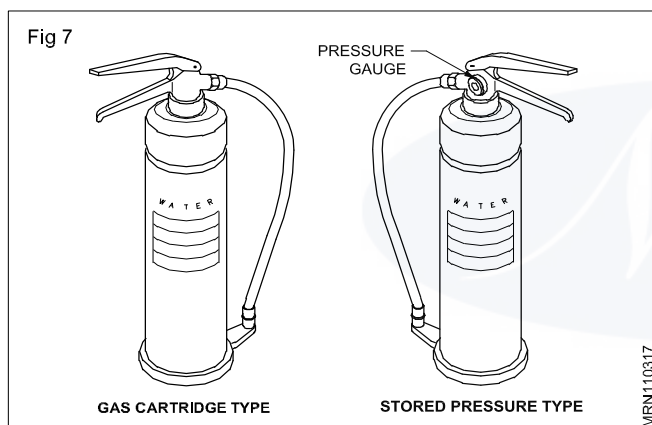
Many types of fire extinguishers are available with different extinguishing 'agents' to deal with different classes of fires. (Fig 6)



Water-filled extinguishers

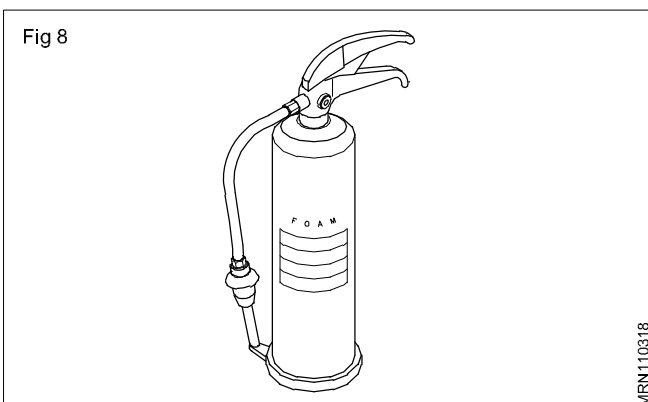
There are two methods of operation. (Fig 7)

- Gas cartridge type
- Stored pressure type



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

Foam extinguishers (Fig 8)



These may be of stored pressure or gas cartridge types.

Always check the operating instructions on the extinguisher before use.

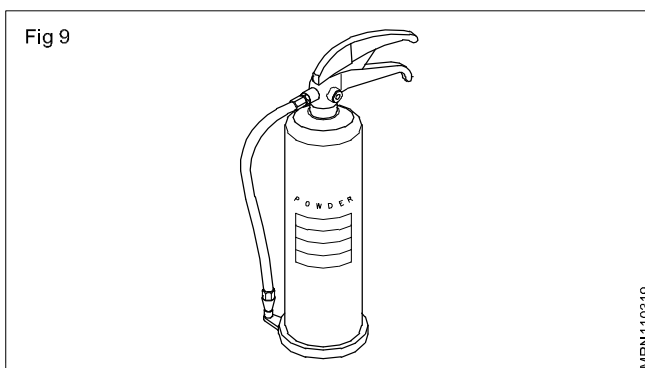
Foam extinguishers are most suitable for:

- flammable liquid fires
- running liquid fires

Must not be used where electrical equipment is involved.

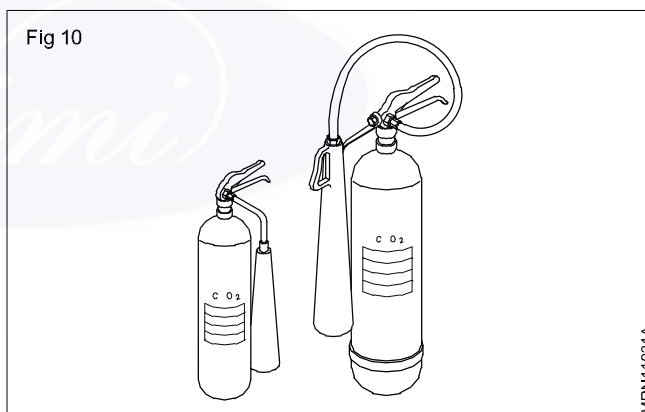
Dry powder extinguishers (Fig 9)

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



Carbon dioxide (CO₂)

This type is easily distinguished by the distinctively shaped discharge horn. (Fig 10)



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

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

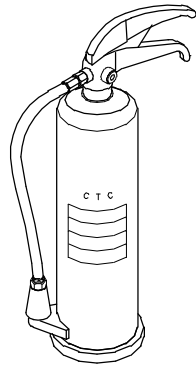
Halon extinguishers (Fig 11)

These extinguishers may be filled with carbon tetrachloride and bromochlorodifluoromethane (BCF). They may be of either gas cartridge or stored pressure type.

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

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

Fig 11



MRN11031B

General procedure to be adopted in the event of a fire to be adopted.

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



Personal Protective Equipment (PPE)

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

- state what is personal protective equipment and its purpose
- list the conditions for selection of personal protective equipment
- define safety
- state the goal of occupational health and safety
- explain need of occupational health and safety
- state the occupational hygiene
- explain occupational hazards.

Personal Protective Equipment (PPE)

Devices, equipments, or clothing used or worn by the employees, as a last resort, to protect against hazards in the workplace. The primary approach in any safety effort is that the hazard to the workmen should be eliminated or the workmen through the use of personal protective controlled by engineering methods rather than protecting the workmen through the use of personal protective equipment (PPE). Engineering methods could include design change, substitution ventilation, mechanical handling, automation, etc. in situations where it is not possible to introduce any effective engineering methods for controlling hazards, the workman shall use appropriate types of PPE.

As changing times have modernized the workplace, government and advocacy groups have brought more safety standards to all sorts of work environments. The Factories Act, 1948 and several other labour legislations 1996 have provisions for effective use of appropriate types of PPE. Use of PPE is very important.

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

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

- Inspection of gear thoroughly to make sure that it has the standard of quality and adequately protect the user should be continuously carried out.

Categories of PPE-Small's

Depending upon the nature of hazard, the PPE is broadly divided into the following two categories.

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

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

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

The guidelines on 'Personal Protective Equipment' is issued to facilitate the plant management in maintaining an effective programme with respect to protection of persons against hazards, which cannot be eliminated or controlled by engineering methods listed in table 1.

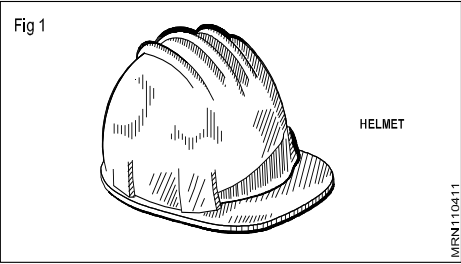
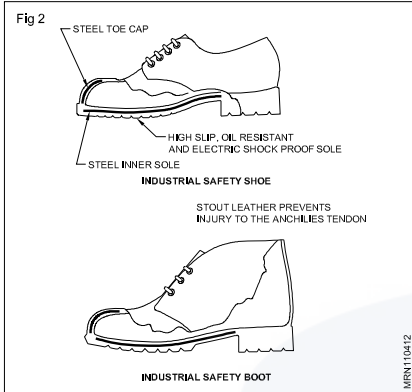
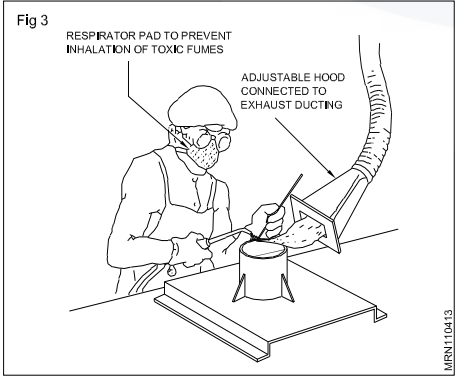
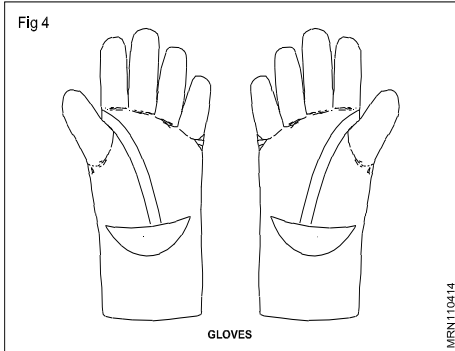
Quality of PPE's

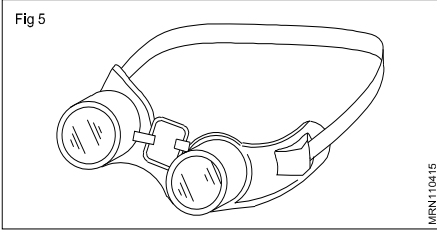
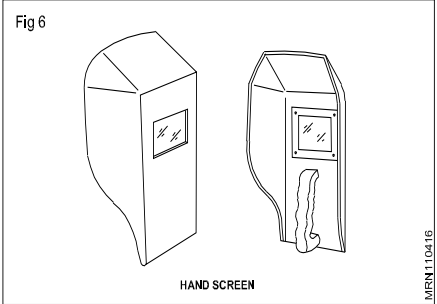
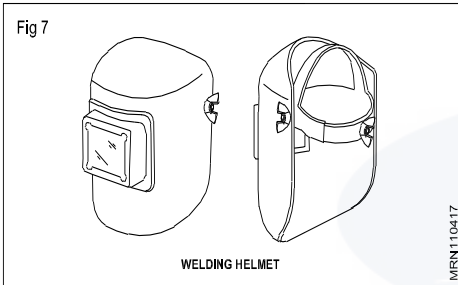
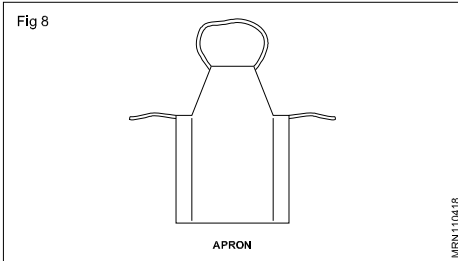
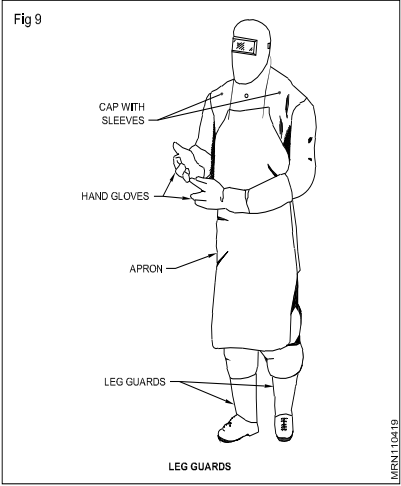
PPE must meet the following criteria with regard to its quality-provide absolute full protection against possible hazard and PPE's be so designed and manufactured out of materials that it can withstand the hazards against which it is intended to be used.

Selection of PPE's requires certain conditions

- Nature and severity of the hazard
- Type of contaminant, its concentration and location of contaminated area with respect to the source of respirable air
- Expected activity of workman and duration of work, comfort of workman when using PPE
- Operating characteristics and limitation of PPE
- Easy of maintenance and cleaning
- Conformity to Indian / International standards and availability of test certificate.

Personal protective equipments and their uses and hazards are listed in Table 2

Types of protection	Hazards	PPE to be used
Head protection (Fig 1) 	1. Falling objects 2. Striking against objects 3. Spatter	Helmets
Foot protection (Fig 2) 	1. Hot spatter 2. Falling objects 3. Working wet area	Leather leg guards Safety shoes Gum boots
Nose Protection (Fig 3) 	1. Dust particles 2. Fumes/gases/ vapours	Nose mask
Hand Protection (Fig 4) 	1. Heat burn due to direct contact 2. Blows spark moderate heat 3. Electric shock	Hand gloves

Types of protection	Hazards	PPE to be used
Eye protection (Fig 5 & Fig 6) Fig 5  Fig 6  HAND SHIELD	1. Flying dust particles 2. UV rays, IR rays heat and High amount of visible	Goggles Face shield radiation Hand shield Head shield
Face protection (Fig 7) Fig 7  WELDING HELMET	1. Spark generated during Welding, grinding 2. Welding spatter striking 3. Face protection from UV rays	Face shield Head shield with or without ear muff Helmets with welders Screen for welders
Ear protection (Fig 7)  Ear muffs Ear plug	1. High noise level	Ear plug
Body protection (Fig 8, & Fig 9) Fig 8  APRON	1. Hot particles Fig 9  CAP WITH SLEEVES HAND GLOVES APRON LEG GUARDS LEG GUARDS	Leather aprons

Proper use of PPEs

Having selected the proper type of PPE, it is essential that the workman wears it. Often the workman avoids using PPE. The following factors influence the solution to this problem.

- The extent to which the workman understands the necessity of using PPE
- The ease and comfort with which PPE can be worn with least interference in normal work procedures
- The available economic, social and disciplinary sanctions which can be used to influence the attitude of the workman
- The best solution to this problem is to make wearing of PPE mandatory for every employee.
- In other places, education and supervision need to be intensified. When a group of workmen are issued PPE for the first time.

Occupational health and safety

Safety

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

Occupational health and safety

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

Need of occupational health and safety

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

Occupational (Industrial) hygiene

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

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

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

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

Control of workplace hazards: Measures like Engineering and Administrative controls, medical examination use of Personal Protective Equipment (PPE) education, training and supervision.

Occupational hazards

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

Types of occupational health hazards

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

1 Physical hazards

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

2 Chemical hazards

- Inflammable
- Explosive
- Toxic
- Corrosive
- Radioactive

3 Biological hazards

- Bacteria
- Virus
- Fungi
- Plant pest
- Infection

4 Physiological

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

5 Psychological

- Wrong attitude
- Smoking
- Alcoholism
- Unskilled
- Poor discipline
 - absentism
 - disobedience
 - aggressive behaviour
- Accident proneness etc,
- Emotional disturbances

- violence
- bullying
- sexual harassment

6 Mechanical

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

7 Electrical

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

8 Ergonomic

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

Safety Slogan

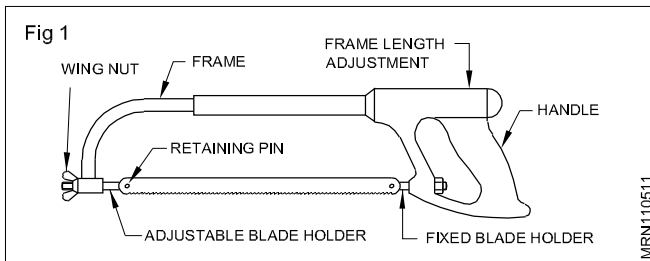
A safety rule breaker, is an accident maker

Hach sawing of precision measuring instruments

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

- name the parts of a hand hacksaw frame
- specify hand hacksaw blades
- list and explain the various fitting hand tools.

The hand hacksaw is used along with a blade to cut metals of different sections. It is also used to cut slots and contours. See Fig 1 to identify the parts.



Types of hacksaw frames

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

1 Solid frame

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

2 Adjustable frame (flat type)

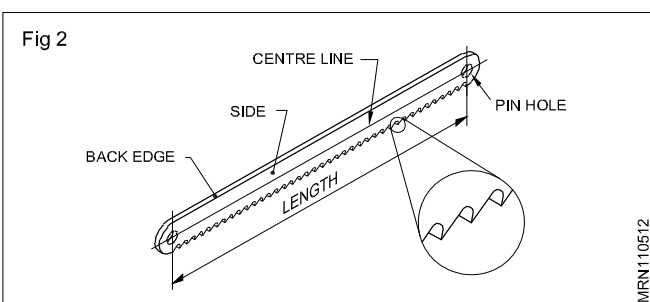
Different standard lengths of blades can be fitted to this frame.

3 Adjustable frame (tubular type)

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

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

b Hacksaw Blades (Fig 2)



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

Types of hacksaw blades

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

1 All hard blades

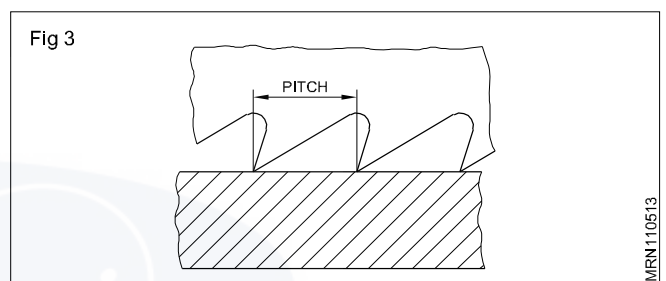
These are hardened to the full length between the pin holes.

2 Flexible blades

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

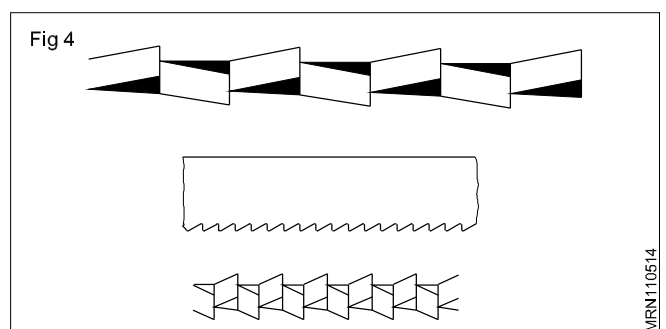
Pitch of the blade (Fig 3)

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



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

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

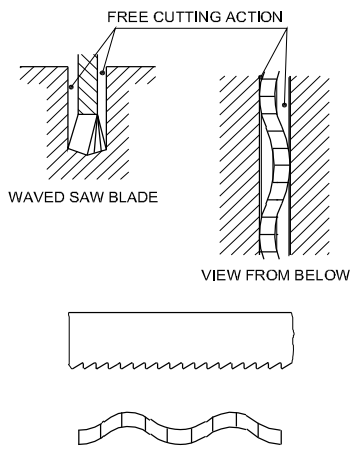


Classification of sets

Pitch	0.8mm	-	wave set.
Pitch	1.0mm	-	wave or staggered.
Pitch over	1.0mm	-	staggered.

For satisfactory results a blade of the correct pitch should be selected and fitted correctly.

Fig 5

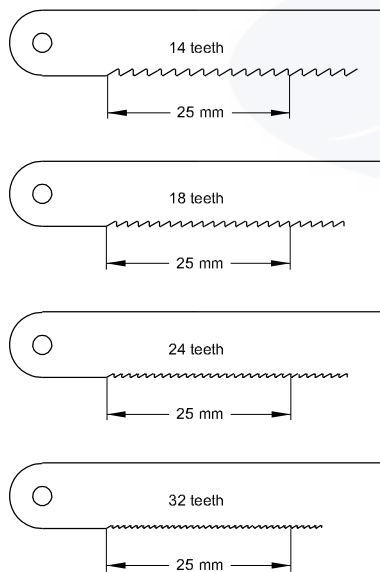


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Saw blades for hacksaws are available with small and large cutting of teeth, depending on the type and size of material they are to cut. The size of the teeth is directly related to their pitch, which is specified by the number of teeth per 25mm of the cutting edge. Hacksaw blades are available in pitches of: (Fig 6)

- 14 teeth per 25 mm
- 18 teeth per 25 mm
- 24 teeth per 25 mm
- 32 teeth per 25 mm.

Fig 6



MRN110516

Fitting hand tools

1 Screwdriver

A screwdriver is a tool, manual or powered, for screwing and unscrewing (inserting and removing) screws. A typical simple screwdriver has a handle and a shaft, ending in a tip the user puts into the screw head before turning the handle. The shaft is usually made of tough steel to resist bending or twisting. The tip may be hardened to resist wear, treated with a dark tip coating for improved visual contrast between tip and screw or ridged or treated for additional 'grip'. Handles are typically wood, metal, or plastic⁽¹⁾ and usually hexagonal, square, or oval in cross-section to improve grip

and prevent the tool from rolling when set down. Some manual screwdrivers have interchangeable tips that fit into a socket on the end of the shaft and are held in mechanically or magnetically. These often have a hollow handle that contains various types and sizes of tips, and a reversible ratchet action that allows multiple full turns without repositioning the tip or the user's hand.

A screwdriver is classified by its tip, which is shaped to fit the driving surfaces-slots, grooves, recesses, etc. - on the corresponding screw head. The two most common are the simple 'blade'-type for slotted screws, and phillips, generically called "cross-recess".

2 Pliers

Pliers are a hand tool used to hold objects firmly, possibly developed from tongs used to handle hot metal in Bronze Age Europe⁽¹⁾. They are also useful for bending and compressing a wide range of materials. Generally, pliers consist of a pair of metal first-class levers joined at a fulcrum positioned closer to one end of the levers, creating short jaws on one side of the fulcrum, and longer handled on the other side. The jaws can also be used to manipulate objects too small or unwidely to be manipulated with the fingers.

3 Ball-peen hammer

A ball-peen hammer, also known as a machinist's hammer, is a type of peening hammer used in metal working having a hemispherical head.

4 Scriber

A scriber is a hand tool used in metal working to mark lines on work pieces, prior to machining. The process of using a scriber is called scribing and is just part of the process of marking out. It is used instead of pencils or ink lines, because the marks are hard to see, easily erased, and inaccurate due to their wide mark; scribe lines are thin and semi-permanent. On non-coated work pieces marking blues is commonly used to increase the contrast of the mark lines

They are a rod with a tip made of cast steel that has been hardened and tempered. The point is sharpened to an angle of 30 or 40 degrees. Some scribers have a point at both ends. It is used by drawing the point over the surfaces of the work piece to leave a shallow scratch on its surface.

5 Engineers steel rule

An engineer's scale is a tool for measuring distance and transferring measurements at a fixed ratio of length. Its units is expressed in mm, Cm and Inch. The least count is 0.05 mm.

6 Chisel

A chisel is a tool with a characteristically shaped cutting edge (such that wood chisels have lent part of their name to a particular grind) of blade on its end, for carving or cutting a hard material such as wood, stone, or metal by hand, struck with a mallet, or mechanical power. The handle and blade of some types of chisel are made of metal or of wood with a sharp edge in it.

Chiselling use involves forcing the blade into some material to cut it. The driving force may be applied by pushing by hand, or by using a mallet or hammer. In industrial use, a hydraulic ram or falling weight ('trip hammer') may be used to driver a chisel into the material.

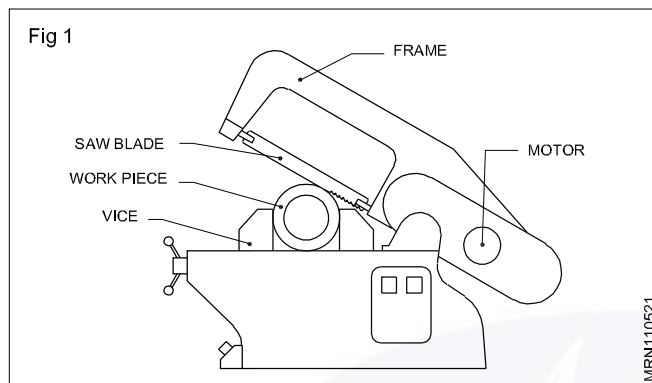
Metal-cutting saws

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

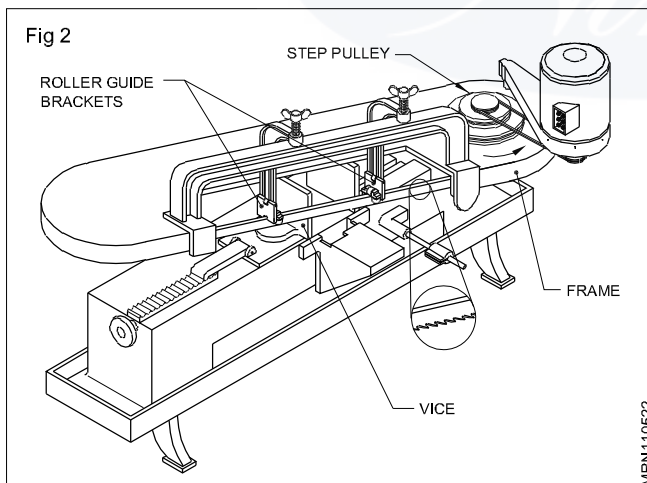
- name the common types of metal-cutting saws
- state the features of different types of cutting saws.

Metal-cutting saws of different types are used in industries. The most commonly used are the:

- 1 **Power saw** (Fig 1): This is the most commonly used metal-cutting saw.



- 2 **Horizontal band-saw** (Fig 2): This has a saw frame on which a motor is fitted.



There are two pulley wheels on which an endless band-saw passes.

Speed variation is obtained through the stepped pulleys on the motor.

The roller-guide brackets provide the rigidity for the blade in the cutting area and also prevent wandering of the blade while cutting.

The blade tension is maintained by using the adjusting handle, provided for this purpose.

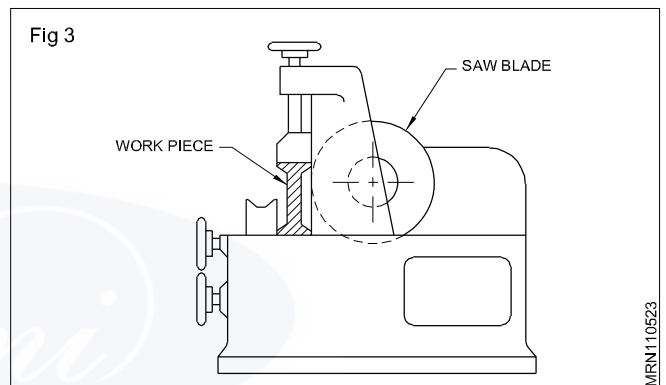
A vice is provided for holding the metal stocks. The vice is adjustable for angular cutting. This machine has the

Grinding machine

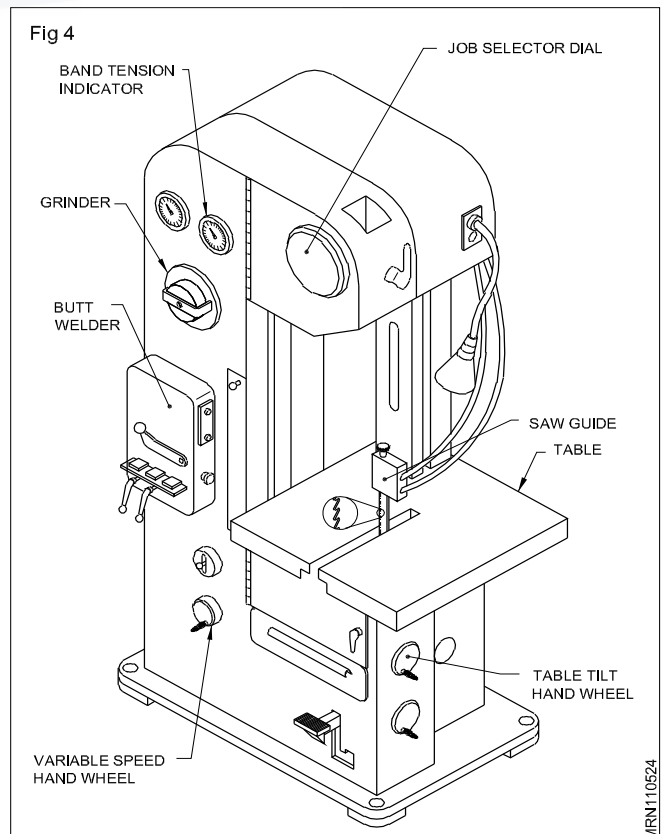
A grinding machine, often shortened to grinder, is any of various power tools or machine tools used for grinding, which is a type of machining using an abrasive wheel as the cutting tool. Each grain of abrasive on the wheel's surface cuts a small chip from the work piece via shear deformation.

advantage of continuous cutting ability, and is much faster than a power saw. It may be noted that a power saw cuts only in every alternate stroke.

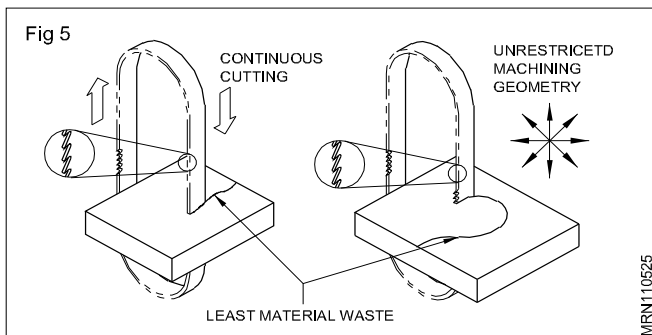
Circular saw (Fig 3): This type of cutting machine is used when cutting materials have a large cross-section. The circular saw has a continuous cutting action and is economical in production work where heavy section metals are used.



- 3 **Contour saw** (Fig 4)



In this, a metal band saw blade is used, and the contour saw has a continuous cutting motion. (Fig 5)



These machines are very much used for cutting metals to different profiles. (Fig 6)

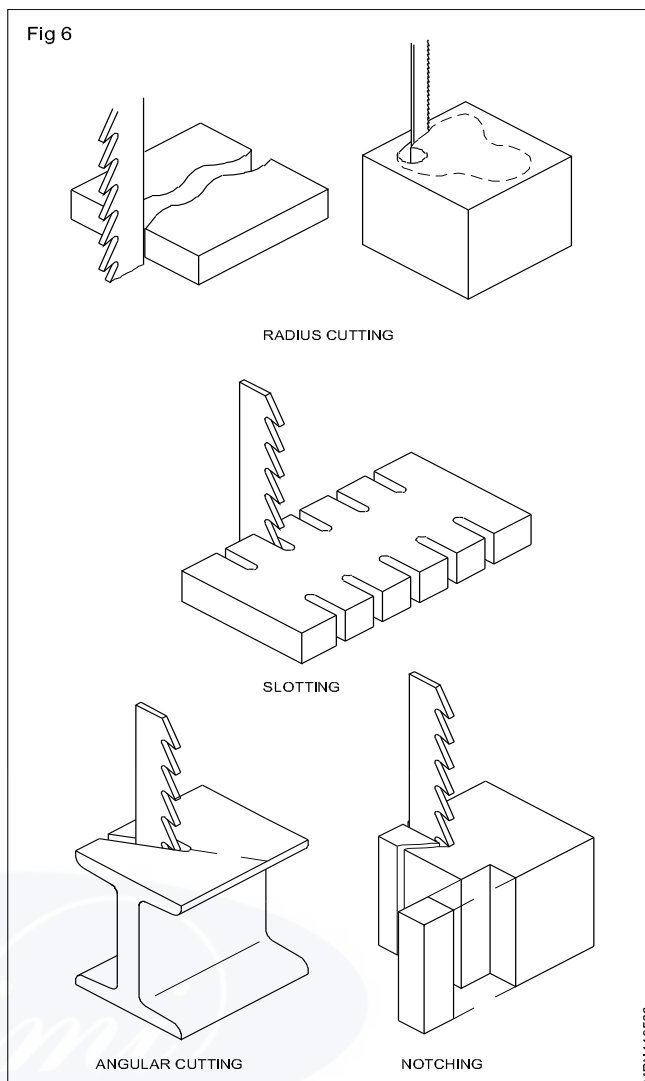
Different speeds can be obtained while cutting, with the help of variable speed pulleys.

For repairing broken contour saw blades, these machines are fitted with a shear for trimming the blade ends, a butt-welding machine for joining the ends and the small grinder to finish the welded joint.

The table can be tilted to any angle for angular cutting.

The blade passes through a guide which prevents the blades from wandering and keeps it rigidly.

These machines are widely used for tool-room work, and not as a machine for cutting raw material stock.



Power hacksaw

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

- state the features of a power hacksaw
- state the features of a power hacksaw blade
- state the features of clamping arrangement
- explain fixing of power saw blades
- state the precautions to be observed while machinist sawing.

Cut-off saws are used to cut metal stock roughly to the required length. The commonly used cut-off saw in small scale industries is a POWER SAW.

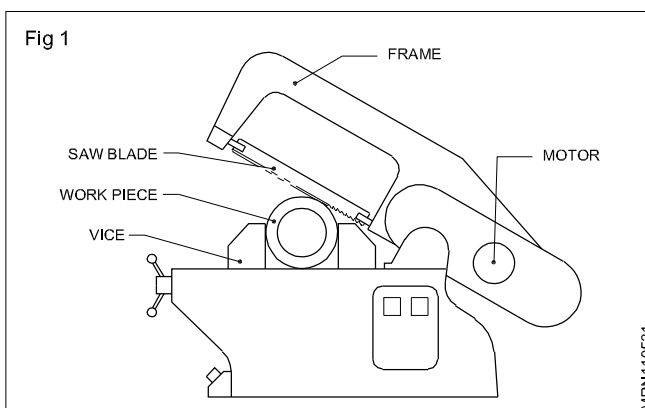
Features (Fig 1): The power saw works like a hand hacksaw, and has an arrangement for cutting during the movement in one direction and releasing pressure on the non-cutting stroke. The rotary motion of the motor is converted into linear motion by a crank mechanism.

The required cutting pressure is obtained hydraulically or by an adjustable weight.

During the non-cutting motion the blade will be lifted away from the work.

A clamping device/vice holds the work firmly.

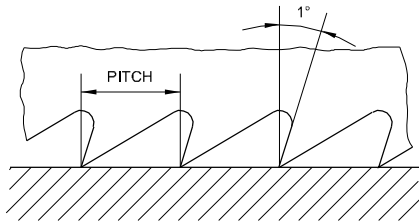
Power hacksaw blades: The saw blades are selected, depending on the machine and the type of work on hand.



The blades are made of Low alloy steel or H.S. Steel and are fully hardened.

For different materials, blades of different pitches are used (number of teeth per 25 mm length). (Fig 2)

Fig 2

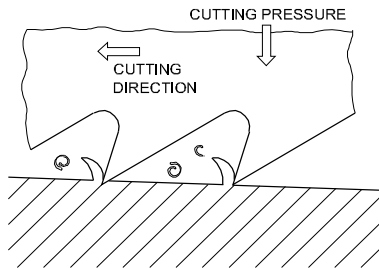


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As a general rule, the softer the material, the lesser is the number of teeth, per length of 25 mm.

Teeth with a large pitch can accommodate large chips. (Fig 3)

Fig 3



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Blades are available with varying coarseness i.e. between 4 to 14 teeth per 25 mm length.

Coarse pitch blades are also used while cutting large sections of stock, as this will help in greater chip clearance and increased penetration.

For cutting hard material (example - tool steel), and thin material, a 14 pitch blade is recommended.

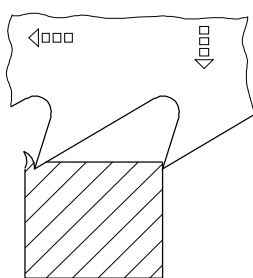
For general purpose sawing, a 10 pitch blade will be useful.

While selecting blades, make sure atleast two teeth of the blade will be in contact with the work at all times.

What will happen if less than two teeth are in contact with the work?

The work can be caught in the tooth gullet, and cause breakage to the blade. (Fig 4)

Fig 4



MRN110534

Blade clearance (Fig 5) : In order to avoid jamming of the teeth and to provide for chip clearance, the teeth of the saw blades are offset or waved.

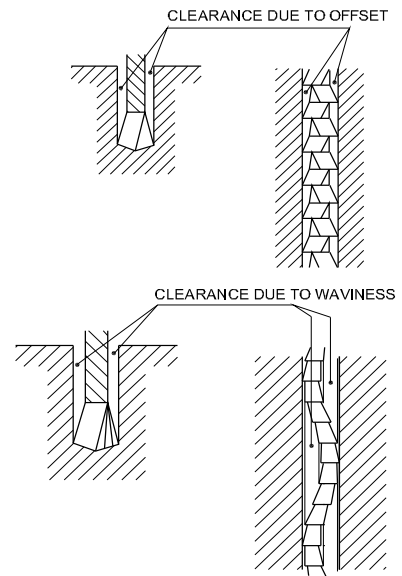
Specification of power hacksaw blades. (Fig 6)

While specifying power hacksaw blades, it is necessary to state:

- the length (the distance between centre of holes).

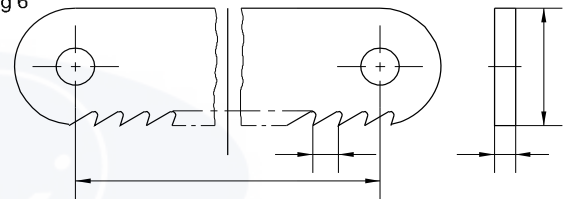
- the width
- the thickness and
- the teeth pitch.

Fig 5



MRN110535

Fig 6

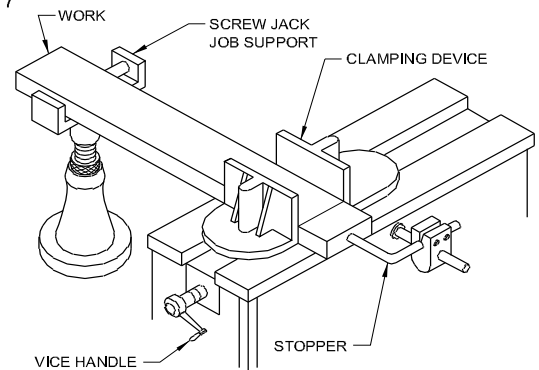


MRN110536

Clamping arrangement (Fig 7)

Power saws are provided with clamping devices similar to those in machine vices, and the work can be gripped by using the crank handle.

Fig 7



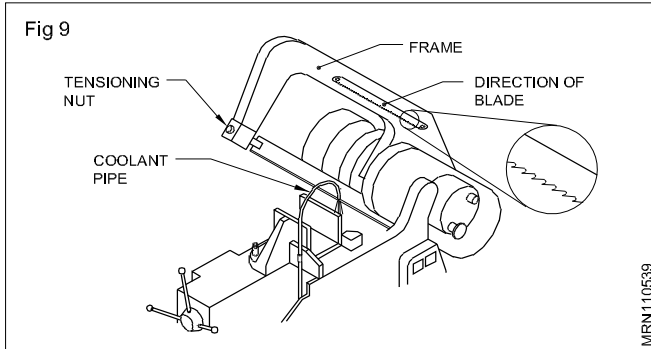
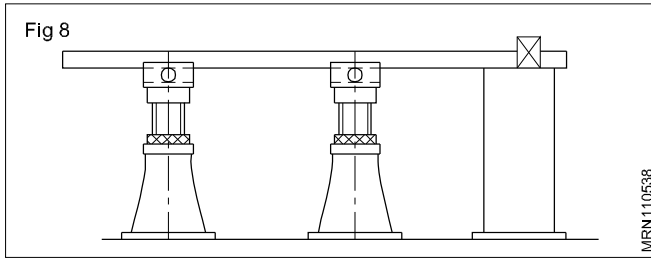
MRN110537

When a number of pieces of the same size are to be cut, an adjustable stop is used.

Long bars are supported, and the level maintained by the use of adjustable floor stands. (Fig 8)

Fixing blades (Fig 9): The blades are mounted on frames using screws.

The teeth of the blade should point towards correct directions. (Depending on the type of machine the blade cuts either on the forward or on the return stroke).



It is necessary to follow the directions given by the manufacturers as indicated in the frame.

Tension the blade using the tensioning device.

Precautions while machine-sawing

In order to work safely and efficiently, certain precautions are to be observed.

While taking measurements of the work for setting, always stop the machine.

Projecting ends of the work should be well guarded, so that safety may be provided to others.

Ensure that the work does not protrude into the gang-ways.

When sawing thin pieces, hold the material flat in the vice to prevent the saw teeth from breaking.

Ensure a cutting fluid is used always.

Avoid giving excessive cutting pressure, because this can cause breakage to the blade, and cut work out of square.

When several pieces of the same length are to be cut, use a stop gauge.

When holding short work pieces in a vice, be sure to place a short piece of the same thickness in the opposite end. This will prevent the vice from twisting when it is tight ended.

Vernier calipers

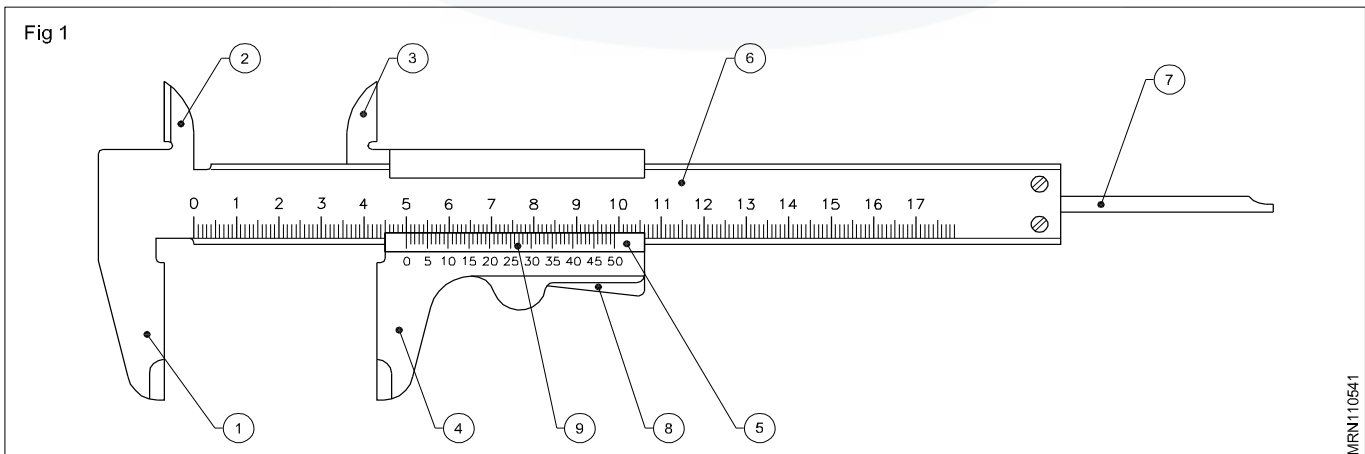
Objectives: At the end of this lesson you shall be able to

- state the constructional features of a vernier caliper
- determine the least count of vernier calipers
- state how graduations are made on vernier calipers with 0.02 mm least count.

A vernier caliper (Fig 1) is a precision measuring instrument. It is used to measure up to an accuracy of 0.02 mm.

Parts of a vernier caliper (Numbers as per Fig 1)

Fixed jaws (1 & 2)



Fixed jaws are part of the beam scale. One jaw is used for taking external measurements, and the other for internal measurements.

Movable jaws (3 & 4)

Movable jaws are part of the vernier slide. One jaw is used for external measurements, and the other for internal measurements. (Figs 2 & 3)

Vernier slide (5)

A vernier slide moves over the beam and can be set in any position by means of a spring-loaded thumb lever.

Beam (6)

The vernier slide, and the depth bar attached to it, slide over the beam. The graduations on the beam are called the main scale divisions.

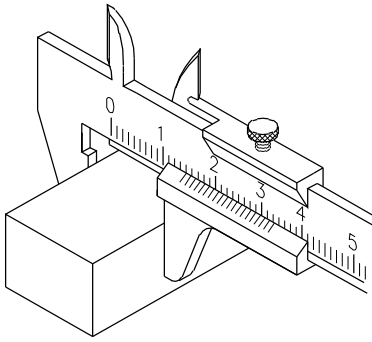
Depth bar (7)

The depth bar is attached to the vernier slide and is used for depth measurements. (Fig 4)

Thumb lever (8)

The thumb lever is a spring-loaded lever which helps to set the vernier slab in any position on the beam scale.

Fig 2



MRN110542

Graduations and reading of vernier calipers

Vernier calipers

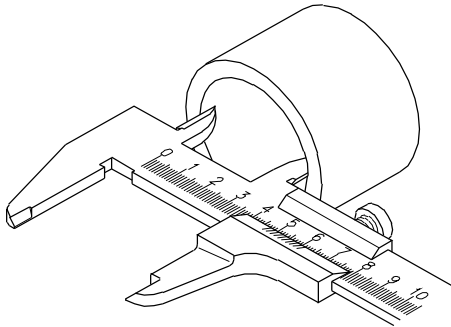
Vernier calipers are available with different accuracies. The selection of the vernier caliper depends on the accuracy needed and the size of the job to be measured.

This accuracy/least count is determined by the graduations of the main scale and the vernier scale divisions.

Determining least count of vernier calipers

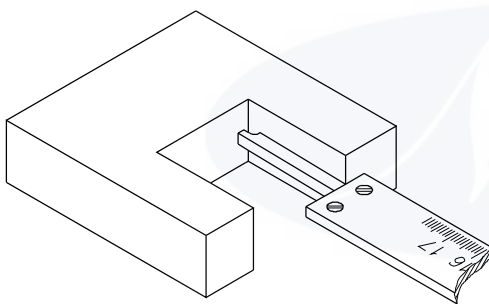
In the vernier caliper shown in Fig 1 the main scale division (9mm) are divided into 10 equal parts in the vernier scale.

Fig 3



MRN110543

Fig 4



MRN110544

Vernier scale (9)

The vernier scale is the graduations marked on the vernier slide. The divisions of this scale are called vernier divisions

Main scale (10)

Main scale graduations or divisions are marked on the beam.

SIZES

Vernier calipers are available in sizes of 150 mm, 225 mm, 900 mm and 1200 mm. The selection of the size depends on the measurements to be taken. Vernier calipers are precision instruments, and extreme care should be taken while handling them.

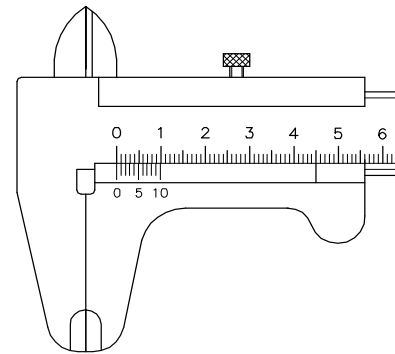
Never use a vernier caliper for any purpose other than measuring.

Vernier calipers should be used only to measure machined or filed surfaces.

They should never be mixed with any other tools.

Clean the instrument after use, and store it in a box.

Fig 5



MRN110545

i.e. One main scale division (MSD) = 1 mm

One vernier scale division (VSD) = $\frac{9}{10}$ mm

Least count is $1 \text{ mm} - \frac{9}{10} \text{ mm} = \frac{1}{10} \text{ mm}$

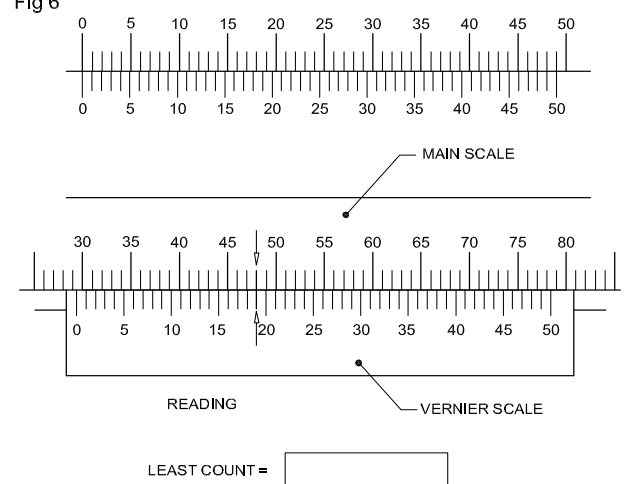
The difference between one MSD and one VSD = 0.1 mm)

Example : Calculate the least count of the vernier given in Fig 2.

Reading vernier measurements

Vernier calipers are available with different graduations and least counts. For reading measurements with a vernier caliper the least count should be determined first. (The least count of calipers is sometimes marked on the vernier slide.)

Fig 6

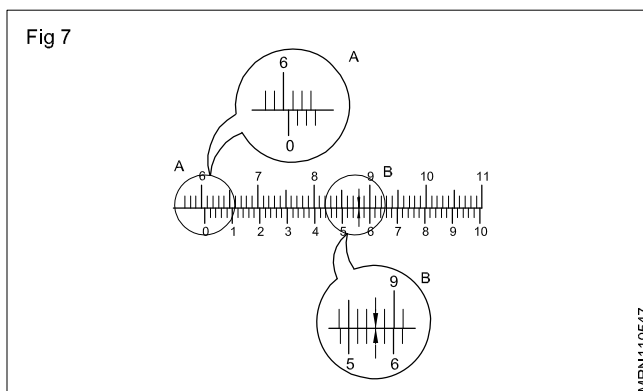


MRN110546

The figure above shows the graduations of a common type of vernier caliper with a least count of 0.02 mm.

In this, 50 divisions of the vernier scale occupy 49 divisions (49 mm) on the main scale.

Example for reading vernier caliper (Fig 3)



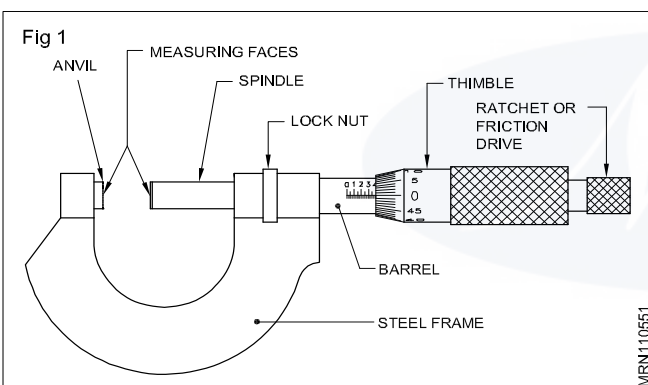
Outside micrometer

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

- state the **constructional features of an outside micrometer**
- read a micrometer, measurements.

An outside micrometer is a precision measuring instrument used to measure the thickness of sheets, plates and the outside diameters of round objects to an accuracy of ± 0.01 mm.

Important parts of an outside micrometer and their functions (Figs 1 & 2): The anvil and spindle ends are the two measuring faces.



On the barrel, a 25 mm long datum line is marked. This line is graduated to full millimetres and half millimetres.

Since the pitch of the spindle screw is 0.5 mm, with the thimble rotating once, the spindle advances by 0.5 mm.

The circumference of the bevelled edge of the thimble is graduated into 50 divisions.

Movement of one division of the barrel = 0.5 mm.

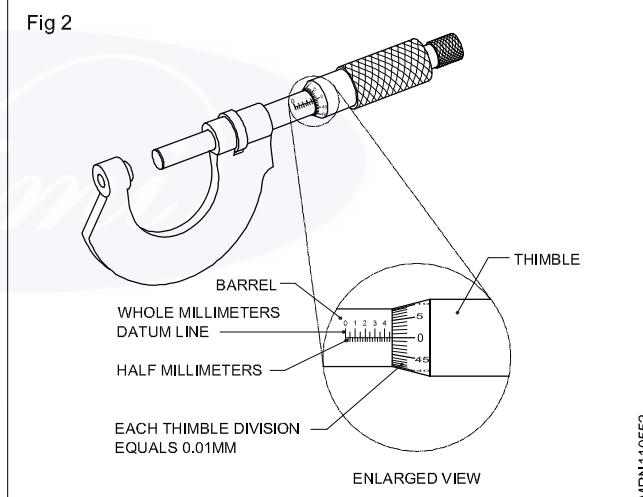
Movement of one division of the thimble

$$\frac{0.5 \times 1}{50} = 0.01$$

The ratchet stop ensures uniform pressure between the measuring surfaces.

A spindle lock is used to lock the spindle at any designed position.

Reading an outside micrometer (Figs 3 and 4): To read measurements with an outside micrometer, read the barrel graduations. Note the value of the visible lines on the left of the thimble edge.



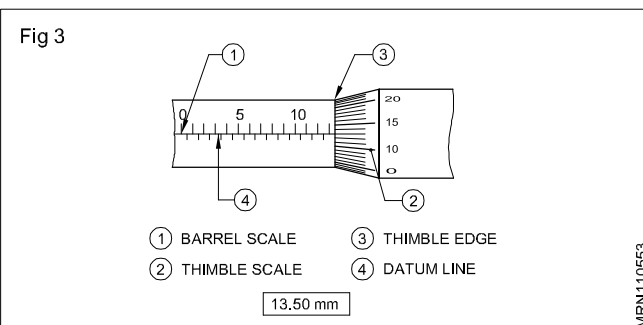
Multiply this value by 0.01 mm. $13 \times 0.01 = 0.13$ mm

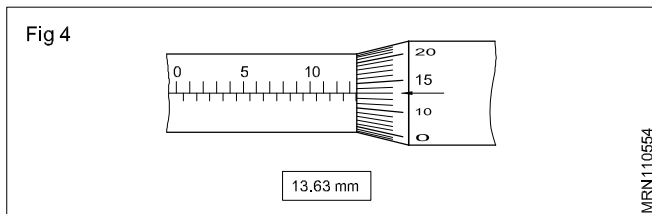
Add

barrel reading = 13.50

thimble reading = .13

Micrometer reading = 13.63 mm



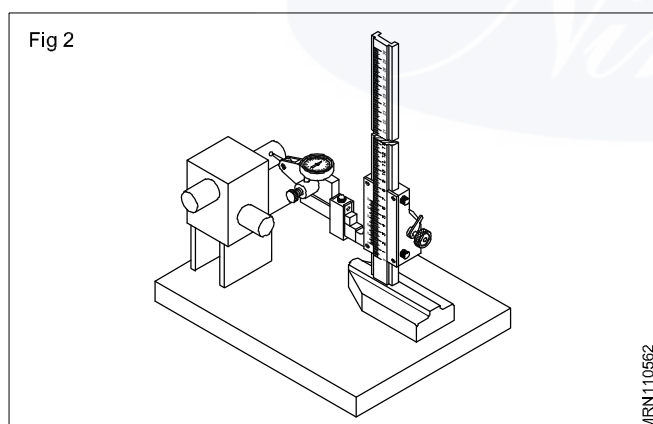
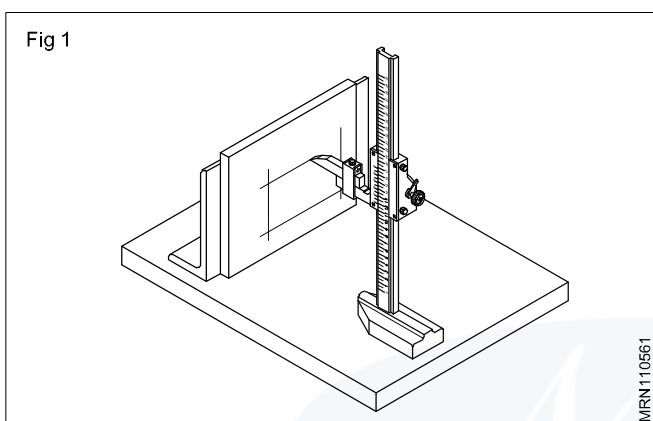


Vernier height gauge

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

- identify the parts of a vernier height gauge
- state the functions of each part.

Specific uses of a vernier height gauge: Accurate measurements are important in the layout (marking off) and in the inspection work. (Fig 1&2)



Vernier height gauges are particularly suitable for marking off accurate distances, and centre locations. The graduations and the readings are the same as those of a vernier caliper.

Parts and their function: Parts of a vernier height gauges and their functions are given here. (Fig 3)

Base (1): This is the datum from which measurements and settings are made. The underside of the base is hardened, ground and lapped.

Beam (2): This is similar to the beam scale of a vernier caliper and is attached to the base.

Vernier slide (3): This unit slides on the beam and carries the vernier plate (5) Locking screws (6), fine setting device (4) and scribe (7).

Some vernier height gauges are provided with a rack and pinion arrangement for moving the slide along the beam.

Vernier height gauges are provided with both straight and offside scribes. (Fig 4)

Zero setting of the vernier height gauge: The offset scribe permits the zero setting of the instrument from the datum surface.

While using a straight scribe, the zero setting of the instrument is at a level above the datum surface. In this case the zero setting is to be checked using the precision round block, supplied along with the instrument.

Vernier height gauges with which we can measure from the datum surface without the special off set scribes are also available. (Fig 3b)

The size of the vernier height gauge is stated by the height of the beam. The most commonly used size has a beam of 300 mm height. Vernier height gauges are used with the surface plates or other accurate flat surfaces.

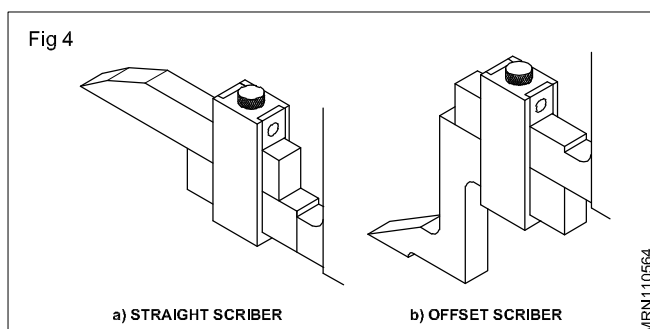
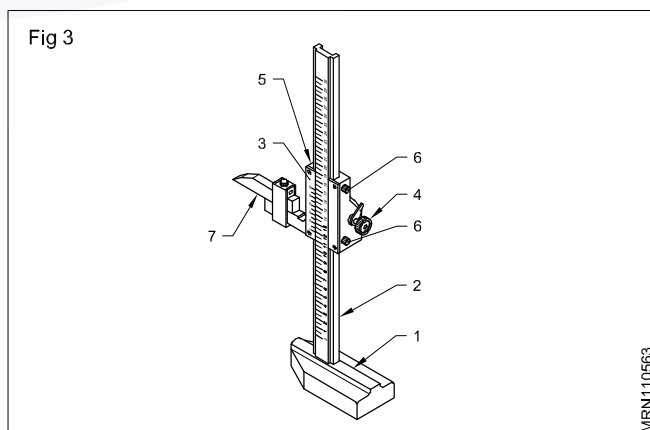
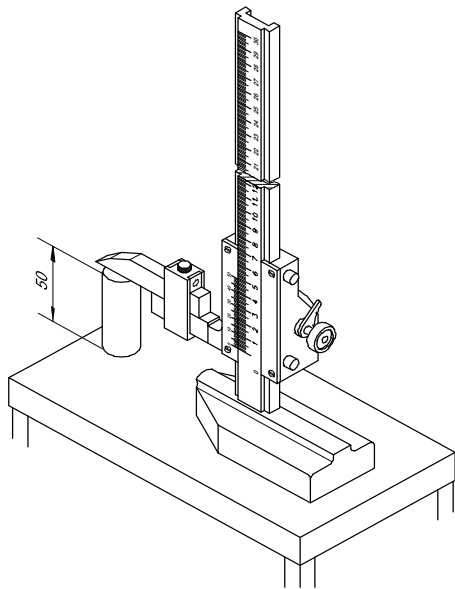


Fig 5



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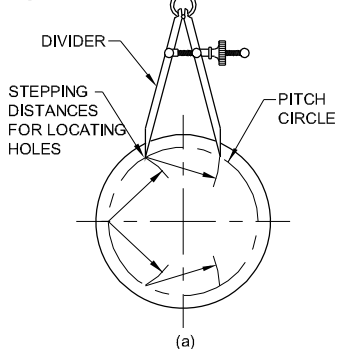
Dividers

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

- identify the parts of a divider
- state the uses of dividers
- state the specifications of dividers.

Dividers are used for scribing circles, arcs and transferring and stepping of distances. Dividers are available with firm joints and spring joints. The measurements are set on the dividers with a steel rule. (Fig 1a&b)

Fig 1



MRN110571

The sizes of dividers range between 50 mm to 200 mm. The distance from the point to the centre of the fulcrum roller (pivot) is the size of the divider. (Fig 2a)

For the correct location and seating of the divider legs, prick punch marks of 30° are used. (Fig 2b)

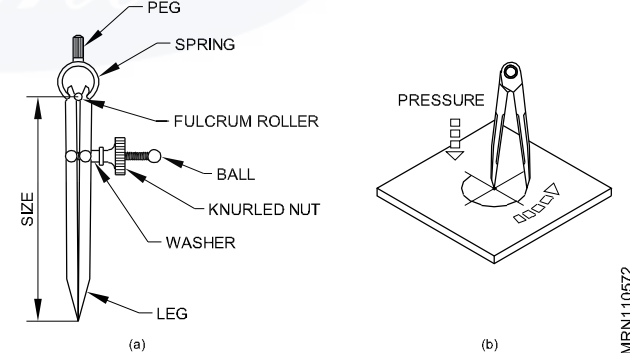
Both the legs of the divider should always be of equal length. (Fig 3)

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

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

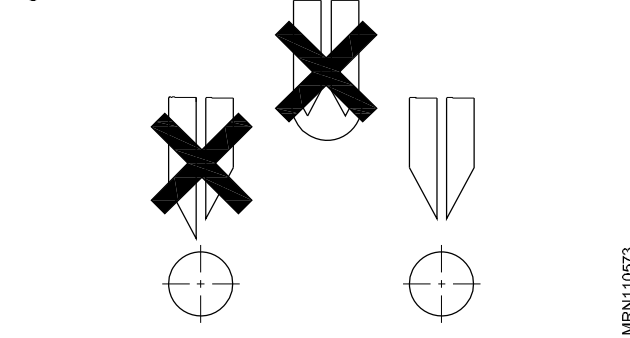
Do not sharpen the divider points on grinding wheels.

Fig 2



MRN110572

Fig 3



MRN110573

Radius gauges

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

- state the uses of radius gauges.

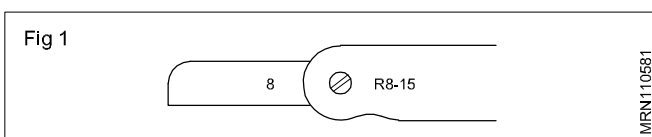
Radius gauges: Radius gauges are used to check the internal and external radius of work pieces.

These gauges are made of high quality steel sheets and are finished to accurate radius.

The radii of parts are checked by comparing the radius of the gauges.

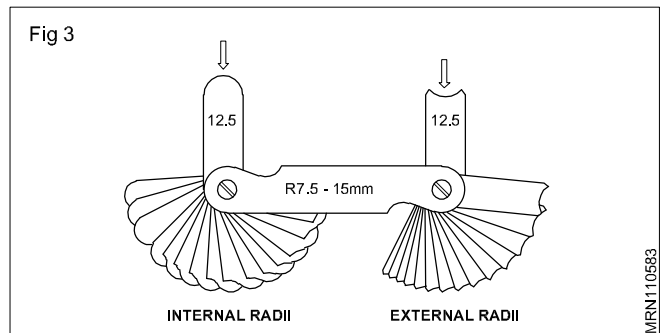
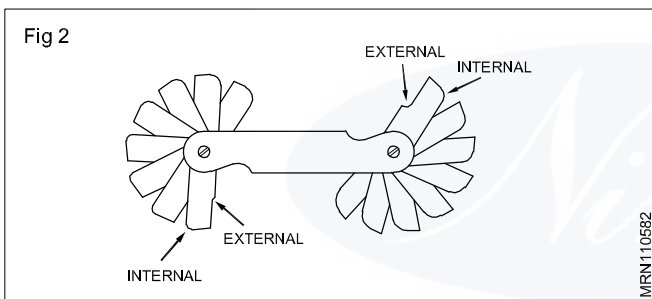
Radius gauges are available in sets of several blades held in a holder. Each blade can be separately pulled out of the holder when in use.

The size of the radius is marked on individual blades of the gauges. (Fig 1)



The radius gauges are available in different combinations.

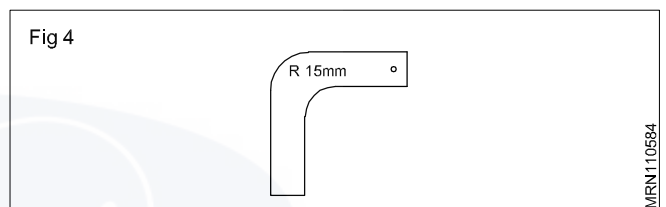
- Sets with internal and external radius. (Figs 2 & 3)



- Individual gauges for each radius. (Fig 4)

Before using radius gauges:

- ensure the gauges are perfectly clean
- remove burrs, if any, from the work piece
- check and make sure there is no damage to the profile of the gauge.



Filing surface gauge and marking punches

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

- state how files are specified
- state the different grades of files and its application
- state the different cuts of files and its application.

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

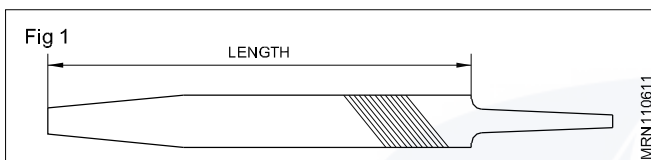
Files are specified according to their length, grade, cut and shape.

Length is the distance from the tip of a file to the heel.

File specification: Files are specified according to their

- length
- grade
- cut
- shape of cross section

Length is the distance from the tip to the heel. It may be 300mm, 250mm, 200mm, 150mm or 100mm. (Fig 1)



Grades of files

Rough, bastard, second cut, smooth and dead smooth are the different **grades** of files commonly available.

File grades are determined by the spacing of the teeth.

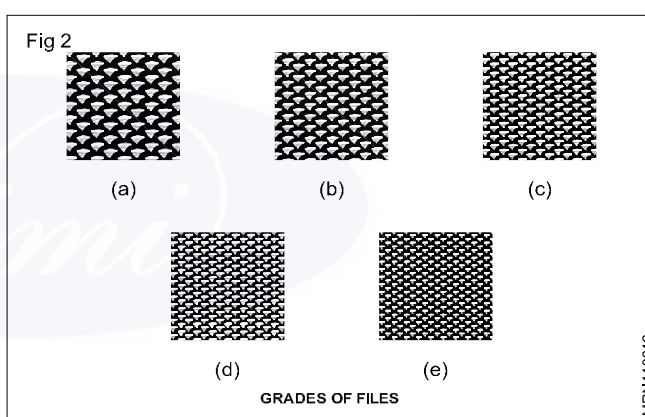
A **rough file** is used for removing rapidly a larger quantity of metal. It is mostly used for trimming the rough edges of soft metal castings.

A **bastard file** is used in cases where there is a heavy reduction of material.

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

A **smooth file** is used to remove small quantity of material and to give a good finish.

A **dead smooth file** is used to bring to accurate size with a high degree of finish.



Cut of files

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

- name the different cuts of files
- state the uses of each type of cut.

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

Types of cuts

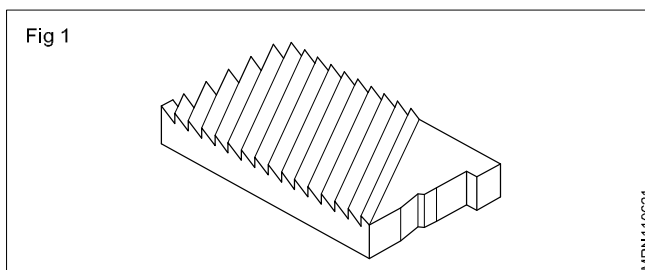
Basically there are four types.

Single cut, Double cut, Rasp cut and Curved cut.

The rows of a teeth determine the cut of a file.

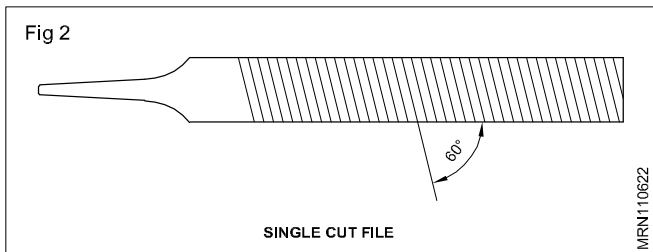
Single cut File (Fig 1)

A single cut file has rows of teeth cut in one direction across its face. The teeth are at an angle of 60° to the centre line. It can cut chips as wide as the cut of the file. Files with this cut are useful for filing soft metals like brass, aluminium, bronze and copper. Single cut files do not remove stock as fast as double cut files, but the surface finish obtained is much smoother.



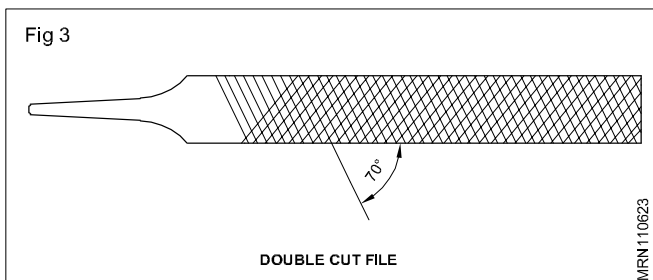
Double cut file (Fig 2)

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



Rasp cut file (Fig 3)

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

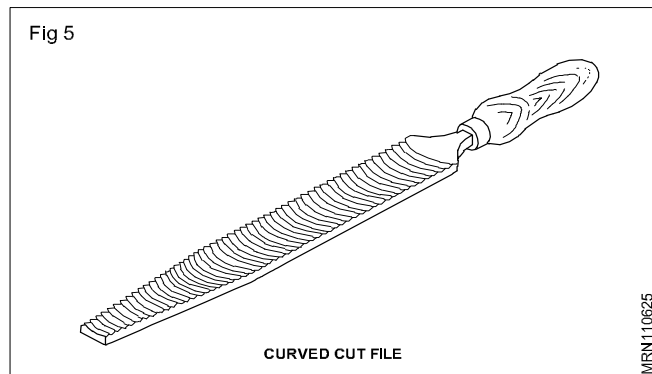
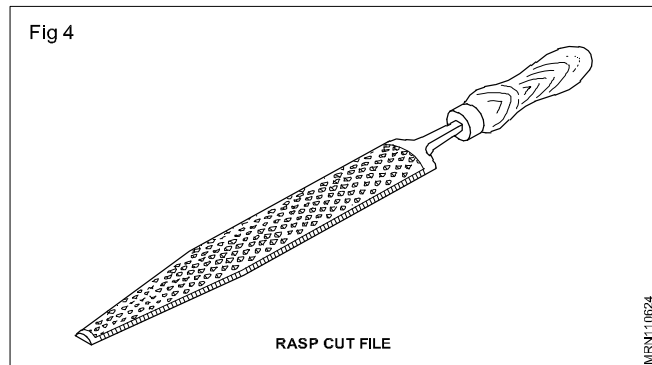


Curved cut file (Fig 4)

These files have deeper cutting action and are useful for filing soft materials like - aluminium, tin, copper and plastic.

The curved cut files are available only in a flat shape.

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



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

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

File shapes

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

- state the features of flat and hand files
- state the application of flat and hand files.

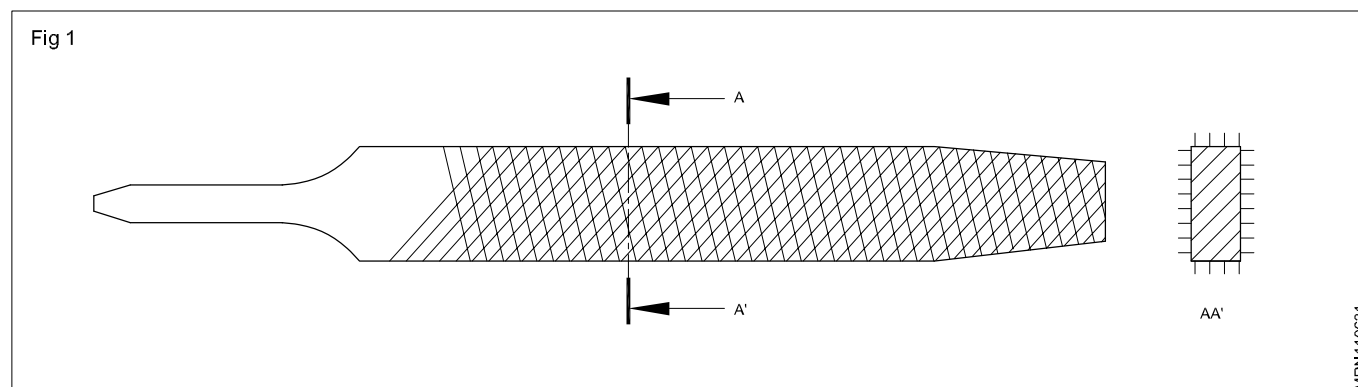
Files are made in different shapes so as to be able to file and finish components to different shapes.

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

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

Flat files (Fig 1)

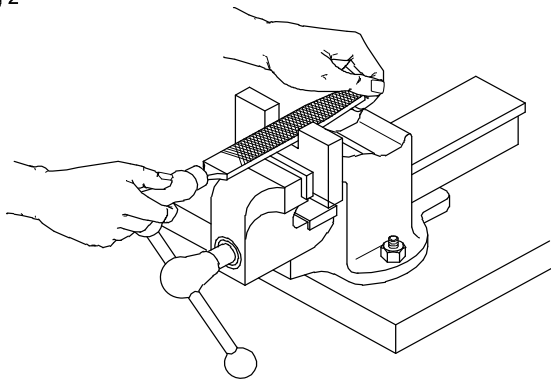
These files are of a rectangular cross section. The edges along the width of these files are parallel up to two-thirds of the length, and then they taper towards the point. The faces are double cut, and the edges single cut. These files are used for general purpose work. They are useful for filing and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



Hand files (Fig 2)

These files are similar to the flat files in their cross section. The edges along the width are parallel throughout the length. The faces are double cut. One edge is single cut whereas the other is safe edge. Because of the safe edge, they are useful for filing surfaces which are at right angles to surfaces already finished.

Fig 2



Flat files are general purpose files. They are available in all grades. Hand files are particularly useful for filing at right angles to a finished surface.

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

Parts of a file (Fig 3)

The parts of a file as can be seen in figure 5, are

Tip or Point

The end opposite to tang

Face or side

The broad part of the file with teeth cut on its surface

Edge

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

Heel

The portion of the broad part without teeth

Shoulder

The curved part of the file separating tang from the body

Tang

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

Handle

The part fitted to the tang for holding the file

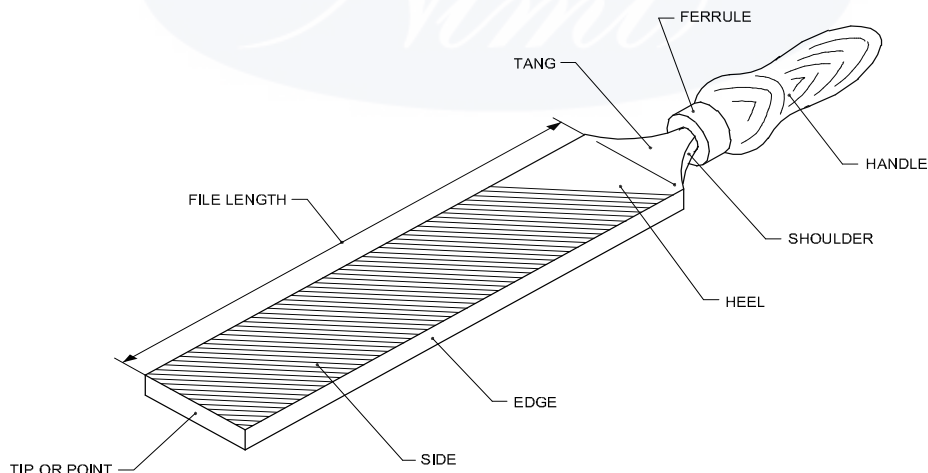
Ferrule

A protective metal ring to prevent cracking of the handle.

Materials

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

Fig 3



Try square

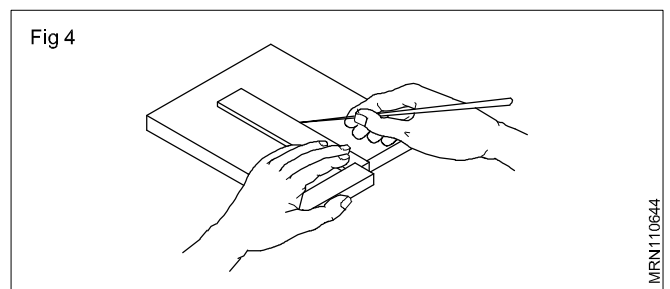
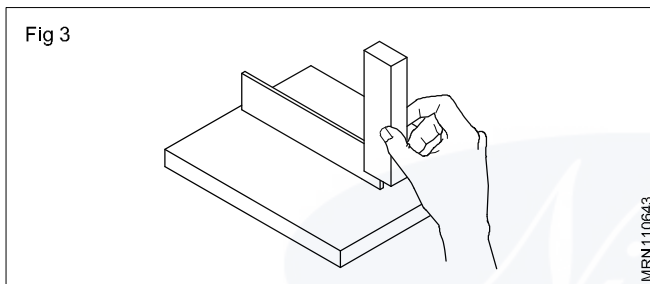
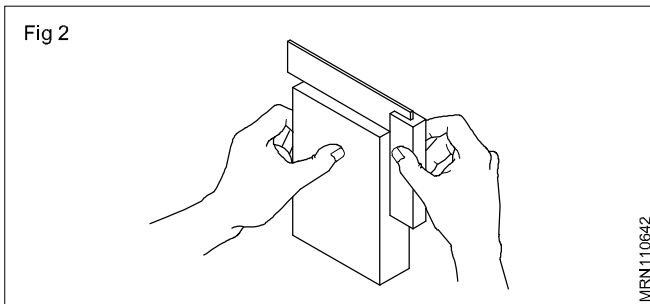
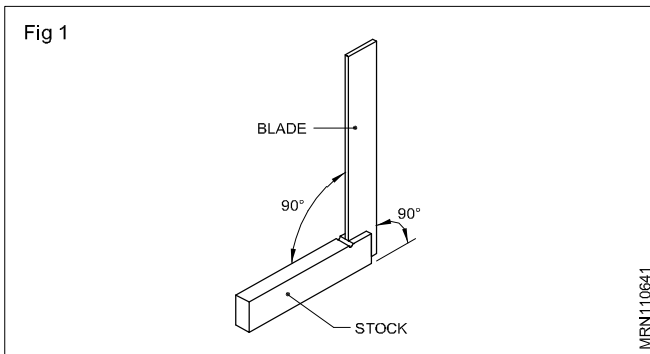
Objectives: At the end of this lesson you shall be able to

- name the parts of a try square
- state the uses of a try square.

Try square: The try square is a precision instrument which is used to check squareness (angles of 90°). The accuracy is about 0.002 mm per 10 mm length, which is accurate enough for most workshop purposes. The try square has a blade with parallel surfaces. The blade is fixed in the stock at 90° . (Fig 1)

The try square is used to

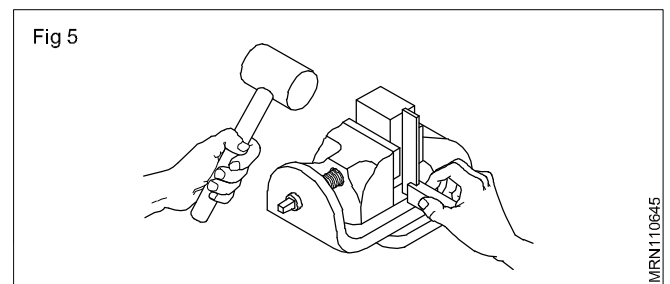
- check the squareness of machined or filed surfaces. (Fig 2)
- check the flatness of surfaces (Fig 3)
- mark lines at 90° to the edges of work pieces (Fig 4)



– set work pieces at right angles on work-holding devices. (Fig 5)

Try squares are made of hardened steel.

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



Shapes of files

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

- identify the different shapes of files
- state the uses of Square, Round, Half Round, Triangular and Knife-edge files
- state the correct shape of files for filing different profiles.

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

The shape of files is stated by its cross section.

Common files of different shapes

Flat file, Hand file, Square file, Round file

Half round file, Triangular file and Knife-edge file.

(Flat and hand files have already been discussed).

Square file

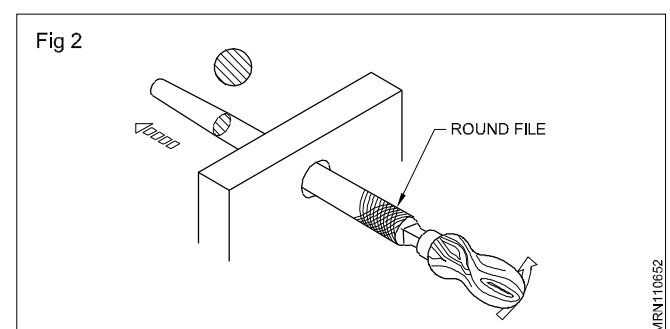
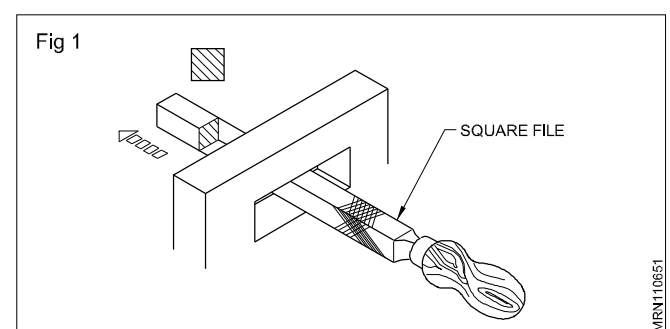
The square file is square in its cross section. It is used for filing square holes, internal square corners, rectangular openings, keyways and splines. (Fig 1)

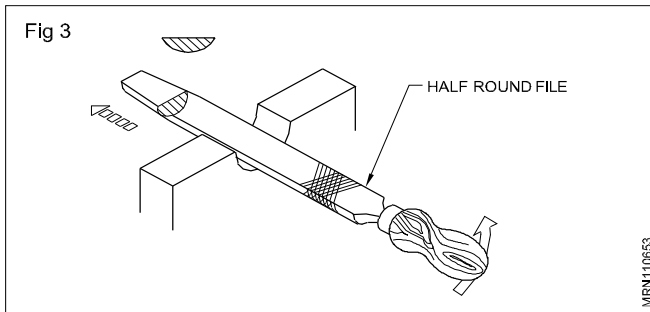
Round file

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

Half round file

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





Triangular file

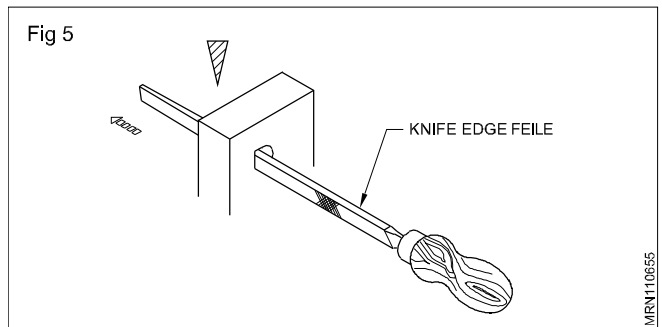
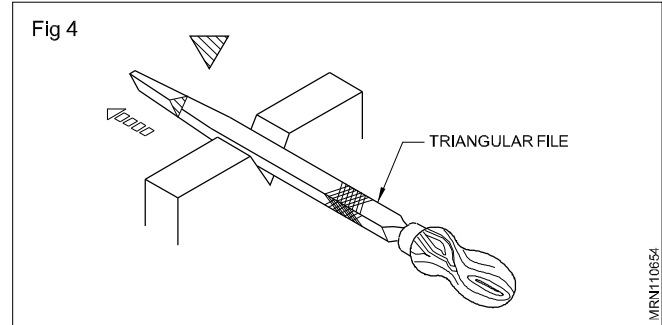
A triangular file is of a triangular cross section. It is used for filing corners and angles which are more than 60° . (Fig 4)

Knife-edge file

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

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

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



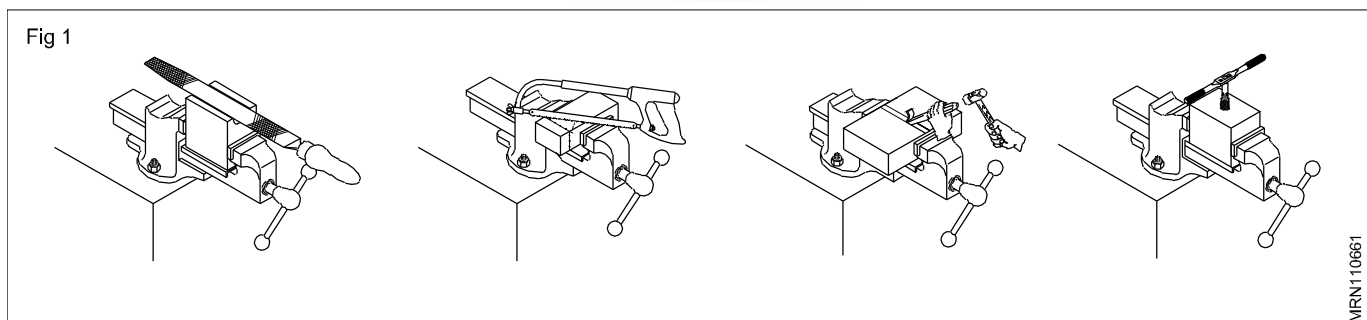
Bench vice

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

- name the parts and uses of a bench vice
- specify the size of a bench vice
- state the uses of vice clamps.

Vices are used for holding work pieces. They are available in different types. The vice used for bench work is the bench vice. (Engineer's vice)

A bench vice is made of cast iron or cast steel and it is used to hold work for filing, sawing, threading and other hand operations. (Fig 1) The size of the vice is stated by the width of the jaws.



Parts of a Bench Vice (Fig 2)

The following are the parts of a vice:

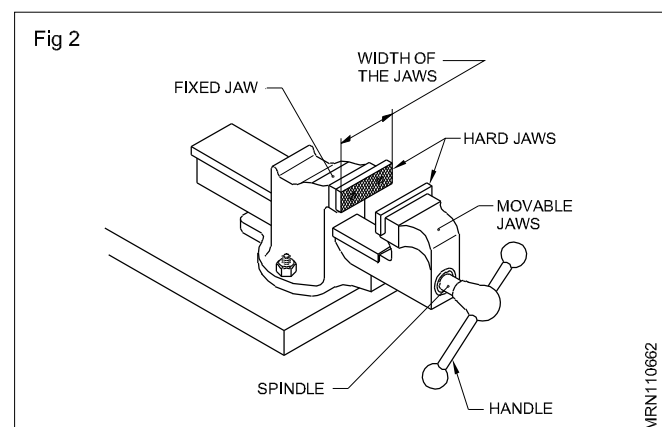
Fixed jaw, Movable jaw, Hard jaws, Spindle, Handle, Box nut and Spring.

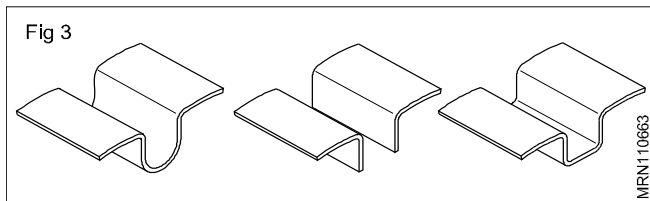
The box nut and the spring are the internal parts.

Vice clamps or Soft jaws (Fig 3)

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

Do not over-tighten the vice, otherwise, the spindle may be damaged.





Marking off and marking table

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

- why marking off is necessary
- the function of witness marks
- the features of marking tables
- the uses of marking tables.
- the maintenance aspects concerning marking tables.

Marking off

Marking off or layout is carried out to indicate the locations of operation to be done, and provide guidance during rough machining or filing.

Witness marks

The line marked on metal surfaces is likely to be erased due to handling. To avoid this, permanent marks are made by placing punch marks at convenient intervals along the marked line. Punch marks act as a witness against inaccuracies in machining and hence, they are known as witness marks.

Marking table (Figs 1 and 2)

A marking table (marking-off table) is used as a reference surface for marking on work pieces.

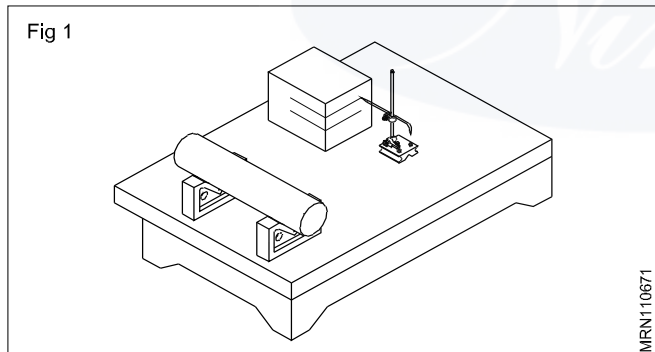
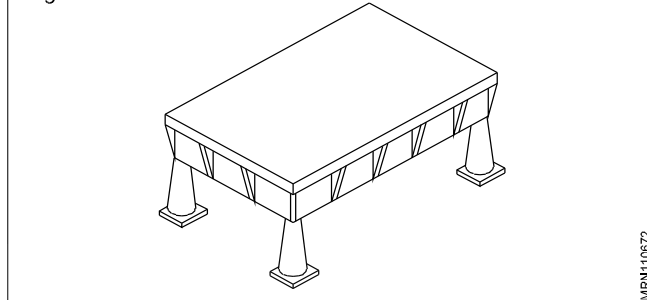


Fig 2



Marking tables are of a rigid construction with accurately finished top surfaces. The edges are also finished at right angles to the top surface.

Marking tables are made of cast iron or granite, and are available in various sizes. These tables are also used for setting measuring instruments, and for checking sizes, parallelism and angles.

A marking table is very precise as an equipment, and should be protected from damage and rust.

After use, the marking table should be cleaned with a soft cloth.

The surface of the marking table, made of cast iron, should be protected by applying a thin layer of oil.

Universal surface gauge

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

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

Universal surface gauge: A surface gauge is one of the most common marking tools used for:

- scribing lines parallel to a datum surface (Fig 1)
- setting jobs on machines parallel to a datum surface (Fig 2)
- checking the height and parallelism of jobs
- setting jobs concentric to the machine spindle.

Types of surface gauges: A surface gauge/scribing block is of two types.

Fig 1

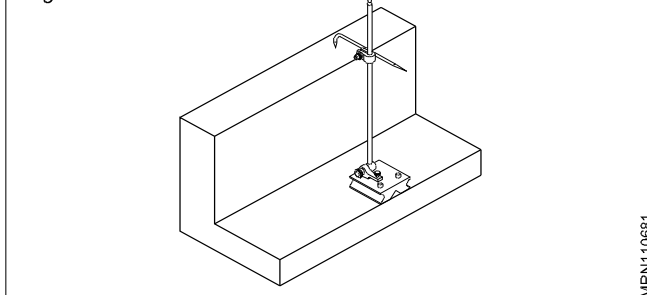
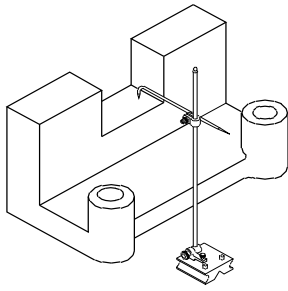


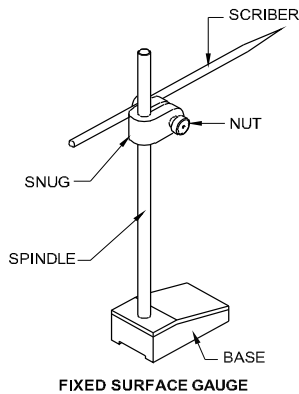
Fig 2



MRN110682

– Fixed (Fig 3)

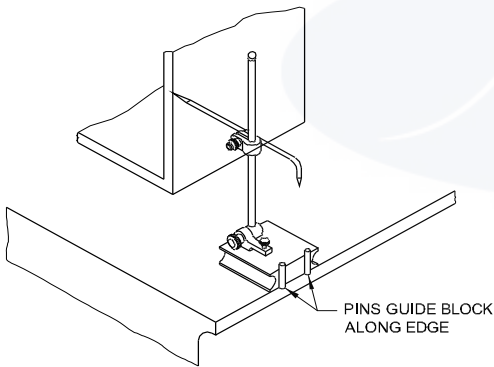
Fig 3



MRN110683

– Universal (Fig 4)

Fig 4



MRN110684

Surface gauge (fixed type): This consists of a heavy flat base and a spindle, fixed upright to which a scribe is attached with a snug and a clamp nut.

Universal surface gauge: This has the following additional features.

- The spindle can be set to any position.
- Fine adjustments can be made quickly.

Angle plate

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

- state the features and functions of angle plates
- name the types of angle plates
- state the uses of angle plates.

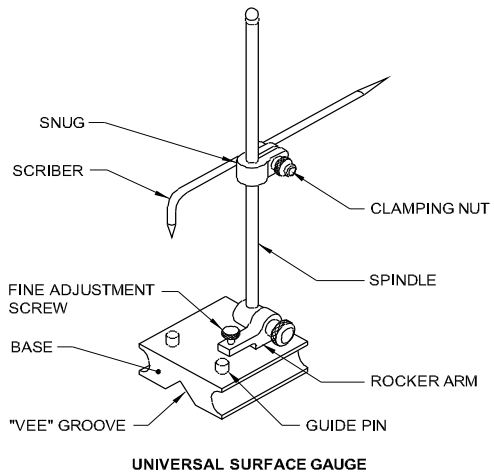
Angle Plate (Fig 1)

Angle plates are used to support the job and to provide a vertical or angular plane for marking.

- Can also be used on cylindrical surfaces.
- Parallel lines can be scribed from any datum edge with the help of guide pins.(Fig 4)

Parts and functions of a universal surface gauge (Fig 5)

Fig 5



MRN110685

Base: The base is made of steel or cast iron with a 'Vee' groove at the bottom. The 'Vee' helps to seat on the circular work. The guide pins fitted in the base are helpful for scribing lines from any datum edge.

Rocker arm:

A rocker arm is attached to the base along with a spring and a fine adjustment screw. This is used for fine adjustments.

Spindle:

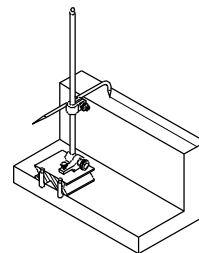
The spindle is attached to the rocker arm.

Scriber:

The scriber can be clamped in any position on the spindle with the help of a snug and clamp nut.

Parallel lines can be scribed from any datum edge with the help of guide pins. (Fig 6)

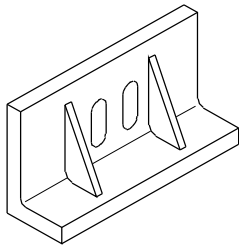
Fig 6



MRN110686

An angle plate is made of cast iron or steel and is machined accurately to an angle of 90°.

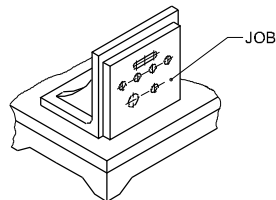
Fig 1



MRN110691

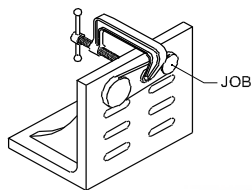
In some types, long slots are made to fix the jobs with bolts and nuts. (Figs 2 & 3)

Fig 2



MRN110692

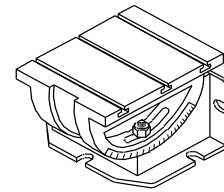
Fig 3



MRN110693

Adjustable angle plates are available to support jobs in different angles. (Fig 4)

Fig 4

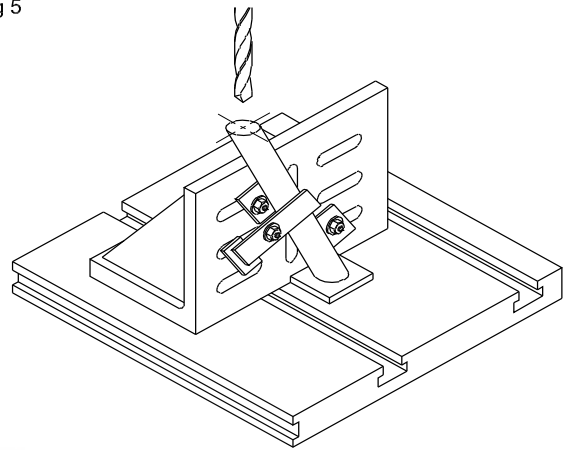


MRN110694

Angle plates can be used to support jobs in different angles. (Fig 5)

Angle plates are also used to set jobs on the machines.

Fig 5



MRN110695

Angle plates should be carefully handled and maintained. Any nicks or scratches can spoil the accuracy of the angle plates.

Types of marking punches

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

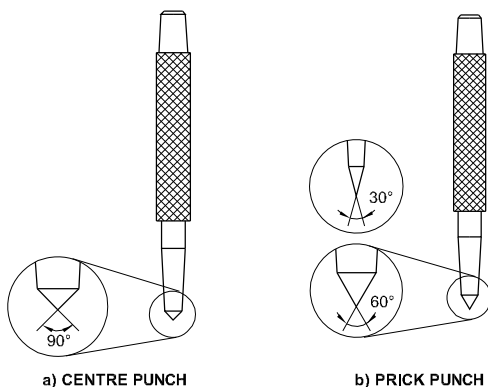
- name the different punches used in marking
- state the features of each punch and its uses.

Types of marking punches: In order to make certain dimensional features of the layout permanent, punches are used. There are two types of punches.

Centre punch: The angle of the point is 90°. The punch mark made by this is wide and not very deep. This punch is used for locating holes. The wide punch mark gives a good seating for starting the drill. (Figs 1a & b)

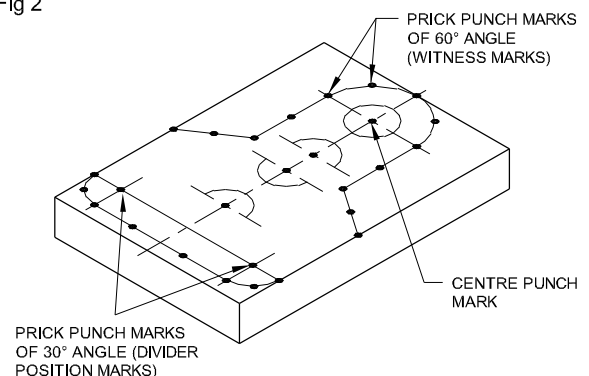
Prick punch: The angle of the prick punch is 30° or 60° (Fig 1b). The 30° point punch is used for making light punch marks needed to position dividers. The divider leg will get proper seating in this punch mark. The 60° punch is used for Witness Marks. Witness marks should not be too close. (Fig 2)

Fig 1



MRN1106A1

Fig 2



MRN1106A2

Drilling & milling machines

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

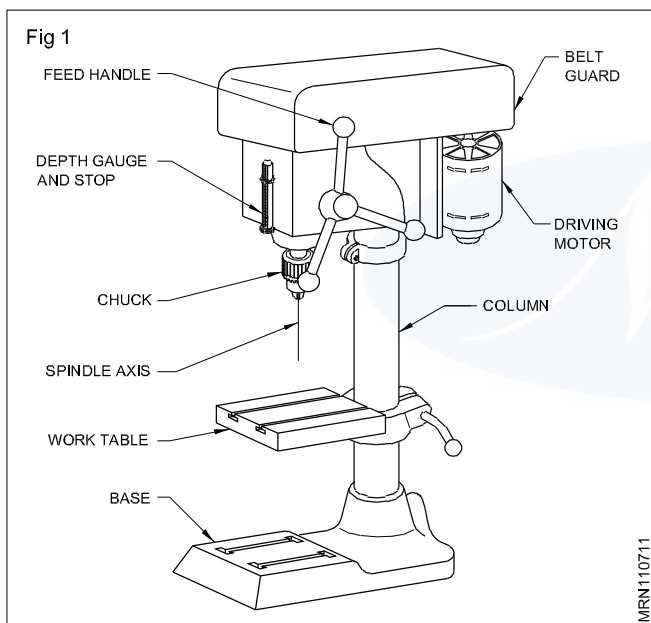
- name the types of drilling machines
- identify the parts of bench and pillar type drilling machine.

The principal types of drilling machines are the sensitive bench drilling machine the pillar drilling machine the column drilling machine and the radial arm drilling machine. (Radial Drilling Machine).

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

The Sensitive Bench Drilling Machine

The simplest type of sensitive drilling machine is shown in the figure with its various parts marked. This is used for light duty work. (Fig 1)



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

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

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

The pillar drilling machine

This is an enlarged version of the sensitive bench drilling machine. These drilling machines are mounted on the floor and driven by more powerful electric motors. They are used for heavy duty work. Pillar drilling machines are available in different sizes. (Fig 3)

Fig 2

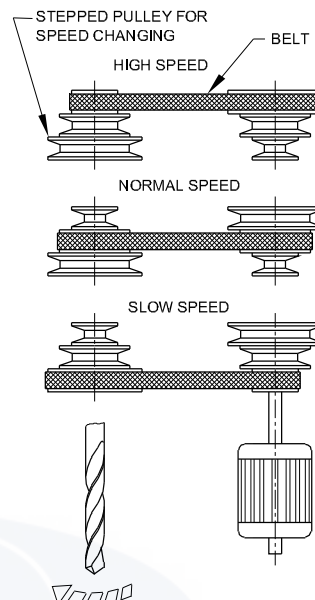
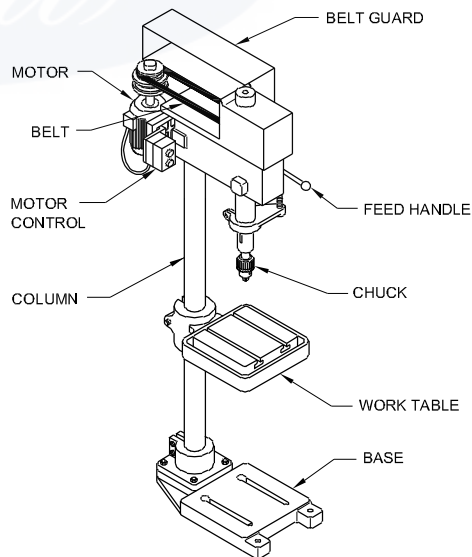


Fig 3



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

Drill-holding devices

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

- name the types of drill-holding devices
- state the features of drill chucks
- state the functions of drill sleeves
- state the function of drift.

For drilling holes on materials, the drills are to be held accurately and rigidly on the machines.

The common drill-holding devices are drill chucks and sleeves and sockets.

Drill chuck

Straight shank drills are held in drill chucks. For fixing and removing drills, the chucks are provided either with a pinion and key or a knurled ring.

The drill chucks are held on the machine spindle by means of an arbor fitted on the drill chuck. (Fig 1)

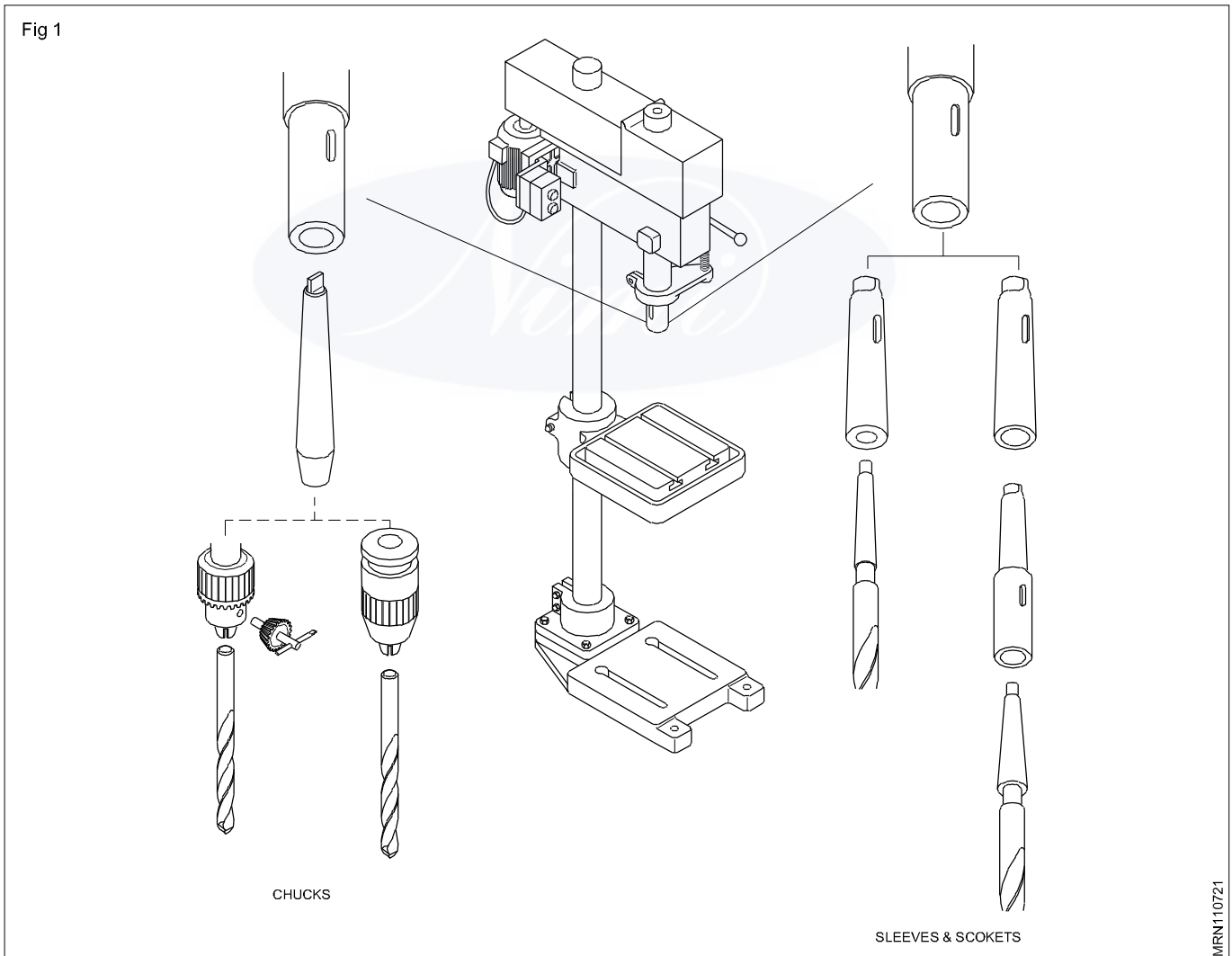
Taper sleeves and sockets (Fig 1)

Taper shank drills have a morse taper. Sleeves and sockets are made with the same taper so that the taper shank of the drill, when engaged, will give a good wedging action. Due to this reason morse tapers are called self-holding tapers.

Drills are provided with five different sizes of morse tapers, and are numbered from MT1 to MT5.

In order to make up the difference in sizes between the shanks of the drills and the type of machine spindles, sleeves of different sizes are used.

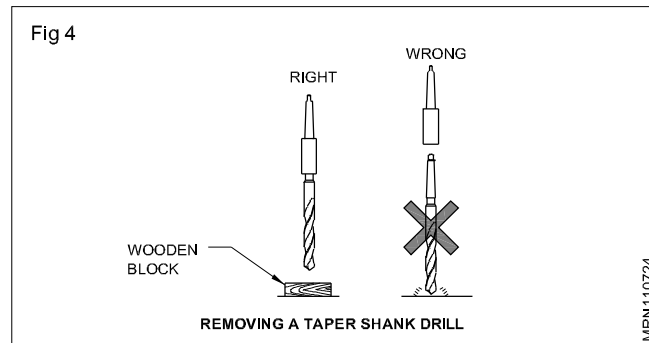
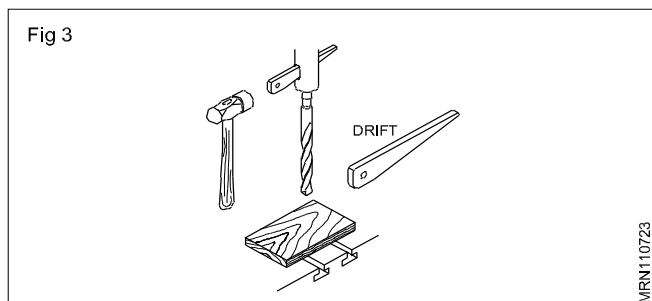
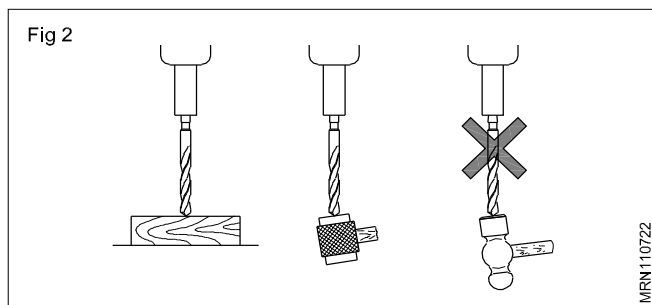
When the drill taper shank is bigger than the machine spindle, taper sockets are used.(Fig 1)



While fixing the drill in a socket or sleeve, the tang portion should align in the slot. (Fig 2) This will facilitate the removal of drill or sleeve from the machine spindle.

Use a drift to remove drills and sockets from the machine spindle. (Fig 3)

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



Work-holding devices

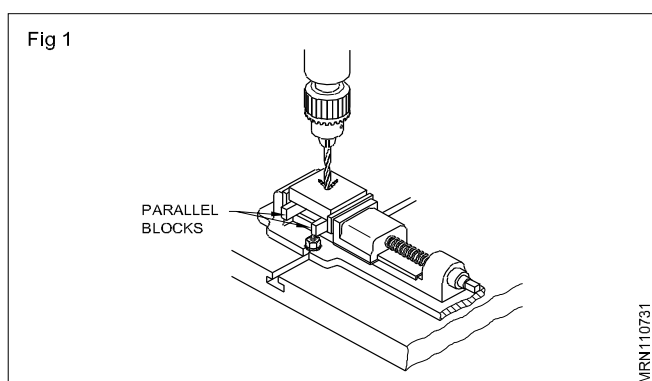
Objectives: At the end of this lesson you shall be able to

- state the purpose of work-holding devices
- name the devices used for holding work
- state the precautions to be observed while using work-holding devices.

Work pieces to be drilled should be properly held or clamped to prevent from rotating along with the drill. Improperly secured work is not only a danger to the operator but can also cause inaccurate work, and breakage to the drill. Various devices are used to ensure proper holding.

The machine vice

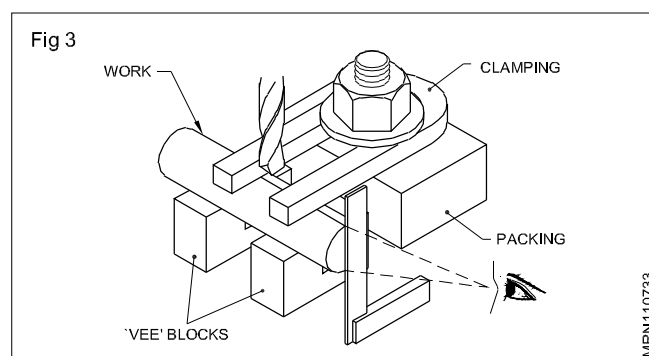
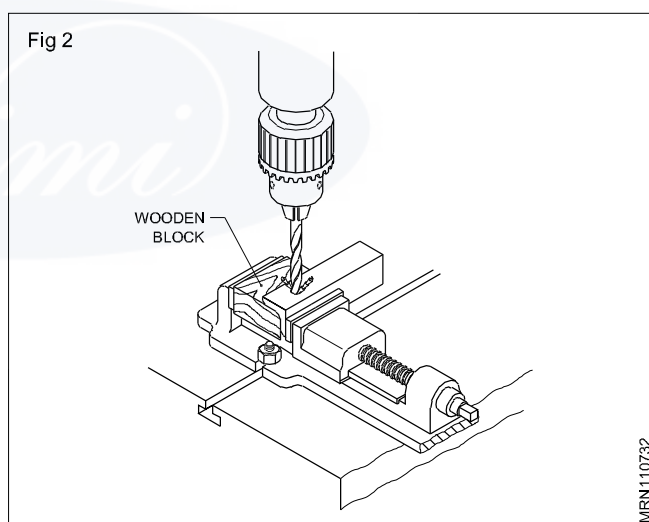
Most of the drilling work can be held in a machine vice. Ensure that the drill does not drill through the vice after it has passed through the work. For this purpose, the work can be lifted up and secured on parallel blocks providing a gap between the work and the bottom of the vice. (Fig 1)



Work pieces which are not accurate may be supported by wooden pieces. (Fig 2)

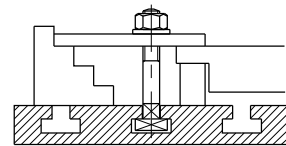
Clamps and bolts

Drilling machine tables are provided with T-slots for fitting bolt heads. Using clamps and bolts, the workpieces can be held very rigidly. (Fig 3) While using this method, the packing should be, as far as possible, of the same height as the work, and the bolt nearer to the work. (Fig 4)

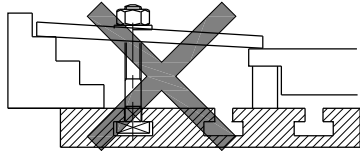


There are many types of clamps and it is necessary to determine the clamping method according to the work. (Figs 5 & 6).

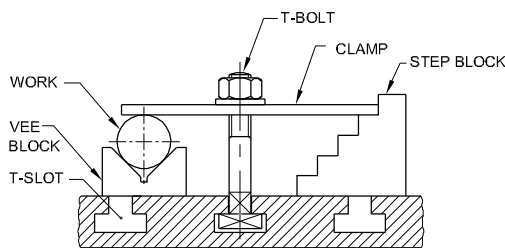
Fig 4



CORRECT METHOD OF HOLDING JOB

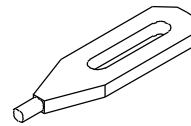


WRONG METHOD OF HOLDING JOB

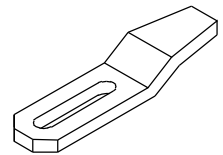


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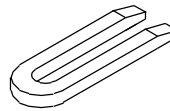
Fig 5



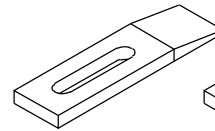
FINGER



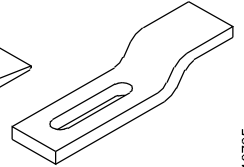
GOOSE NECK



'U' STRAP



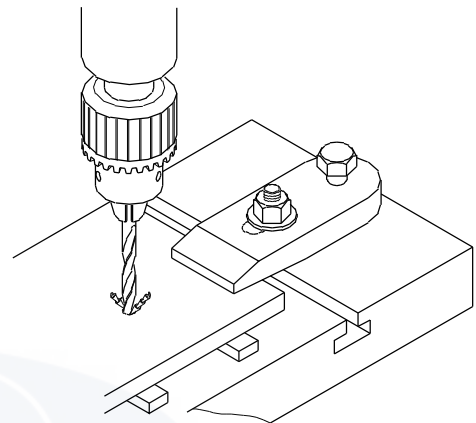
STRAIGHT



BENT

MRN110735

Fig 6



MRN110736

Cutting speed and RPM

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

- define cutting speed.
- state the factors for determining the cutting speed
- differentiate between cutting speed and RPM
- determine RPM/spindle speed
- select RPM for drill sizes from tables.

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

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

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

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

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

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

Calculating RPM

Materials being drilled for HSS	Cutting speed (m/min)
Aluminium	70 - 100
Brass	35 - 50
Bronze(phosphor)	20 - 35
Cast iron (grey)	25 - 40
Copper	35 - 45
Steel (medium carbon/mild steel)	20 - 30
Steel (alloy, high tensile)	5 - 8
Thermosetting plastic (low speed due to abrasive properties)	20 - 30

$$v = n \times d \times \pi \text{ m/min}$$

$$n = \frac{v \times 1000}{d \times \pi}$$

n - RPM

v - cutting speed in m/min.

d - diameter of the drill in mm

$\pi = 3.14$

b= Examples: Calculate the RPM for a high speed steel drill Ø24 to cut mild steel.

The cutting speed for MS is taken as 30 m/min. from the table.

$$n = \frac{1000 \times 30}{3.14 \times 24} = 398 \text{ RPM}$$

It is always preferable to set the spindle speed to the nearest available lower range. The selected spindle speed is 300 RPM.

The RPM will differ according to the diameter of the drills. The cutting speed being the same, larger diameter drills will have lesser RPM and smaller diameter drills will have higher RPM.

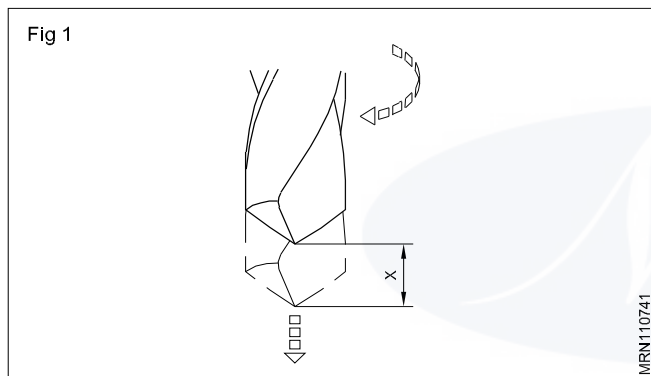
The recommended cutting speeds are achieved only by actual experiments.

Feed in drilling

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

- state what is meant by feed
- state the factors that contribute to an efficient feed rate.

Feed is the distance (X) a drill advances into the work in one complete rotation. (Fig 1)



Feed is expressed in hundredths of a millimeter.

Example - 0.040mm

The rate of feed is dependent upon a number of factors.

Finish required

Type of drill (drill material)

Material to be drilled

Factors like rigidity of the machine, holding of the work piece and the drill, will also have to be considered while determining the feed rate. If these are not to the required standard, the feed rate will have to be decreased.

It is not possible to suggest a particular feed rate taking all the factors into account.

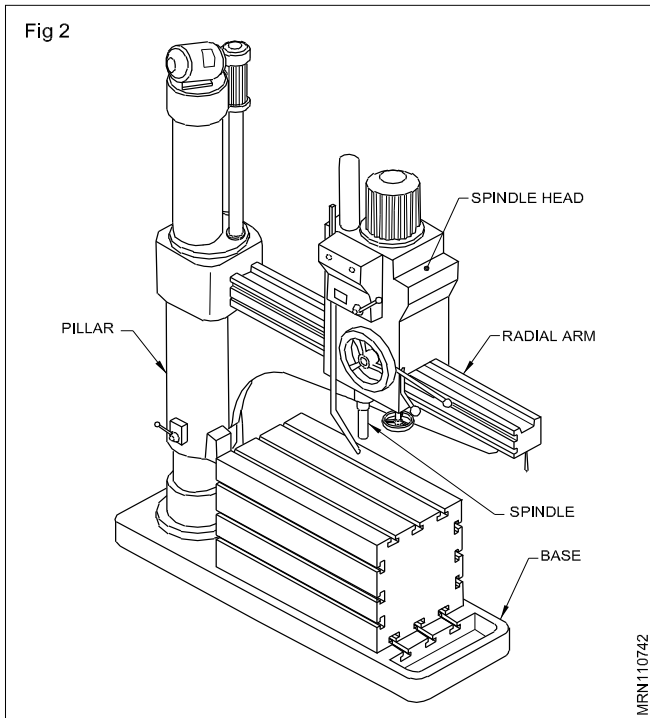
The table for the feed rate given here is based on the average feed values suggested by the different manufacturers of drills. (Table 1)

Too coarse a feed may result in damage to the cutting edges or breakage of the drill.

TABLE 1

Drill diameter (mm) H.S.S.	Rate of feed (mm/rev)
1.0 - 2.5	0.040 - 0.060
2.6 - 4.5	0.050 - 0.100
4.6 - 6.0	0.075 - 0.150
6.1 - 9.0	0.100 - 0.200
9.1 - 12.0	0.150 - 0.250
12.1 - 15.0	0.200 - 0.300
15.1 - 18.0	0.230 - 0.330
18.1 - 21.0	0.260 - 0.360
21.1 - 25.0	0.280 - 0.380

- Ensure that the spindle-head and the arms are locked properly to avoid vibration. (Fig 2)
- The work piece and the drill should be rigidly held.
- Bring back the spindle head nearer to the pillar after use.
- Switch off power when not in use.
- Use the drill drift for removing the drills, chucks or sockets.
- Use a minimum number of sockets and sleeves to make for the spindle bore size.
- Clean and oil the machine after use.
- Stop the machine to remove the swarf.
- Use a brush to clean the chips and swarf.



Drill angles

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

- identify the various angles of a twist drill
- state the functions of each angle
- list the tool types for drill as per ISI
- distinguish the features of different types of drills
- designate drills as per ISI recommendations.

Like all cutting tools the drills are provided with certain angles for efficiency in drilling.

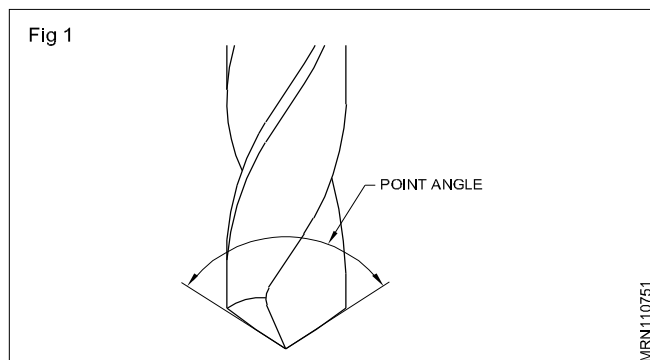
Angles

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

Point Angle, Helix angle, Rake angle, Clearance angle and Chisel edge angle.

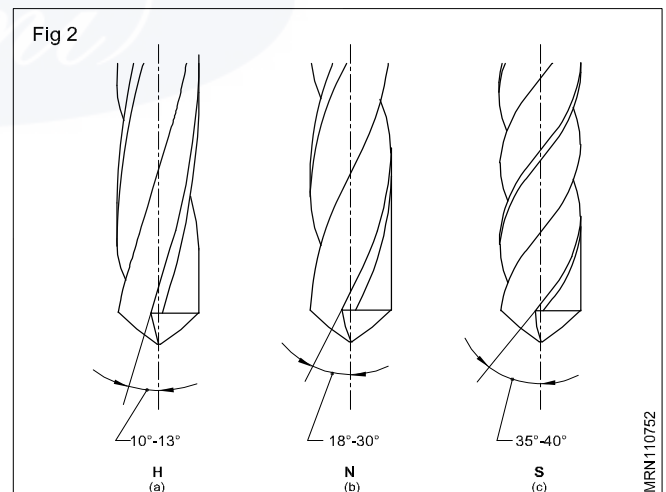
Point angle/cutting angle

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



Helix angle (Figs 2a, 2b, 2c)

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



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

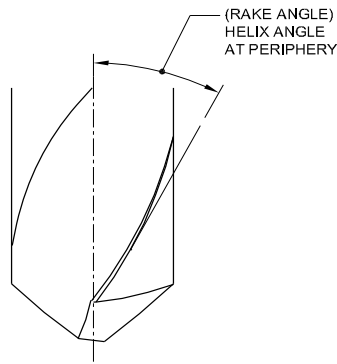
- Type N - for normal low carbon steel.
- Type H - for hard and tenacious materials.
- Type S for soft and tough materials.

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

Rake angle (Fig 3)

Rake angle is the angle of flute (helix angle).

Fig 3

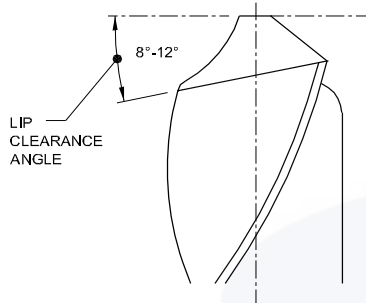


MRN110753

Clearance angle (Fig 4)

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

Fig 4

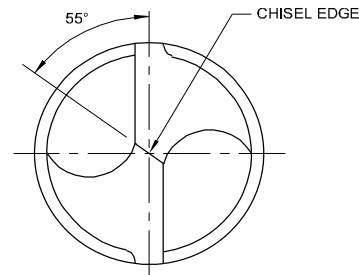


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Chisel edge angle/web angle (Fig 5)

This is the angle between the chisel edge and the cutting lip.

Fig 5



MRN110755

Designation of drills

Twist drills are designated by the

- diameter
- tool type
- material

Example

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

Twist drill 9.50 - H - IS5101 - HS

Diameter of drill
IS NO.
Tool type
Material

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

Drills for different materials

Recommended drills						
Material to be drilled	Point angle	Helix angle d=3.2-5 5-10 10-			Material to be drilled	Point angle Helix angle d=3.5-5 5-
Steel and cast steel up to 70 kgf/mm ² strength Gray cast iron Malleable cast iron Brass German silver, nickel.		22°	25°	30°	Copper (up to 30 mm drill diameter) Al-alloys, forming curly chips Celluloid	35° 40°
Brass, CuZn 40		12°	13°	13°	Austenitic steels Magnesium alloys Moulded plastics (with thickness s>d)	12° 13°
Steel and cast steel 70...120 Kgf/mm ²		27°	25°	30°	Moulded plastics, with thickness s<d Laminated plastics, hard rubber (ebonite) marble, slate, coal	35° 40°
Stainless steel; Copper (drill diameter more than 30 mm) Al-alloy, forming short broken chips		22°	25°	30°	Zinc alloys	12° 13°
						35° 40°

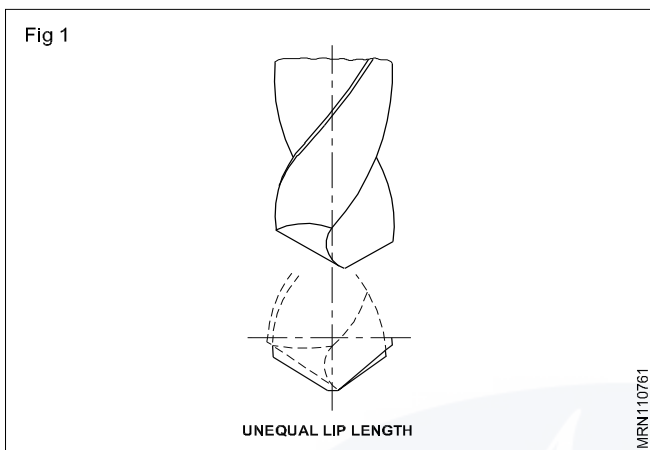
Drilling defects and causes

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

- state the common drilling defects
- identify the causes of drilling defects
- suggest remedial steps for preventing drill failures.

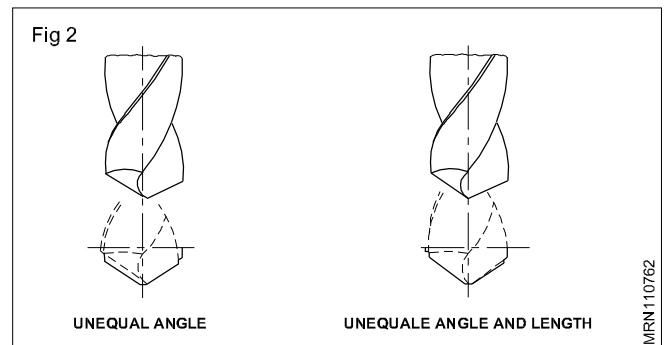
The common defects in drilling are listed below.

- Oversized holes
- Overheated drills
- Rough holes
- Unequal and interrupted flow of chips
- Split webs or broken drills



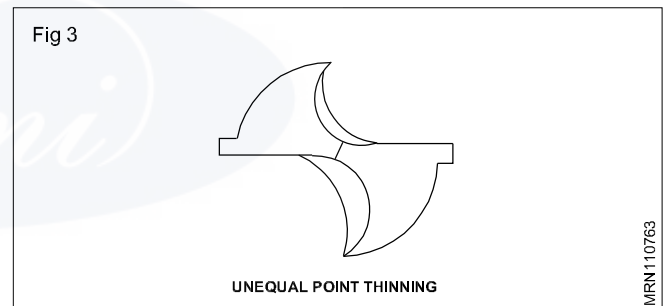
Oversized holes

- Oversized holes can be due to the
- unequal length of cutting edges
- unequal angle of cutting edges
- unequal point thinning
- spindle running out of centre
- drill point not in centre.



Overheated drills

- The drills may get overheated if the
- cutting speed is too high
- feed rate is too high
- clearance angle is incorrect
- cooling ineffective point angle is incorrect
- drill is not sharp.



Tap drill size

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

- state what is tap drill size
- choose the tap drill sizes for different threads from tables
- calculate the tap drill sizes for ISO metric and ISO inch.

What is a tap drill size?

Before a tap is used for cutting internal threads, a hole is to be drilled. The diameter of the hole should be such that it should have sufficient material in the hole for the tap to cut the thread.

Tap drill sizes for different threads

ISO Metric Thread

Tapping drill size

for M10 x 1.5 thread

Minor diameter = Major diameter – 2 x depth

depth of thread = 0.6134 x pitch of a screw

2 depth of thread = 0.6134 x 2 x pitch

= 1.226 x 1.5 mm = 1.839 mm

Minor dia (D1) = 10 mm – 1.839 mm

= 8.161 mm or 8.2 mm

This tap drill will produce 100% thread because this is equal to the minor diameter of the thread. For most fastening purposes a 100% formed thread is not required.

A standard nut with 60% thread is strong enough to be tightened until the bolt breaks without stripping the thread. Further it also requires a greater force for turning the tap if a higher percentage formation of thread is required.

Considering this aspect, a more practical approach for determining the tap drill sizes is

$$\begin{aligned}\text{Tap drill size} &= \text{Major diameter} - \text{pitch} \\ &= 10 \text{ mm} - 1.5 \text{ mm} \\ &= 8.5 \text{ mm}.\end{aligned}$$

Compare this with the table of tap drill sizes for ISO metric threads.

ISO Inch (Unified) threads Formula

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

For calculating the tap drill size for 5/8" UNC thread

$$\begin{aligned}\text{Tap drill size} &= 5/8" - 1/11" \\ &= 0.625" - 0.091" \\ &= 0.534"\end{aligned}$$

The next drill size is 17/32" (0.531 inches)

Compare this with the table of drill sizes for unified inch threads.

What will be the tapping size for the following threads?

- (a) M 20
- (b) UNC 3/8



Hand taps and wrenches

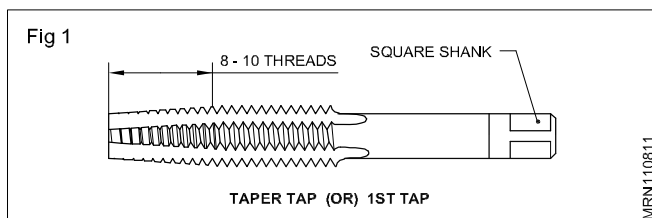
Objectives: At the end of this lesson you shall be able to

- identify the uses of hand taps
- state the features of each tap
- state the different types of tap wrenches, and state their uses.

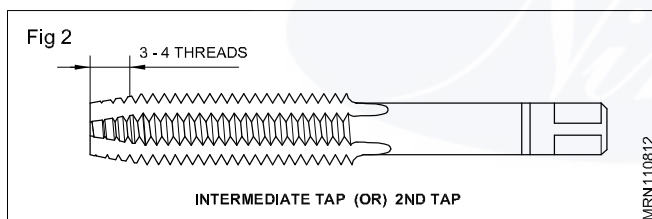
Taps: A tap cuts an internal (female) thread either left or right hand. Taps are usually made in sets of three.

- First tap or taper tap
- Second tap or intermediate tap
- Plug or bottoming tap.

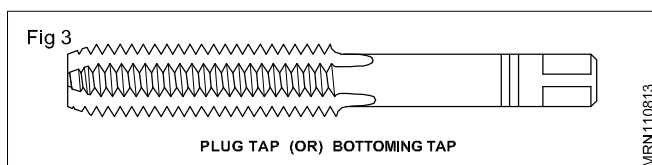
The taper tap is tapered off for 8 to 10 threads and is used first, cutting to the full thread gradually. (Fig 1)



The intermediate tap usually has three or four threads chamfered. This second tap can finish a through hole. (Fig 2)



The plug tap has a full-sized untapered thread to the end, and is the main finishing tap. In the case of a blind hole, a plug tap must be used. (Fig 3)



Beware of the cutting edges of taps when handling them.

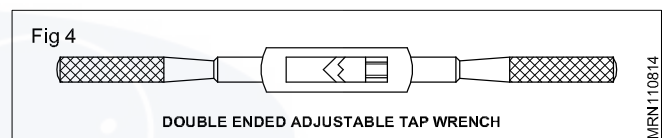
Tap wrenches: Tap wrenches are used to align and drive the hand taps correctly into the hole to be threaded.

Tap wrenches are of different types.

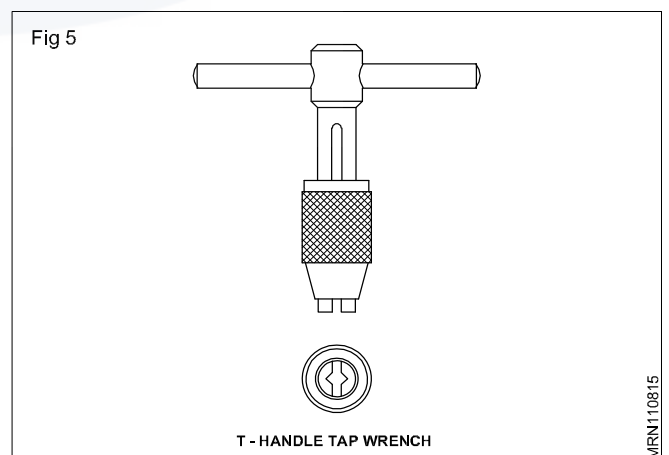
- Double - ended adjustable wrench
- T-handle tap wrench
- Solid type tap wrench

Double-ended adjustable tap wrench (Bar type tap wrench) (Fig 4)

This is the most commonly used type of tap wrench. These tap wrenches are available in various sizes. They are more suitable for large diameter taps, and can be used in open places where there is no obstruction to turn the tap. It is important to select the correct size of the wrench.



T-handle tap wrench (Fig 5): These are small adjustable chucks with two jaws and a handle to turn the wrench.



Reamers

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

- state the use of reamers
- state the advantages of reaming
- distinguish between hand and machine reaming
- name the elements of a reamer and state their functions.

What is a reamer?

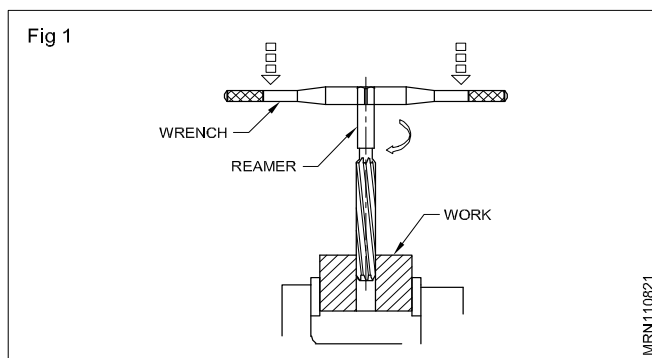
A reamer is a multipoint cutting tool used for enlarging by finishing previously drilled holes to accurate sizes. (Fig 1)

Advantages of 'reaming'

Reaming produces
high quality surface finish

dimensional accuracy to close limits.

Also small holes which cannot be finished by other processes can be finished.



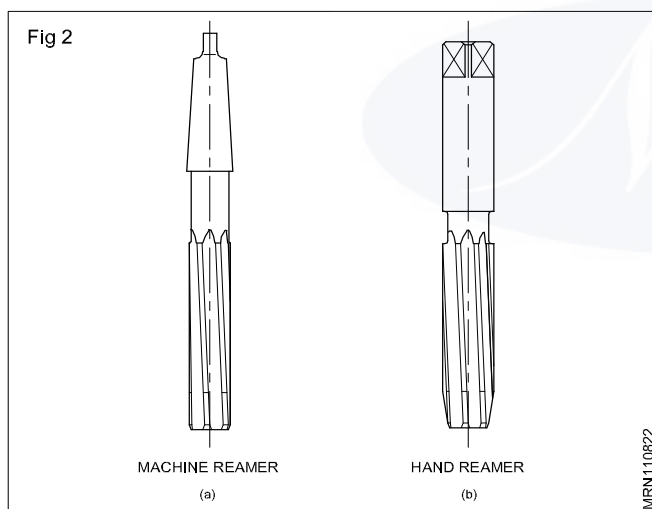
Classification of reamers

Reamers are classified as hand reamers and machine reamers. (Figs 2a,b) Reaming by using hand reamers is done manually for which great skill is needed.

Machine reamers are fitted on spindles of machine tools and rotated for reaming.

Machine reamers are provided with morse taper shanks for holding on machine spindles.

Hand reamers have straight shanks with 'square' at the end, for holding with tap wrenches. (Figs 2a,b)



Parts of a hand reamer

The parts of a hand reamer are listed here under. Refer to Fig 3.

Axis

The longitudinal centre line of the reamer.

Body

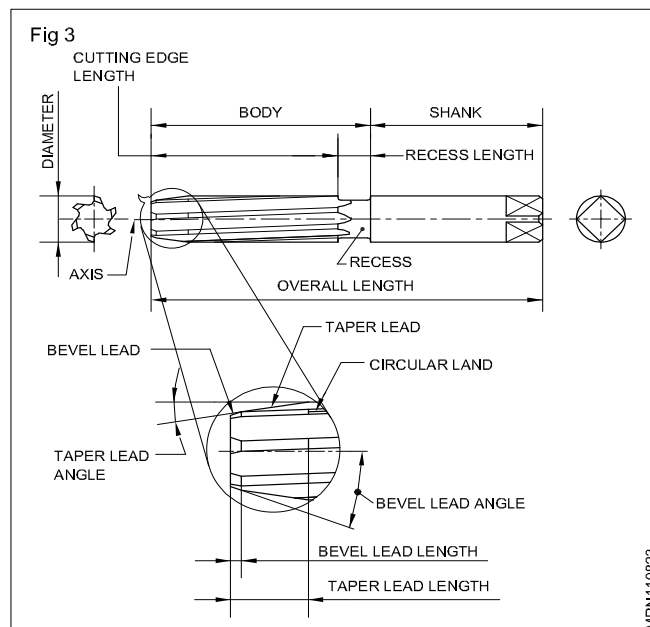
The portion of the reamer extending from the entering end of the reamer to the commencement of the shank.

Recess

The portion of the body which is reduced in diameter below the cutting edges, pilot or guide diameters.

Shank

The portion of the reamer which is held and driven. It can be parallel or taper.



Circular land

The cylindrically ground surface adjacent to the cutting edge on the leading edge of the land.

Bevel lead

The bevel lead cutting portion at the entering end of the reamer cutting its way into the hole. It is not provided with a circular land.

Taper lead

The tapered cutting portion at the entering end to facilitate cutting and finishing of the hole. It is not provided with a circular land.

Bevel lead angle

The angle formed by the cutting edges of the bevel lead and the reamer axis.

Taper lead angle

The angle formed by the cutting edges of the taper and the reamer axis.

Terms relating to cutting geometry

flutes

The grooves in the body of the reamer to provide cutting edges, to permit the removal of chips, and to allow the cutting fluid to reach the cutting edges. (Fig 4)

Heel

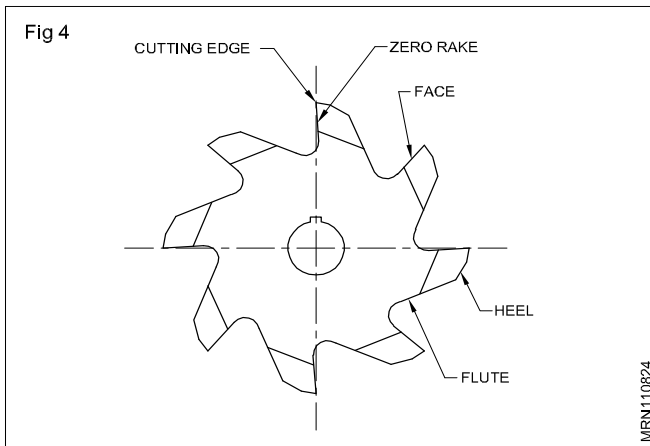
The edge formed by the intersection of the surface left by the provision of a secondary clearance and the flute. (Fig 5)

Cutting edge

The edge formed by the intersection of the face and the circular land or the surface left by the provision of primary clearance. (Fig 4)

Face

The portion of the flute surface adjacent to the cutting edge



on which the chip impinges as it is cut from the work. (Fig 5)

Rake angles

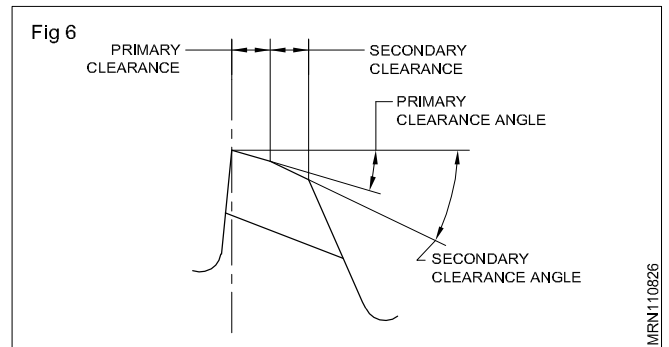
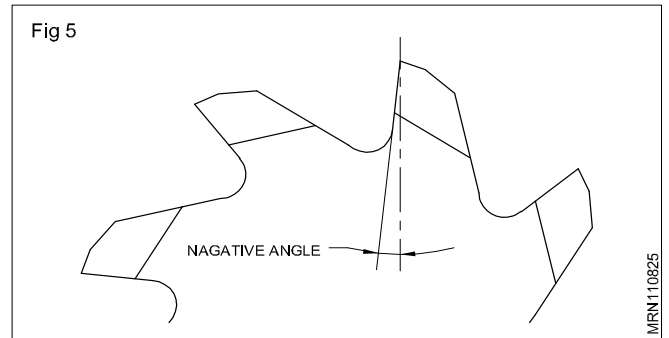
The angles in a diametric plane formed by the face and a radial line from the cutting edge. (Fig 6)

Clearance angle

The angles formed by the primary or secondary clearances and the tangent to the periphery of the reamer at the cutting edge. They are called primary clearance angle and secondary clearance angle respectively. (Fig 7)

Helix angle

The angle between the edge and the reamer axis. (Fig 8)

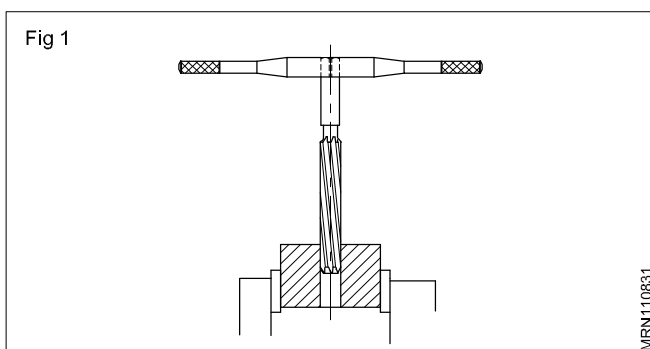


Hand reamers

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

- state the general features of hand reamers
- identify the types of hand reamers
- distinguish between the uses of straight fluted and helical fluted reamers
- name the materials from which reamers are made and specify reamers.

General features of hand reamers (Fig 1)

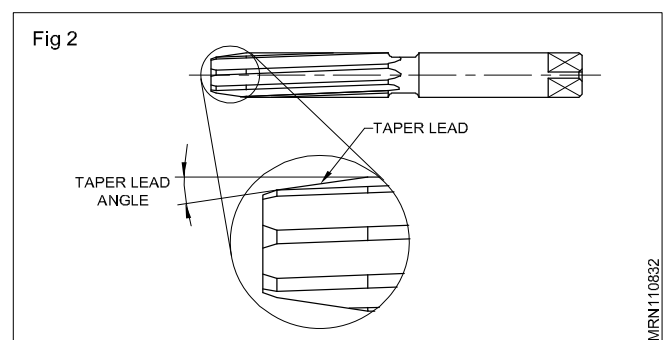


Hand reamers are used to ream holes manually using tap wrenches.

These reamers have a long taper lead. (Figure 2) This allows to start the reamer straight and in alignment with the hole being reamed.

Most hand reamers are for right hand cutting.

Helical fluted hand reamers have left hand helix. The left



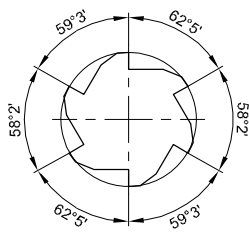
hand helix will produce smooth cutting action and finish.

Most reamers, machine or hand, have uneven spacing of teeth. This feature of reamers helps to reduce chattering while reaming. (Fig 3)

Types, features and functions

Hand reamers with different features are available for meeting different reaming conditions. The commonly used types are listed here under:

Fig 3



MRN110833

1 Parallel hand reamer with parallel shank (Fig 4a)

A reamer which has virtually parallel cutting edges with taper and bevel lead. The body of the reamer is integral with a shank. The shank has the nominal diameter of the cutting edges. One end of the shank is square shaped for tuning it with a tap wrench. Parallel reamers are available with straight and helical flutes. This is the commonly used hand reamer for reaming holes with parallel sides.

Reamers commonly used in workshop produce H8 holes.

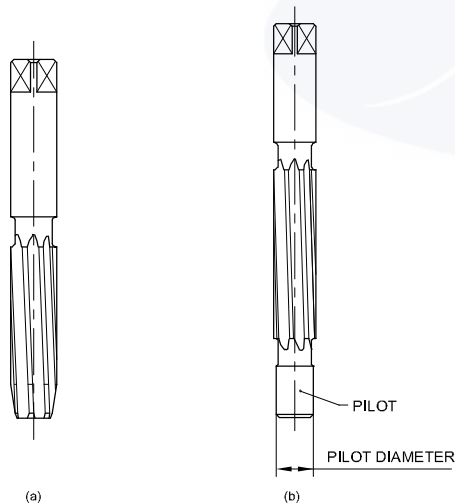
2 Hand reamer with pilot (Fig 4b)

For this type of reamer, a portion of the body is cylindrically ground to form a pilot at the entering end. The pilot keeps the reamer concentric with the hole being reamed.

3 Socket reamer with parallel shank (Figs 5a,b)

This reamer has tapered cutting edges to suit metric morse tapers. The shank is integral with the body, and is square shaped for driving. The flutes are either straight or helical.

Fig 4



MRN110834

The socket reamer is used for reaming internal morse tapered holes.

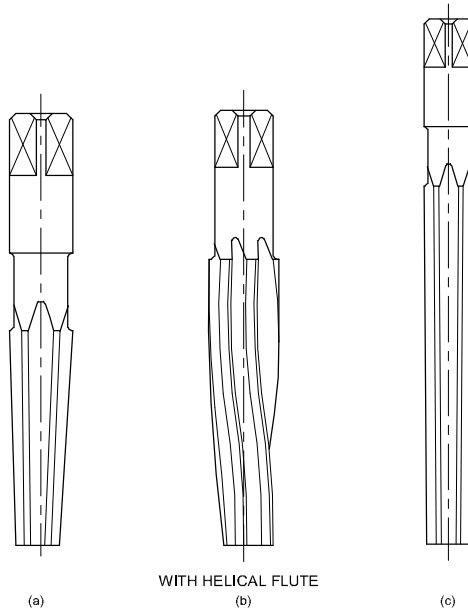
4 Taper pin hand reamer (Fig 5c)

This reamer has tapered cutting edges for reaming taper holes to suit taper pins. A taper pin reamer is made with a taper of 1 in 50. These reamers are available with straight or helical flutes.

Use of straight and helical fluted reamers (Fig 6)

Straight fluted reamers are useful for general reaming work. Helical fluted reamers are particularly suitable for reaming holes with keyway grooves or special lines cut into them.

Fig 5



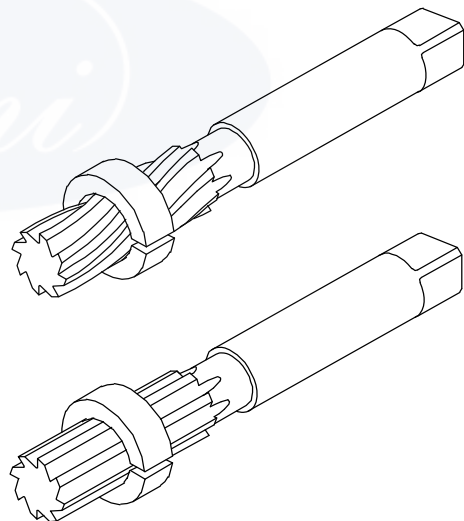
MRN110835

The helical flutes will bridge the gap and reduce binding and chattering.

Material of hand reamers

When the reamers are made as a one-piece construction, high speed steel is used. When they are made as two-

Fig 6



MRN110836

piece construction then the cutting portion is made of high speed steel while the shank portion is made of carbon steel. They are butt-welded together before manufacturing.

Specifications of a reamer

To specify a reamer the following data is to be given.

Type, Flute, Shank end Size

Example: Hand reamer, Straight flute, Parallel shank of f 20 mm.

Drill size for reaming

For reaming with a hand or a machine reamer, the hole drilled should be smaller than the reamer size.

The drilled hole should have sufficient metal for finishing with the reamer. Excessive metal will impose a strain on the cutting edge of the reamer and damage it.

Calculating drill size for reamer

A method generally practiced in workshop is by applying the following formula.

Drill size = Reamed size – (Undersize + Oversize)

Finished size

Finished size is the diameter of the reamer.

Undersize

Undersize is the recommended reduction in size for different ranges of drill diameter. (See Table 1)

Under sizes for reaming

TABLE 1

Diameter of ready reamed hole (mm)	Undersize of rough bored hole (mm)
under 5	0.1.....0.2
5.....20	0.2.....0.3
21....50	0.3.....0.5
over 50	0.5.....1



Snips

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

- state the six types of metal sheets used in sheet metal work
- state how the plate and the sheet are differentiated from each other
- state the features of a snip
- identify the different types of snips.

Sheet metal work

A large quantity of sheet metal used in the sheet metal industry is steel, rolled into sheets of various thicknesses and coated with zinc, tin or other metals. Other than steel, the worker uses sheets made out of zinc, copper, aluminium, stainless steel etc.

The term 'sheet metal' generally applies to metals and alloys in sheets rolled into various thicknesses less than 5mm. Sheets over 5 mm thick are called plates.

Earlier, the sheets were specified by standard wire gauge numbers. Each gauge is designated with a definite thickness. (Table 1) The larger the gauge number, the lesser the thickness. Now the sheet thickness is specified in mm, say 0.40, 0.50, 0.63, 0.80, 0.90, 1.00, 1.12, 1.25 etc.

Sheet thickness

Gauge No.	Inch	mm
18	0.048	1.22
19	0.040	1.02
20	0.036	0.91
21	0.032	0.81
22	0.028	0.71
23	0.024	0.61
24	0.022	0.56
25	0.020	0.51
27	0.0164	0.42
28	0.0148	0.38

Types of sheets

Sheet steel: It is an uncoated sheet with bluish-black appearance. The use of this metal is limited to articles that are to be painted or enamelled.

Galvanised iron sheet: The zinc-coated iron sheet is known as galvanised iron sheet, popularly known as GI sheet. The zinc coating resists rust. Articles like pans, buckets, furnaces, cabinets are made with GI sheet.

Copper sheets: Copper sheets are available either as cold-rolled or hot-rolled sheets. Cold-rolled sheets are worked easily in sheet metal shops. Gutters, roof flashing and hoods are common examples where copper sheet is used.

Aluminium sheets: Aluminium sheets are highly resistive to corrosion, whitish in colour and light in weight. They are widely used in the manufacture of a number of articles such as household utensils, lighting fixtures, windows etc.

Tin plates: Tin plate is sheet iron coated with tin to protect the iron sheet against rust. The size and thickness of the tin plate are denoted by special marks, not by gauge numbers.

Tin plates are used for food containers, dairy equipment, furnace fittings etc.

Brass sheet: Brass is an alloy of copper and zinc in various proportions. It will not corrode and is extensively used in craft.

Snips

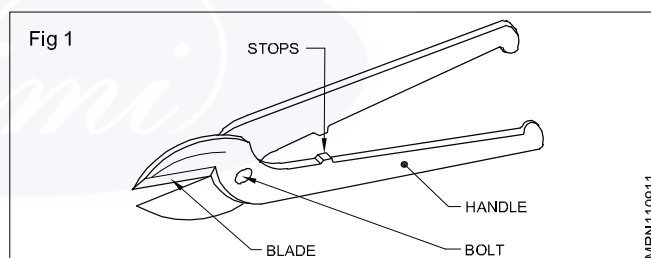
A snip is a cutting tool and is used for cutting thin sheets of metal.

There are two types of snips.

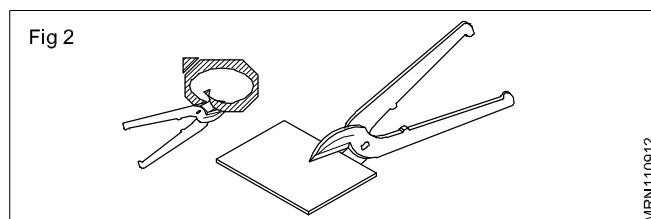
- Straight snips
- Bent snips

Parts of a straight snip (Fig 1)

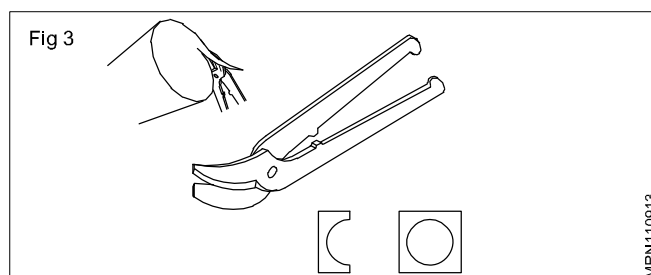
- Handle (1)
- Blade (2)
- Stops (3)



Straight snips: A straight snip has straight blades for straight line cutting. It can also be used for external curved cuts. (Fig 2)



Bent snip: Bent snips have curved blades used for cutting internal curves. For trimming a cylinder keep the lower blade on the outside of cut. (Fig 3)



Sheet metal seams and folding tools

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

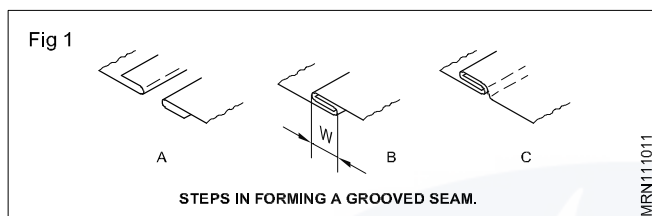
- state the types of seams.

Introduction

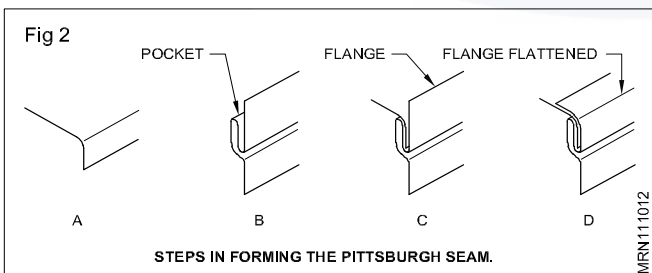
In Sheet metal construction, mechanical seams are employed when joining light and medium gauge metal sheets. While fabricating sheet metal articles, the sheet metal worker should be able to select the type of seam that is best suited for the specific job.

Types of seams

1 Grooved seam : Grooved seam is most commonly used for joining sheet metal. This seam consists of two folded edges called locks as shown in Fig 1. The edges are hooked together and locked with a hand groover or a grooving machine.



2 Pittsburgh seam: This seam is also called hammer lock or hobo lock. This seam is used as a longitudinal corner seam for various types of pipes such as duct work. The single lock is placed in a pocket lock and then the flange is hammered over, step by step as shown in Fig 2.



The advantage of the Pittsburgh seam is that the single lock can be turned on a curve and the pocket lock can be formed on a flat sheet and rolled to fit the curve as shown in Fig 3. If roll forming machine is not available in shop, Pittsburgh seam is formed on the brake.

3 Dovetail seam : This seam is an easy and convenient method of joining flanges to collars. There are three types of dovetail seams - plain dovetail, beaded dovetail and the flange dovetail as shown in Fig 4.

Dovetail seams are used mainly on round or elliptical pipe and rarely on rectangular ducts.

A Plain dovetail seam : It is used when joining a collar to a flange without the use of solder, screws or rivets. It is made by slitting the end of the collar and bending every other tab as shown in Fig 5

Fig 3

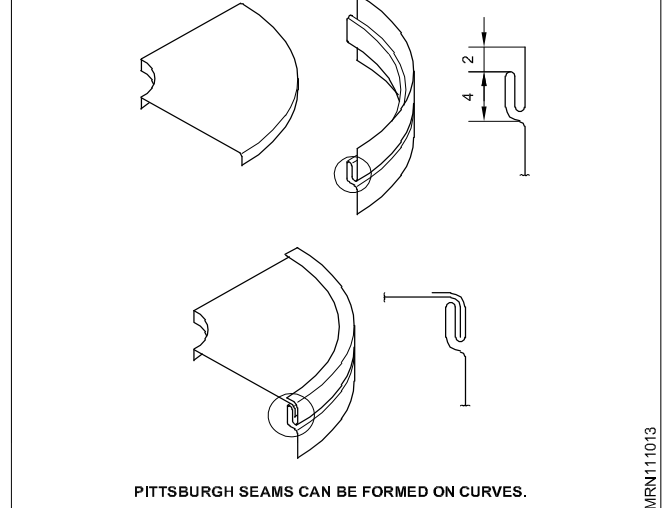
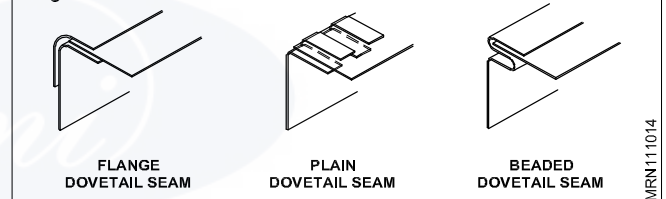
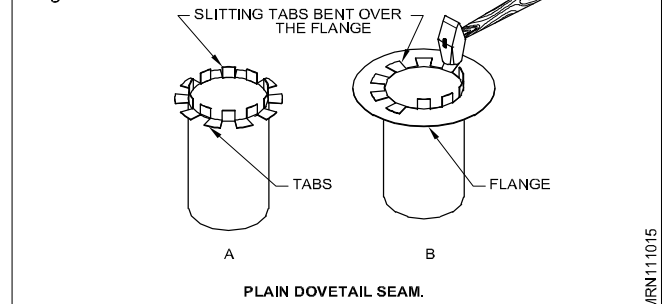


Fig 4



The straight tabs are bent over the part to be joined and the bent tabs act as stops. This seam may be made water tight by soldering around the joint.

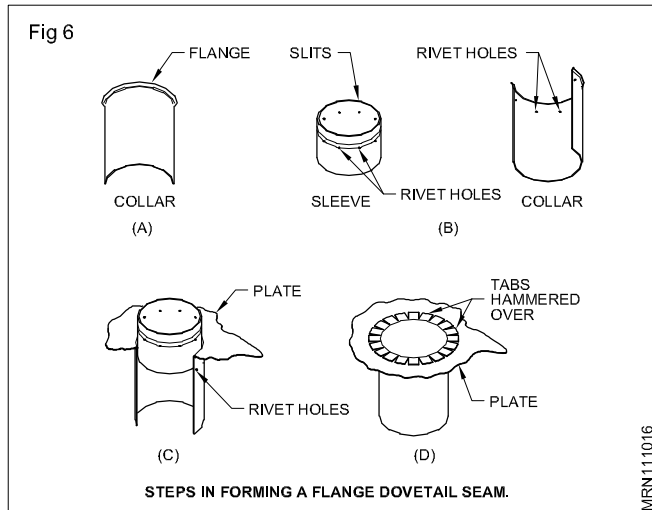
Fig 5



B Flange dovetail seam

This seam is used where neat appearance and strength are important. The seam shown in Fig 6 is the assembly of a flange type dovetail seam for a cylindrical pipe. It is commonly used where pipes intersect with a metal plate such as furnace flues, ceilings etc. Steps in forming a flange dovetail seam are shown in Fig 6. First, a flange is turned on the collar, next, slits are cut at regular intervals at the end of the sleeve and matching rivet

holes are drilled in the sleeve and the collar. The rivet holes are aligned and the rivets are installed and finally the tabs are hammered over to complete the seam.



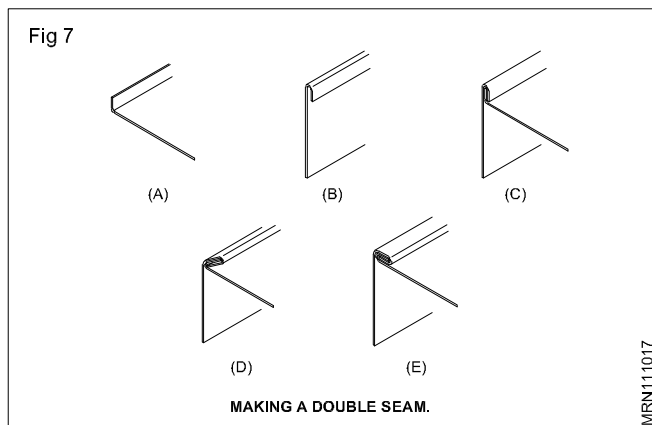
C Beaded dovetail seam

This is similar to the plain dovetail seam, except a bead is formed around one end of the cylinder by a beading machine. This bead acts as the stop for the flange to rest upon and the tabs are bent over to hold the flange in the desired place.

4 Double seam

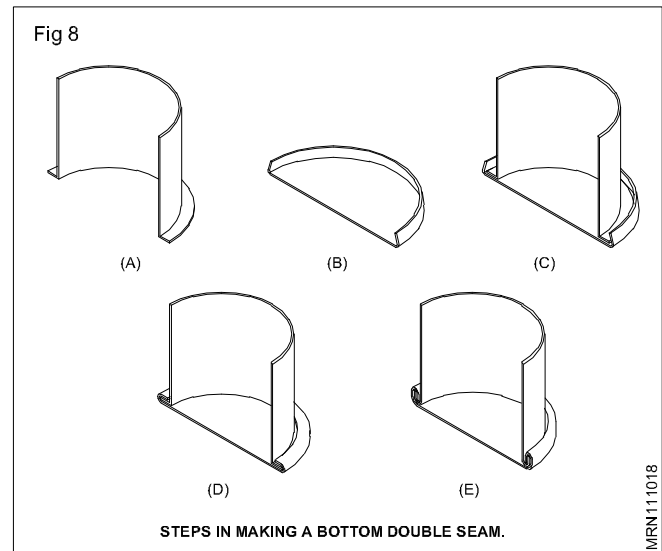
There are two types of double seams. One type is used for making irregular fittings such as square elbows, boxes, offsets, etc. This seam is used on corners and can also be used as a longitudinal seam on small square and rectangular ducts. A double edge is formed and placed over the single edge and the seam is completed step by step as shown in Fig 7.

The other type is used to fasten bottoms to cylindrically shaped jobs such as pails, tanks etc.



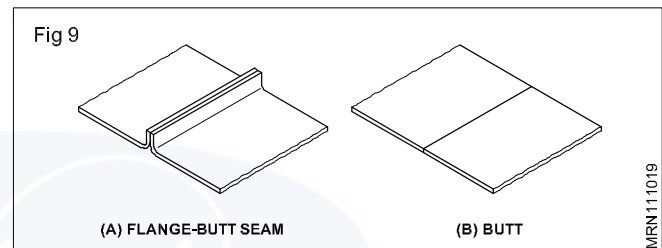
The steps in making this type of double seam is shown in Fig 8, where A is turned on the machine. B is burred on the burring machine. The bottom is snapped on the body as in C and is peened down as in D. Finally the seam is completed by using a mallet as in E. This seam is called Bottom double seam or Knocked up seam.

If the seam is not turned up, as in D, the seam is called paned down seam.



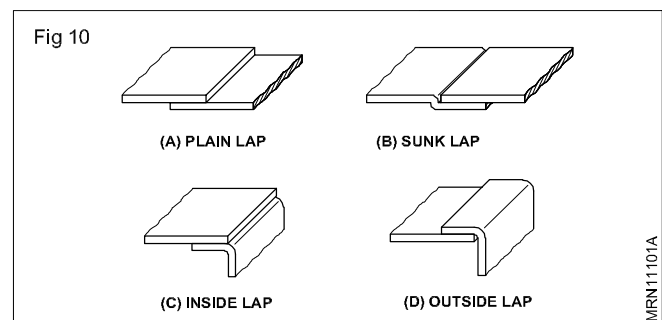
5 Butt seam

This seam has two pieces butt together and soldered as shown in Fig 9. Figure shows two types of butt seams. One is flanged butt seam and the other one is butt seam.



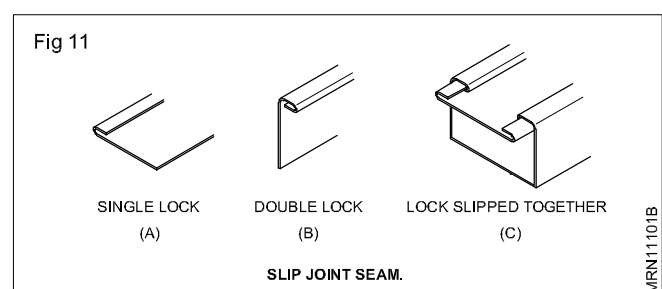
6 Lap seam

The lap seam is made by lapping the edge of one piece over the other piece and soldered as shown in Fig 10. Figure shows plain lap, sunk lap, inside lap and outside lap seams.



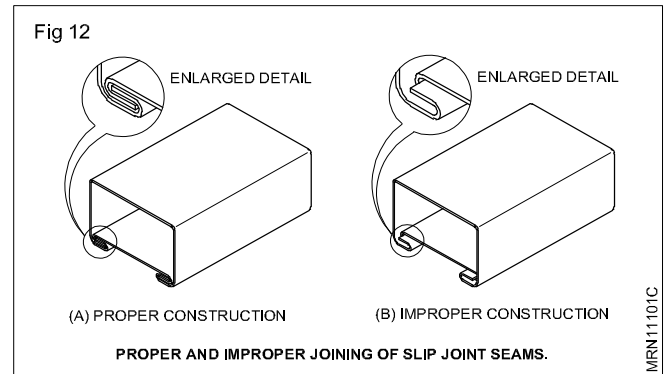
7 Slip joint seam

This seam is used for a longitudinal corner seam as shown in Fig 11.



The assembly of the seam consists of a single lock A and a double lock B. The single lock is slipped into the double lock C to complete the seam.

For making pipes with a slip joint seam, proper care should be taken to see that the corners of the metal are squared and the edges are trimmed. The proper slip joint is shown as A and improper as B in Fig 12. If the edges are not trimmed, it will twist the pipe out of shape and may cause the edges of the pipe to be uneven.



Locked grooved joint (Seam)

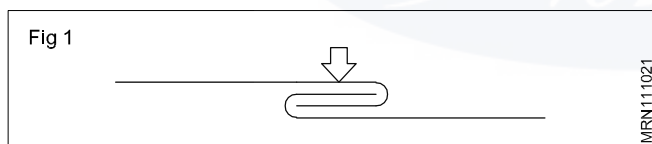
Objectives: At the end of this lesson you shall be able to

- state the purpose of a joint
- state the use of the groover
- determine the allowance for the locked grooved joint
- know the type of shears
- know the uses of shears
- know about the shearing force
- know the blade clearance for optimum cutting.

Locked grooved joint: Many methods are employed to join and strengthen the pieces of a sheet metal. One of the common joint is called locked grooved joint.

This is usually done on straight lines. The work pieces to be joined are made in the form of a hook, inserted and locked using a groover.

When they are interlocked and tightened only then it is called a “grooved joint” (Fig 1).



When the grooved joint is clinched down, making one side plane using a groover is called a “Locked grooved joint”. (Fig 2)



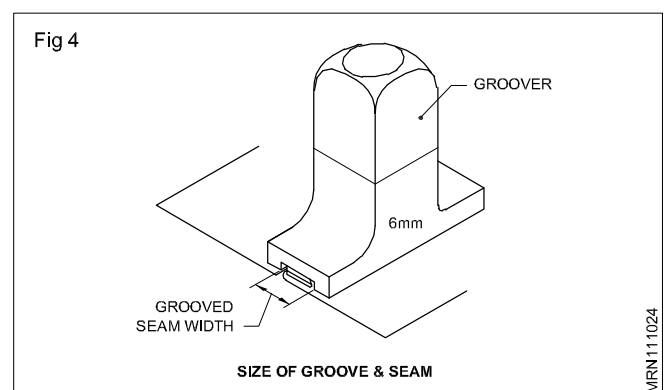
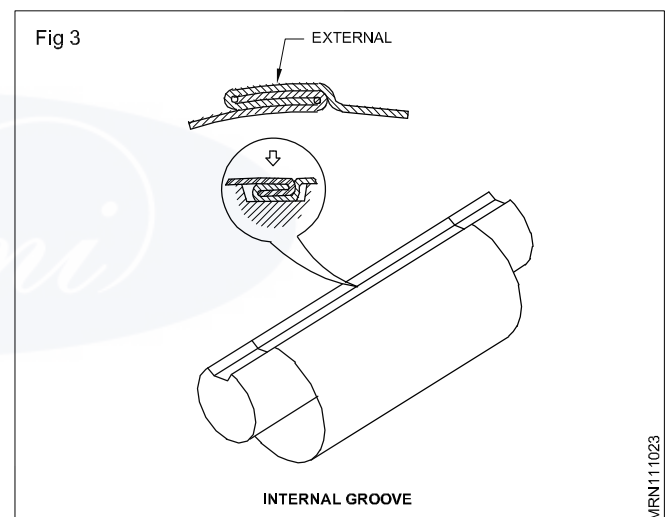
External and internal locked grooved joints: This joint is used to join the two ends of a sheet metal to form a circular shape in longitudinal direction. When the seam is formed outside as shown in Fig 3 then it is called ‘external locked grooved joint’.

If the seam is formed using grooved mandrel then it is called ‘Internal locked grooved joint’ (Fig 3)

Hand groover: The hand groover is made up of cast steel and is used to make external locked grooved joint.

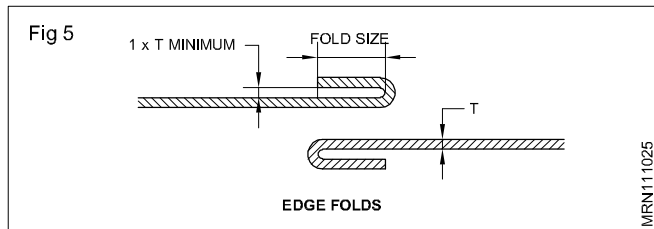
A groove is made at the bottom of this tool to the required width and depth.

This has a handle in square or hexagonal shape like chisel to hold. This whole part is hardened and tempered. (Fig 4)



The hand groover is specified according to the size of the groove of the groover.

Locked grooved joint allowance: To arrive the size (width) of the fold to suit a particular groover, subtract the thickness by 3 times from the width of the groove. (Fig 5)



For example, the width of the groove is 6 mm and the sheet thickness is 0.5 mm,

Then the width of the fold

$$= 6 - (3 \times 0.5)$$

$$= 4.5 \text{ mm (See Fig 6).}$$

Stake Joint

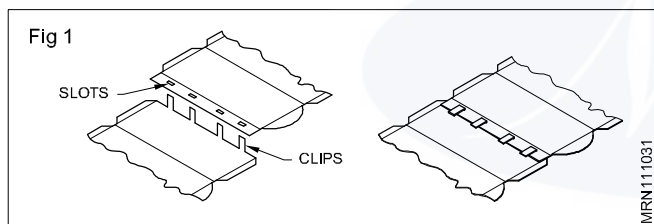
Objectives: At the end of this lesson you shall be able to

- state the applications of stake joint
- state the types of stake joints.

Stake joint

It is one of the folded joint and is used in light articles such as toys. It is also called as toy joint.

In this type of joint, clips are cut on one piece of metal and slots are cut on another piece to be jointed. Clips are inserted in slots and folded flat either in one direction or alternate clips are folded in opposite direction. (Fig 1)



Type of stake joint

A Straight stake joint B Zigzag stake joint

Folding tools

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

- state the uses of different folding tools.

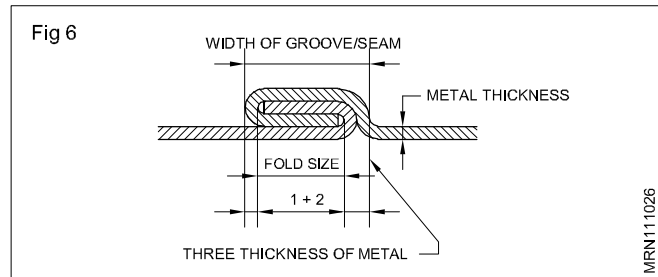
The common tools used in the folding of sheet metal are:

- angle steel and folding bar
- C clamp
- stakes
- mallet.

Angle steel: Two pieces of angles are used for folding at 90°. For longer sheets lengthy angles will be used along clamp (or) hand vice. (Fig 1)

Folding bar: The sheet metal to be bent is clamped in the folding bars. The folding bars are clamped in the vice as shown in the figure. (Fig 2)

'C' clamp: The shape of the clamp is in the form of the letter 'C'. 'C' clamp is a holding device. This clamp is used

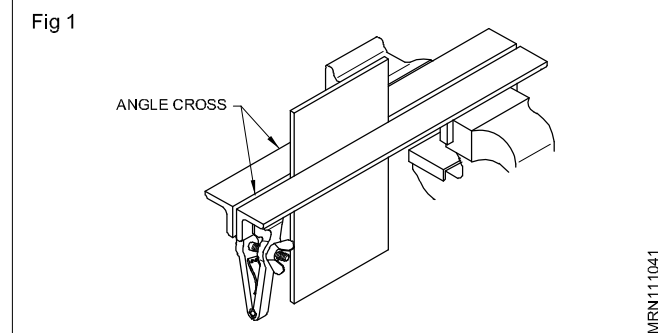
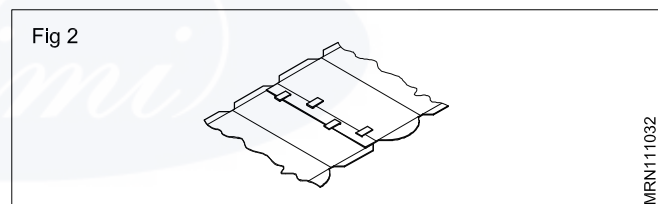


Straight stake joint

In this joint, clips and slots are in a line and the clips are inserted directly into the slots, folded and smashed in opposite direction. (Fig 1)

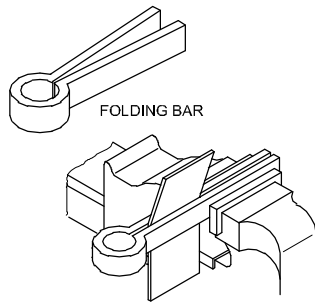
Zigzag stake joint

In this joint, clips are inserted in the slots, and alternate clips are folded in opposite direction. (Fig 2)



when the piece has to be securely fixed to another piece. It is available in different sizes according to the opening of the jaws. (Fig 3)

Fig 2



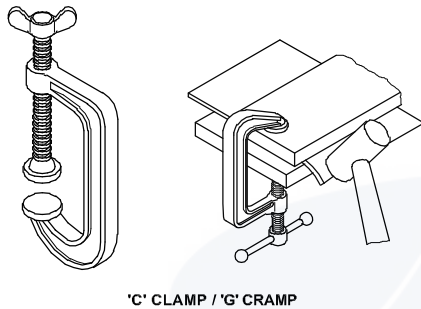
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Stakes: Stakes are used for bending, seaming and forming of sheet metal that cannot be done on any regular machine. For the above purposes, different stakes are used. Stakes are made of forged steel or cast steel.

Types of stakes

- Hatchet stake
- Square stake

Fig 3



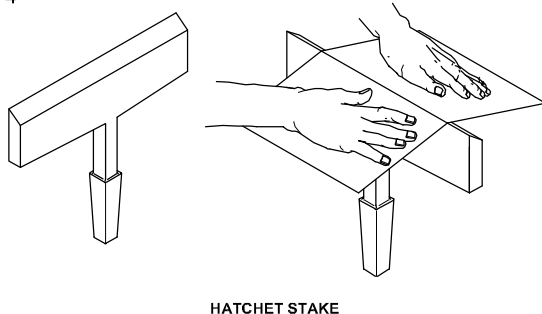
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- Blow-horn square stake
- Bevel-edge square stake.

Hatchet stake: A hatchet stake has a sharp straight edge bevelled on one side. It is used for making sharp bends, for bending edges and for folding sheet metal. (Fig 4)

Square stake: A square stake has a flat and square-shaped head with a long shank. It is used for general purposes. (Fig 5)

Fig 4



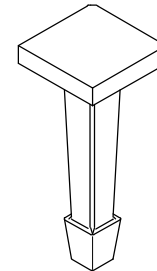
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Blow-horn stake: It has a short tapered horn at one end, and a long tapered one at the other end. It is used in forming, riveting or seaming tapered, cone-shaped articles, such as funnels etc. (Fig 6)

Bevel-edged square stake: A bevel-edged square stake is used to form corners and edges. (Fig 7)

Mallet: A mallet is used for working on sheet metal. It will not damage the sheet surface while working. Mallets are made of wood, rubber, copper etc. (Fig 8)

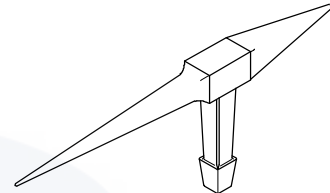
Fig 5



SQUARE STAKE

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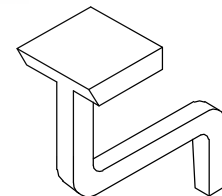
Fig 6



BLOW HORN STAKE

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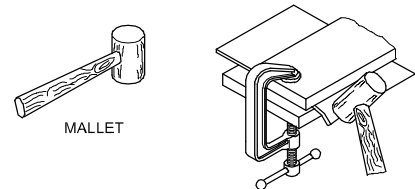
Fig 7



BEVEL-EDGED SQUARE STAKE

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Fig 8



MALLET

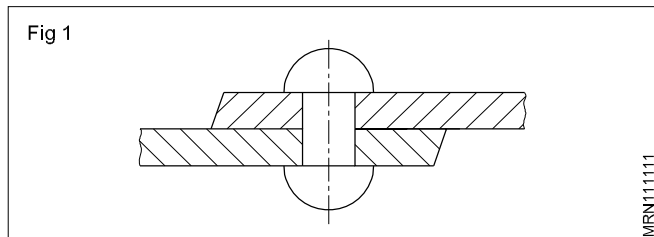
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Securing metal sheets by rivetting

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

- define riveting
- state the uses of rivets
- name the materials from which rivets are made
- identify the different types of rivets.

Riveting: Riveting is one of the satisfactory methods of making permanent joints of two pieces - metal snips. (Fig 1)



It is customary to use rivets of the same metal as that of the parts that are being joined.

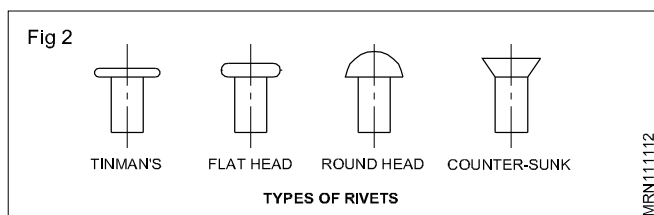
Uses: Rivets are used for joining metal sheets and plates in fabrication work, such as bridges, ships, cranes, structural steel work, boilers, aircraft and in various other works.

Material: In riveting, the rivets are secured by deforming the shank to form the head. These are made of ductile materials like low carbon steel, brass, copper and aluminium.

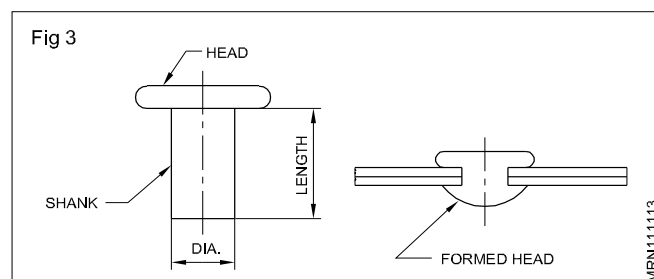
Types of rivets (Fig 2)

The four most common types of rivets are:

- tinmen's rivet
- flat head rivet
- round head rivet
- countersunk head rivet.



Each rivet consists of a head and a cylindrical body called as shank. (Fig 3)



Sizes of rivets: Sizes of rivets are determined by the diameter and length of the shank.

Selection of rivet size: The diameter of the rivet is calculated by using the formula

$$D = \left(\frac{21}{2} \text{ to } 3 \right) \times T \text{ where } T \text{ is total thickness.}$$

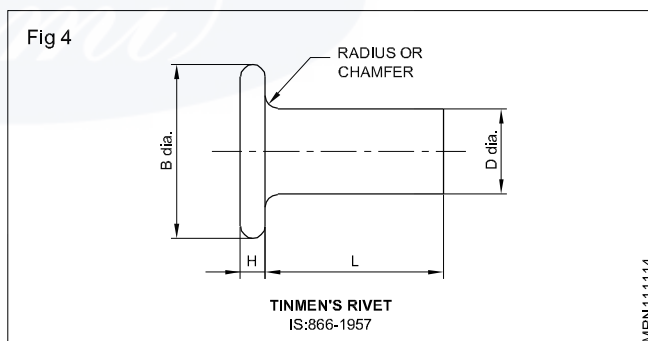
The shank length is given by

$$L = T + T + \left(\frac{11}{2} D \right)$$

where 'T' is the sheet thickness and 'D' is the diameter of the rivet.

Normally tinmen's rivets are designated by numbers.

The ISI table giving the dimension of the tinmen's rivets is given below. (Fig 4)



Method of riveting: Riveting may be done by hand or by machine.

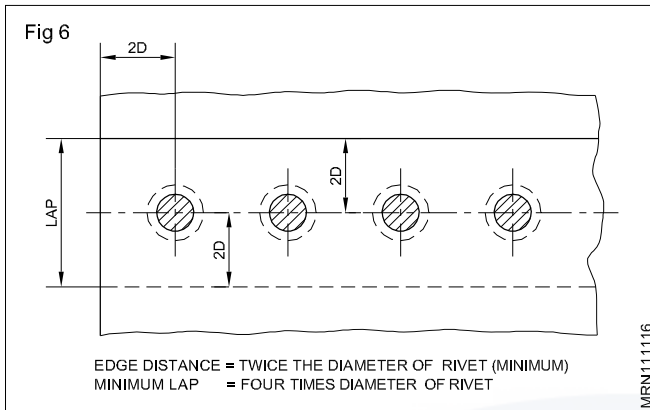
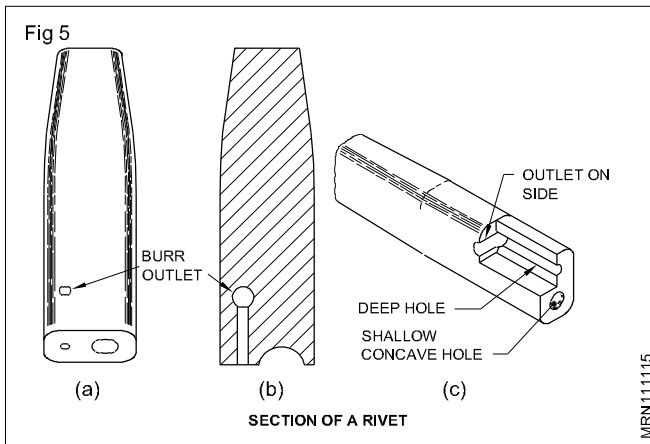
While riveting by hand, it can be done with a hammer and a rivet set.

Rivet set: A cross-section of a rivet set is shown in the figure 5a, b and c. The shallow, cup-shaped hole is used to draw the sheet and the rivet together. The outlet on the side allows the slug to drop out.

The cup shape is used for forming the rivet head.

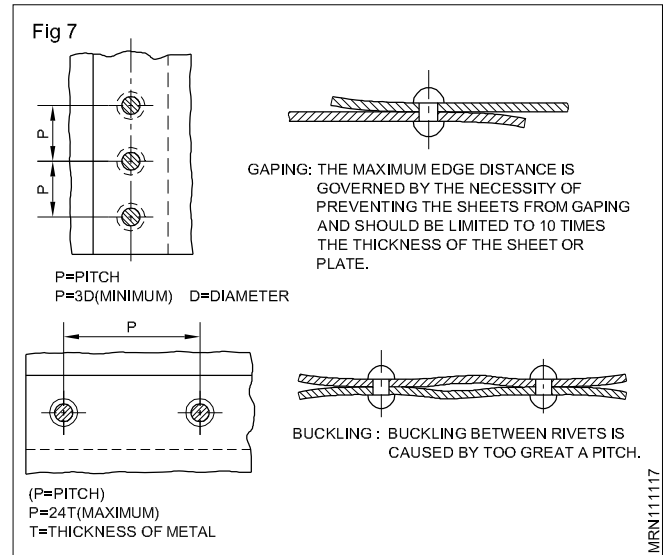
The rivet set selected should have a hole slightly larger than the diameter of the rivet.

Spacing of rivets: The space or distance from the edge of the metal to the centre of any rivet should be atleast twice the diameter of the rivet to avoid tearing. The 'Lap' distance (4D) is shown in Fig 6.



The minimum distance between the rivets (pitch) should be sufficient to allow the rivets to be driven without interference. The distance should be atleast three times the thickness of the sheet or above.

The maximum distance should never exceed 24 times the thickness of the sheet. Otherwise buckling will take place as shown in Fig 7.



Soldering

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

- state the process of soldering
- state the different types of solder and their application.

There are different methods of joining metallic sheets. Soldering is one of them.

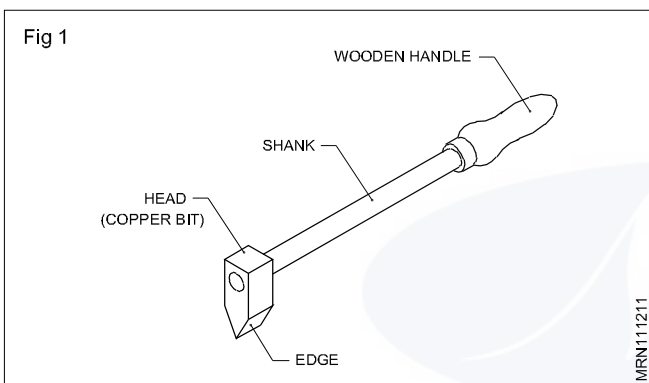
Soldering is the process by which metallic materials are joined with the help of another liquified metal (solder).

The melting point of the solder is lower than that of the materials being joined.

The solder wets the base material without melting it.

Soldering iron (Fig 1)

The soldering iron is used to melt the solder and heat the metal that are to be joined together.



A soldering iron has the following parts.

- Head (copper bit)
- Shank
- Wooden handle
- Edge

Shape of head

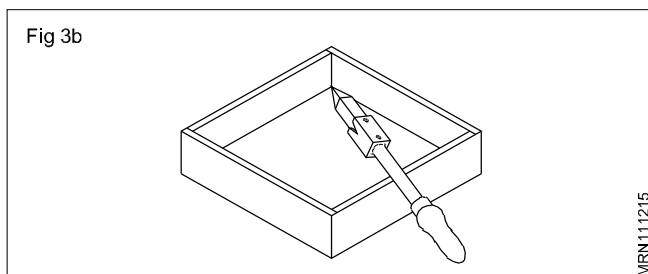
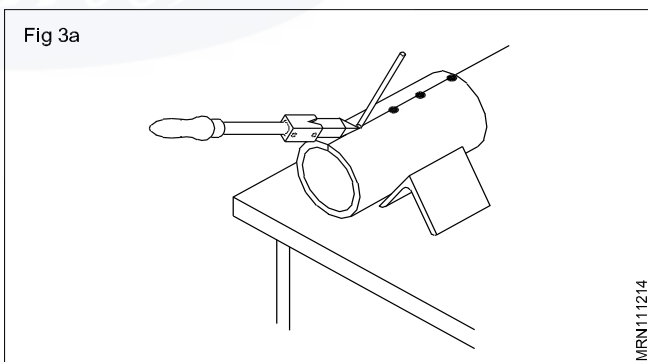
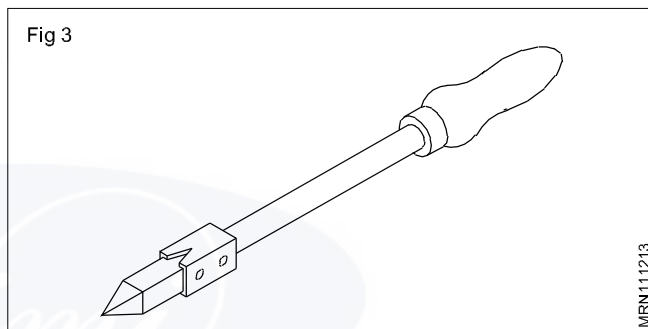
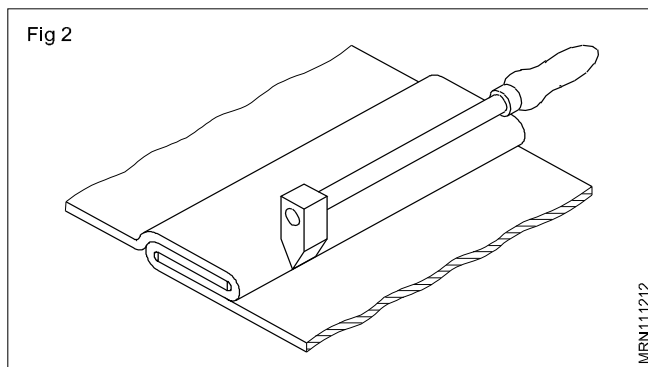
The head of the iron is made of forged copper. This is because copper has a good heat conductivity and has a strong affinity for the solder so that the solder melts easily and sticks to the bit.

A Hatchet type soldering as in (Fig 1) has shank fitted at 90° to the head. The soldering edge is 'V' shaped.

This type is used for straight soldering joints. (Fig 2)

The other type is the square pointed soldering iron or a standard workshop pattern soldering iron. (Fig 3) For this type the edge is shaped to an angle on four sides to form a pyramid shape.

This is used for tacking and soldering of joining points. (Fig 3a and 3b)

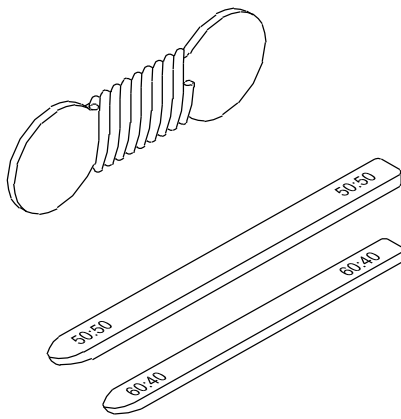


Solders

Pure metals or alloys are used for solders.

Solders are applied in the form of wires, sticks, ingots, rods, threads, tapes, formed sections, powder and pastes. (Fig 4)

Fig 4



Types of solders

There are two types of solders.

- Soft solder
- Hard solder

One distinguishes between soft solders whose melting points are below 450° C and hard solders whose melting points lie above 450° C.

Soft solders

These are alloys of the metals- tin, lead, antimony, copper, cadmium and zinc and are used for soldering heavy (thick) and light metals.

Hard solders

These are alloys of copper, tin, silver, zinc, cadmium and phosphorus, and are used for soldering heavy metals.

Flux

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

- state the criteria for the selection of fluxes
- distinguish between corrosive and non-corrosive fluxes
- name the different types of flux and their application.

Fluxes are non-metallic materials which are used at the time of soldering.

Functions of flux

- Flux removes oxides from the soldering surface.
- It prevents corrosion.
- It helps molten solder to flow easily in the required place.
- It promotes the wet surface.

Selection of flux

The following criteria are important for selecting a flux.

- Working temperature of the solder
- Soldering process
- Materials to be joined.

Classes of flux

Flux can be classified into corrosive flux, and non-corrosive flux.

Corrosive flux in acid form is corrosive and should be washed immediately after the soldering operation is completed.

Non-corrosive flux is in the form of lump, powder, paste or liquid.

Different types of fluxes

1 Hydrochloric acid

Concentrated hydrochloric acid is a liquid which fumes when it comes into contact with air. After mixing with water, 2 or 3 times the quantity of the acid, it is used as dilute hydrochloric acid.

Hydrochloric acid combines with zinc forming zinc chloride and acts as a flux. So it cannot be used as a flux for sheet metals other than zinc, iron or galvanised sheets.

2 Zinc chloride

It is mainly used for soldering copper sheets, brass sheets and tin plates.

As it is extremely corrosive, the flux must be perfectly washed off after soldering.

3 Ammonium chloride

This is in the form of powder or lump. It evaporates when heated.

Ammonium chloride, dissolved in water, is used as a flux for soldering steel.

A solution of a mixture of hydrogen chloride, zinc chloride and ammonium chloride is used as a flux for stainless steel sheets.

4 Resin

As resin is not very effective for removing oxidation coating, and, as it is not highly corrosive, it is used as flux for copper and brass. Resin melts at about 80° to 100°C.

5 Paste

This is a mixture of zinc chloride, resin, glycerine and others and is available as a paste.

As it is effective for removing oxidation coating, it is used for soldering small handworks and radio wiring.

Development of surface

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

- state what is a pattern, a layout and a stretch out
- state & notching and clipping the allowances for edges and seaming considered in pattern development
- state different methods of pattern layout development.

Pattern: The pattern is a piece of material, which is cut to the exact size and shape, to form the desired object.

It is nothing but, a flat outline of an object, to be formed to its final shape.

The pattern may be drawn on a paper first, then transferred to the sheet metal. This makes possible the corrections if any, saving valuable material. Paper patterns are not suitable for repeated use.

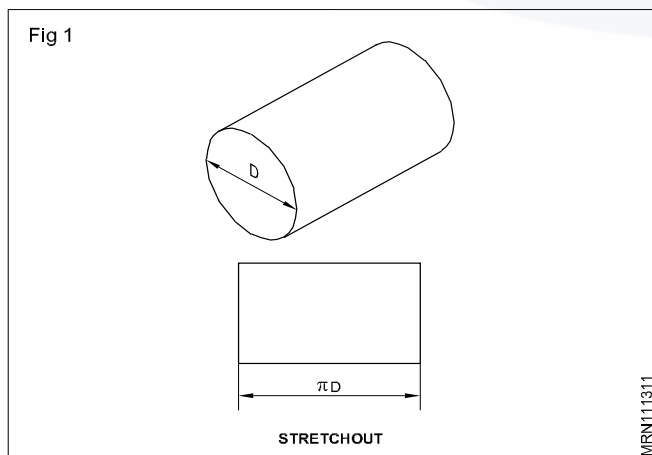
However, experienced skilled sheet metal worker do pattern layouts directly on the sheet metal.

Layout: It is the method of developing the lines and curves which form the pattern.

Pattern layout is done by employing different geometrical constructions.

Different geometrical constructions are taught in the engineering drawing subject.

Stretchout: The term “stretchout” refers to the sizes of flat piece of metal before it is formed into shape. For example, the stretchout of a round pipe is the circumference of the pipe. (Fig 1)



Allowances for edges and seaming, considered in pattern layout development.

Allowances of edges: Different types of edges, are used to stiffen the edges of sheet metal articles and to eliminate sharp edges.

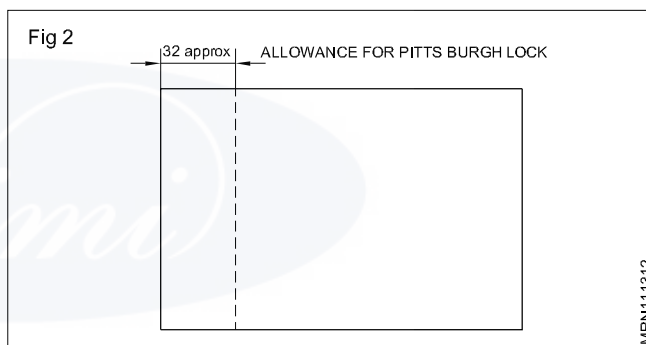
Edges are made either by bending or by wrapping the metal.

The amount of metal allowed for the edges is called allowance for edges.

The following table shows the allowance for different edge.

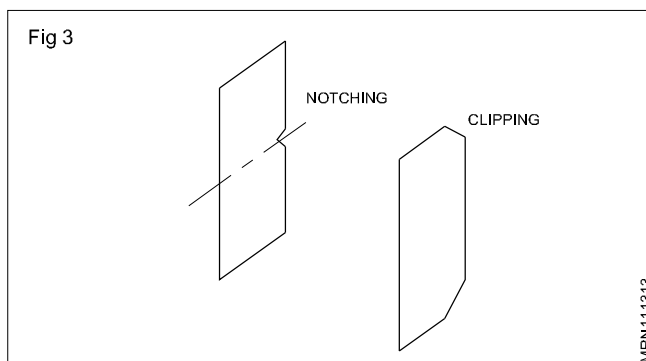
S.No	Type of edge	Allowance generally kept
1	Single hem	6 mm above 22 gauge sheet 8 mm below 22 gauge sheet
2	Double hem	Twice the hem size - 1.6 mm
3	Wired edge gauge sheet	2.5 x dia of wire - above 24G 2.5 x dia of wire + thickness of metal - below 24 gauge sheet

Allowances for seaming: Sheet metal parts are joined by various types of seams. The amount of metal allowed for seaming is called “Allowances for seaming”. The following table shows the allowance for different seams. (Fig 2)



S.No	Type of edge	Allowance generally kept
1	Grooved seam	3 x width of lock above 24 gauge sheet 3 x width of lock + 5 thickness of metal-below 24 gauge sheet

Allowances for Notching & Clipping: Notching and clipping are used to cut away that portions of the metal to prevent overlapping and bulging on seams and edges. (Fig 3) For detail information, please refer next lesson.



Four methods are commonly used for pattern development.

- 1 Parallel line development method
- 2 Radial line development method

- 3 Triangulation development method
- 4 Geometric construction method.

Parallel line development method

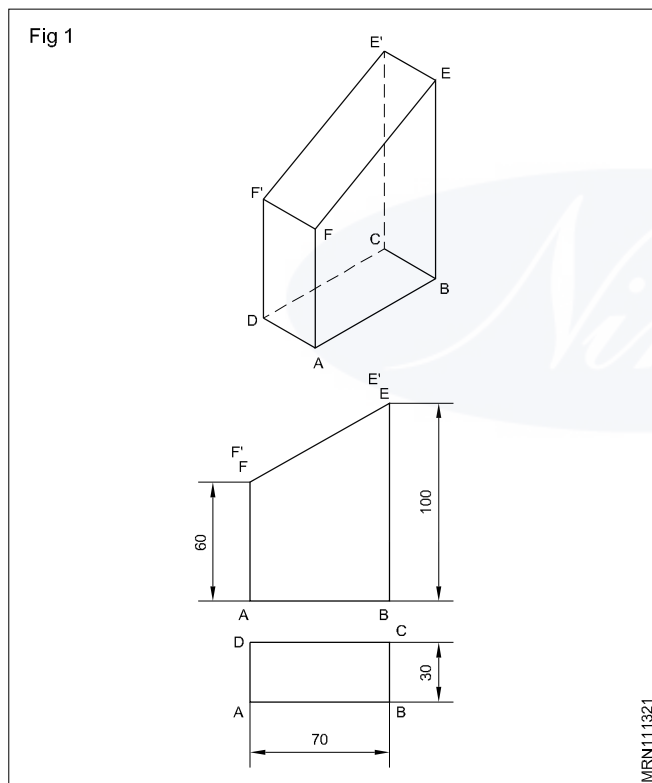
Objectives: At the end of this lesson you shall be able to

- state what is parallel line development method
- layout patterns for simple objects by parallel line development method.

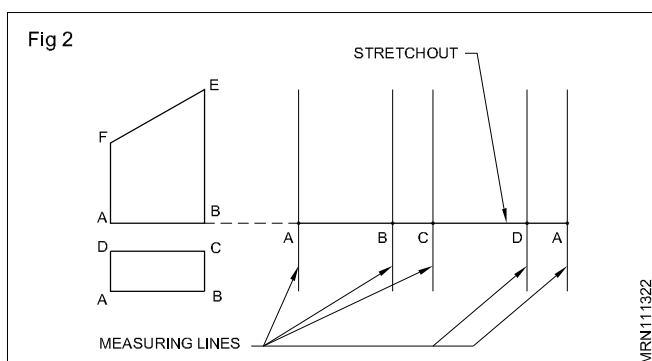
Parallel line development method: Parallel line development method is used for pattern development of the objects whose sides run parallel to one another as in ducts, elbows and T joints.

In developing any pattern by parallel line development method, following procedure is followed (for illustration refer object shown in Fig 1).

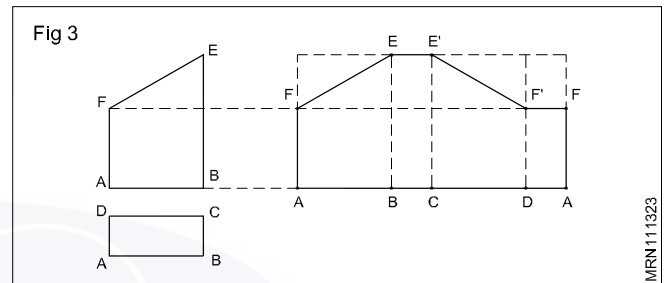
- 1 Draw the elevation and plan of the object with dimensions (Fig 1)



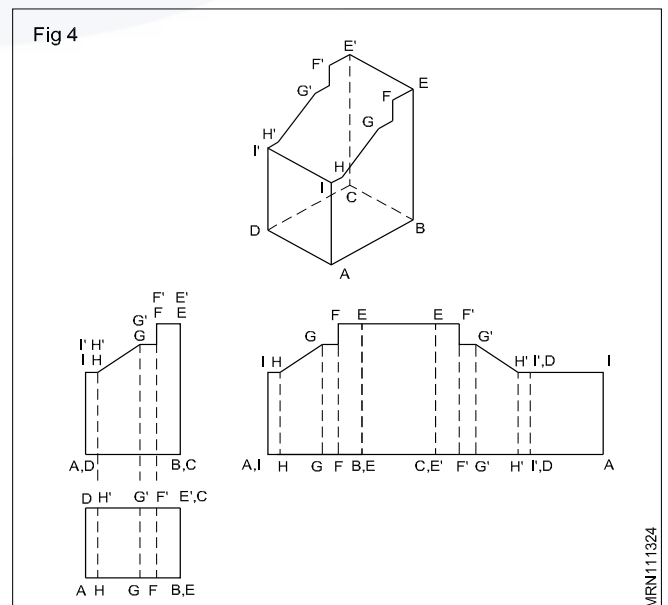
- 2 Draw the stretchout of the pattern (Fig 2).



- 3 Locate measuring lines from elevation or plan on the pattern stretch out. While locating measuring lines, these lines should be in proper distance apart and in proper order.(Fig 3)
- 4 Transfer the lengths of the measuring lines from elevation to the same lines on the pattern.(Fig 3)
- 5 Connect the points located on the measuring lines. (Fig 3)



By this method, the pattern layout of the following object is shown for better understanding of parallel line development method. (Fig 4)

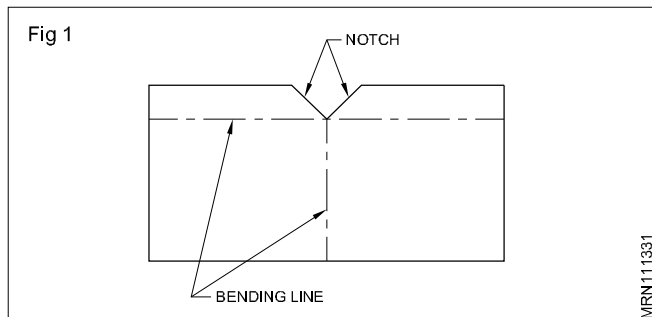


Notches in sheet metal

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

- state the purpose of notches
- name the types of notches
- distinguish the features of different notch forms and state the uses of each.

Notches: Notches are the spaces provided for joining the edges when sheet metals are cut from the layout. (Fig 1)



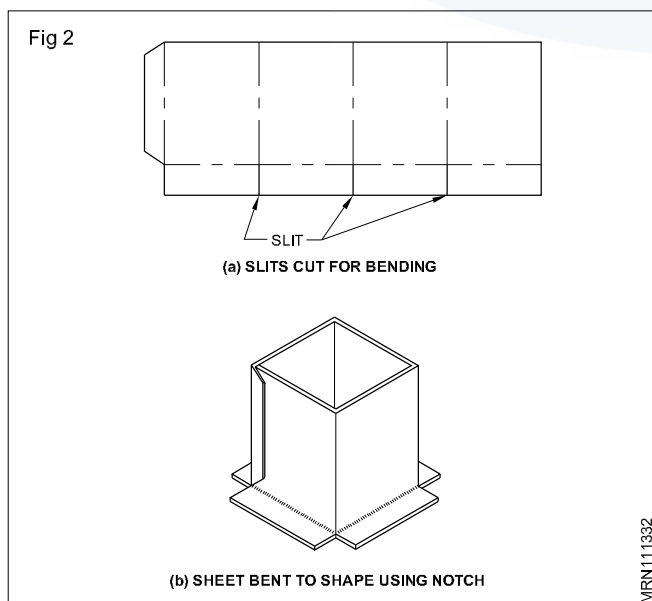
Purpose of notches

Notches help to :

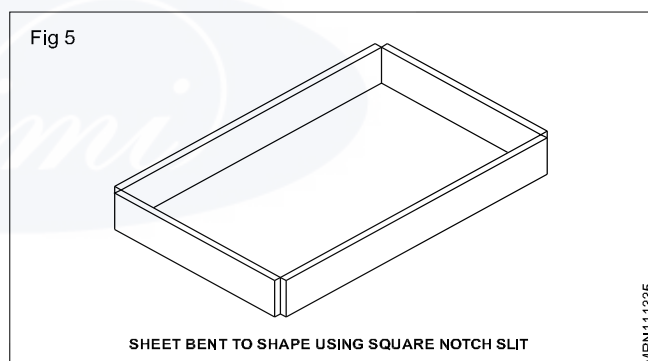
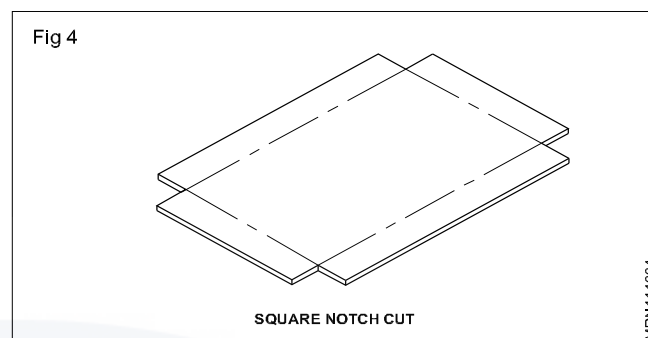
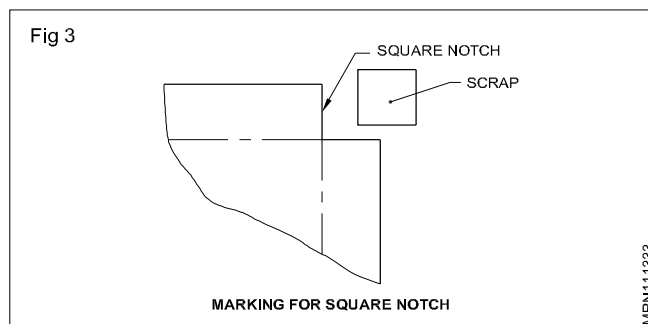
- to prevent surplus material from overlapping and causing a bulge at the seam and edges
- to allow the work to be formed to the required size and shape
- to allow the work to assemble better.

Types of notches

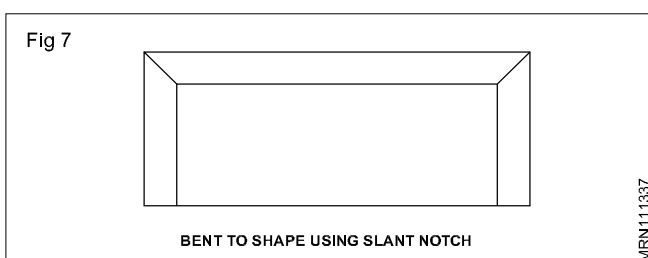
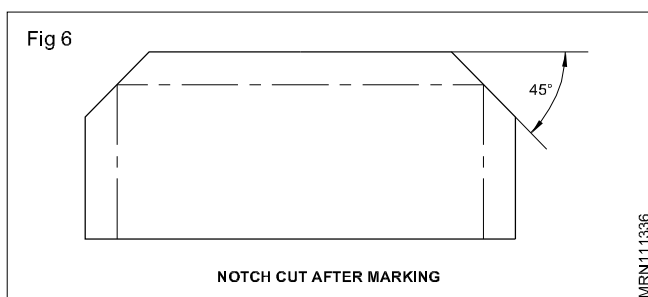
Straight notch or slit: Straight cuts made from the edge of the sheet to a distance where it is to be bent is known as a straight notch. (Figs.2a and 2b)



Square notch: A square notch is used when forming a square or rectangular box. (Figs.3,4 and 5)



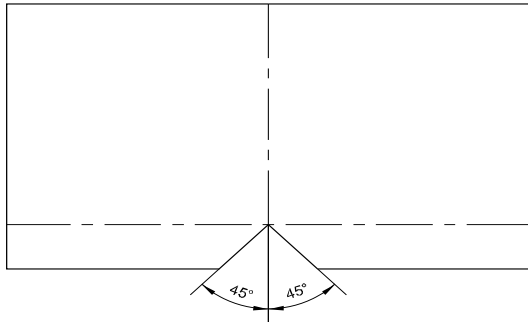
Slant notch: This notch is cut at an angle of 45° to the corner of the sheet. It is used when a single hem meets at right angles. (Figs.6 & 7)



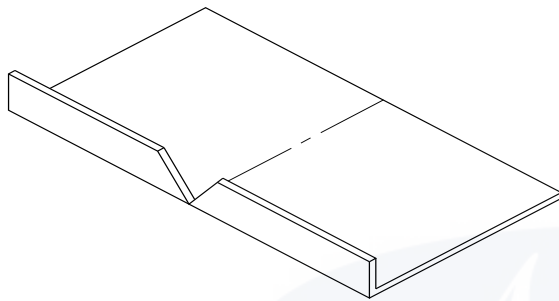
V' Notch: In this notch, both the sides are cut at a 45° angle to the edge of the sheet.

The sides of the notch meet at 90°. This notch is used when making a job with a 90° bend and an inside flange. (Figs.8, 9 and 10)

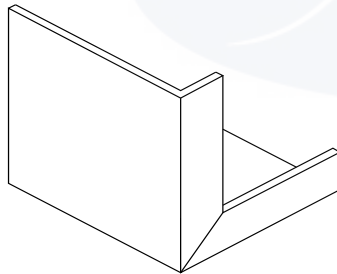
Fig 8



(a) 'V' NOTCH MARKED AND CUT



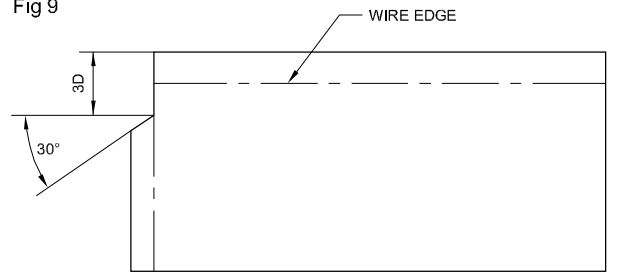
(b) FIRST FOLDING 'V' NOTCH



(c) BENT TO SHAPE USING 'V' NOTCH

MRN11338

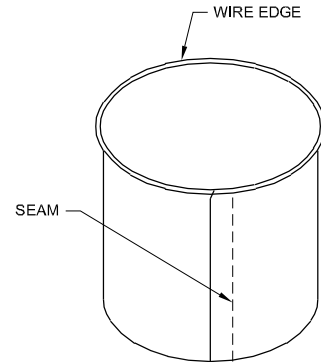
Fig 9



WIRE NOTCH MARKED CUT

MRN11339

Fig 10



AN EDGE WIRED USING WIRE NOTCHES

MRN1133A

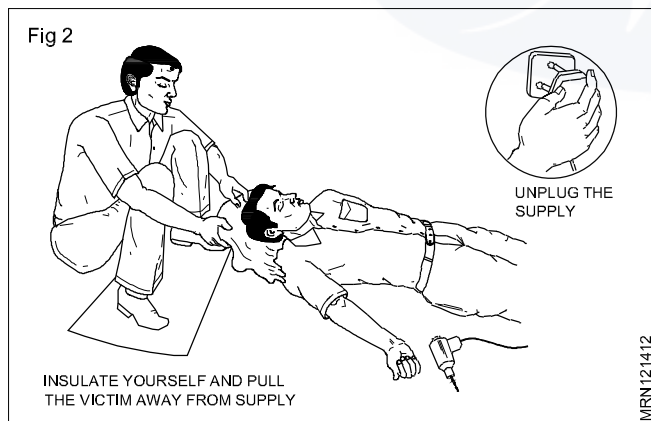
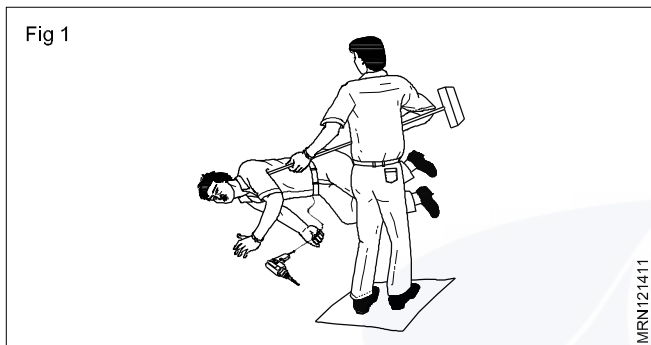
Electrical safety precaution and first aid

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

- rescue a person who is in contact with a live wire
- safety practice-first aid for electric shock and injury.

The severity of an electric shock will depend on the level of current which passes through the body and the length of time of contact. Do not delay, act at once. Make sure that the electric current has been disconnected.

If the casualty is still in contact with the supply - break the contact either by switching off the power, removing the plug or wrenching the cable free. If not, stand on some insulating material such as dry wood, rubber or plastic, or using whatever is at hand to insulate yourself and break the contact by pushing or pulling the person free. (Figs 1 & 2)



If you remain un-insulated, do not touch the victim with your bare hands until the circuit is made dead or person is moved away from the equipment.

If the victim is aloft, measures must be taken to prevent him from falling or atleast make him fall safe.

Safety practice- first aid

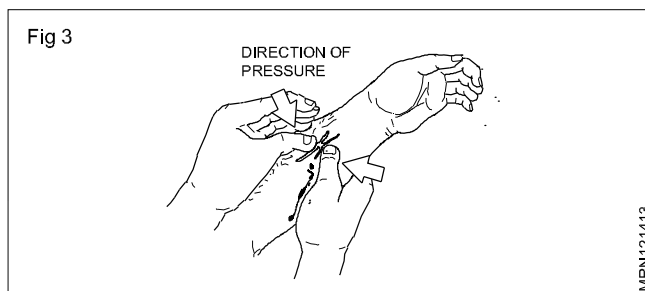
Objectives: At the end of this lesson you shall be able to

- explain how to treat a person affected due to electric shock/injury.

Electric shock: The severity of an electric shock will depend on the level of the current which passes through the body and the length of time of the contact.

Electric burns on the victim may not cover a big area but may be deep seated. All you can do is to cover the area with a clean, sterile dressing and treat for shock. Get expert help as quickly as possible.

If the casualty is unconscious but is breathing, loosen the clothing about the neck, chest and waist and place the casualty in the recovery position. (Fig 3)



Keep a constant check on the breathing and pulse rate.

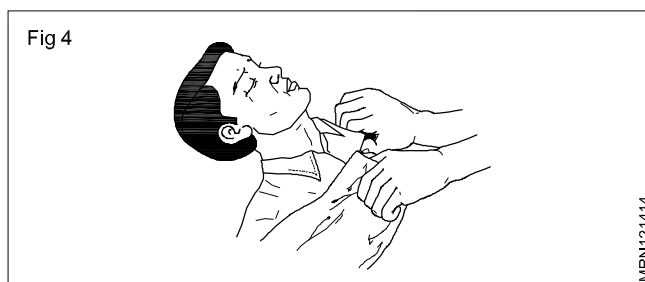
Keep the casualty warm and comfortable. (Fig 4)

Send for help.

Do not give an unconscious person anything by mouth.

Do not leave an unconscious person unattended.

If the casualty is not breathing - Act at once - don't waste time!



- not wearing insulating footwear or wearing wet footwear
- weather condition
- floor is wet or dry
- mains voltage etc.

Effects of electric shock: The effect of current at very low levels may only be an unpleasant tingling sensation, but this by itself may be sufficient to cause one to lose his balance and fall.

At higher levels of current, the person receiving the shock may be thrown off his feet and will experience severe pain, and possibly minor burns at the point of contact.

At an excessive level of current flow, the muscles may contract and the person unable to release his grip on the conductor. He may lose consciousness and the muscles of the heart may contract spasmodically (fibrillation). This may be fatal.

Electric shock can also cause burning of the skin at the point of contact.

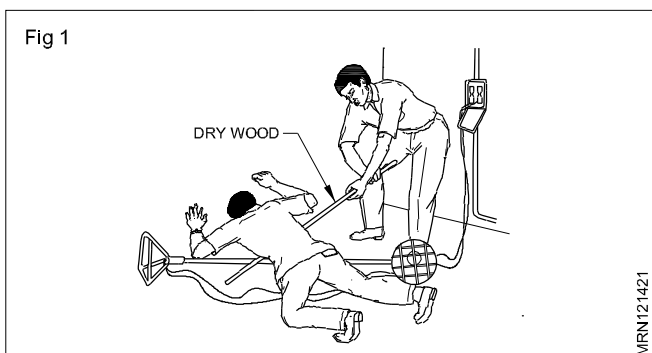
Treatment of electric shock

Prompt treatment is essential.

If assistance is close at hand, send for medical aid, then carry on with emergency treatment.

If you are alone, proceed with treatment at once.

Switch off the current, if this can be done without undue delay. Otherwise, remove the victim from contact with the live conductor, using dry non-conducting materials such as a wooden bar, rope, a scarf, the victim's coat-tails, any dry article of clothing, a belt, rolled-up newspaper, non-metallic hose, PVC tubing, bakelised paper, tube etc. (Fig 1)



Avoid direct contact with the victim. Wrap your hands in dry material if rubber gloves are not available.

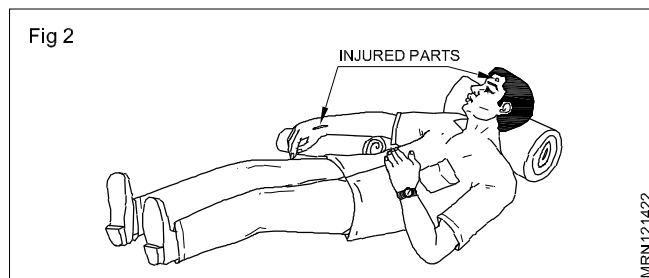
Electrical burns: A person receiving an electric shock may also sustain burns when the current passes through his body. Do not waste time by applying first aid to the burns until breathing has been restored and the patient can breathe normally - unaided.

Burns and scalds: Burns are very painful. If a large area of the body is burnt, give no treatment, except to exclude the air, eg. by covering with water, clean paper, or a clean shirt. This relieves the pain.

Severe bleeding: Any wound which is bleeding profusely, especially in the wrist, hand or fingers must be considered serious and must receive professional attention. As an immediate first aid measure, pressure on the wound itself is the best means of stopping the bleeding and avoiding infection.

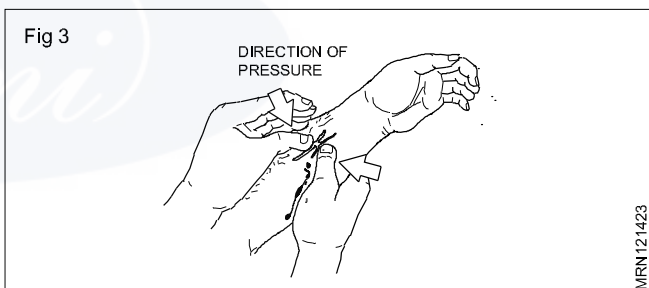
Immediate action: Always in cases of severe bleeding:

- make the patient lie down and rest
- if possible, raise the injured part above the level of the body (Fig 2)



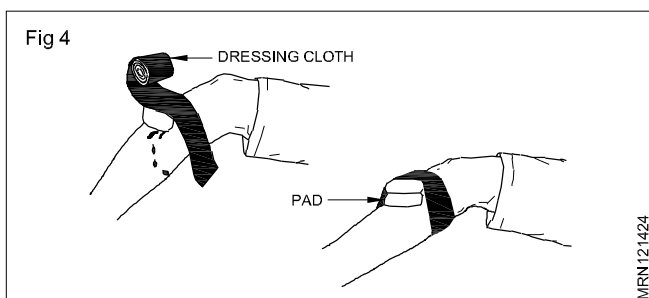
- apply pressure to the wound
- summon assistance.

To control severe bleeding: Squeeze together the sides of the wound. Apply pressure as long as it is necessary to stop the bleeding. When the bleeding has stopped, put a dressing over the wound, and cover it with a pad of soft material. (Fig 3)



For an abdominal stab wound, such as may be caused by falling on a sharp tool, keep the patient bending over the wound to stop internal bleeding.

Large wound: Apply a clean pad (preferably an individual dressing) and bandage firmly in place. If bleeding is very severe apply more than one dressing. (Fig 4)



Follow the right methods of artificial respiration.

Electrical tools

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

- list the tools necessary for R&AC
- identify and specify the tools
- identify the use of each tool
- explain the care and maintenance of a R&AC.

It is important that the R&AC uses proper tools for his work. The accuracy of workmanship and speed of work depend upon the use of correct tools. If the tools are properly used, and maintained, the wireman will find the working efficiency increases and the skills becomes a work habit.

Listed below are the most commonly used tools by R&AC.

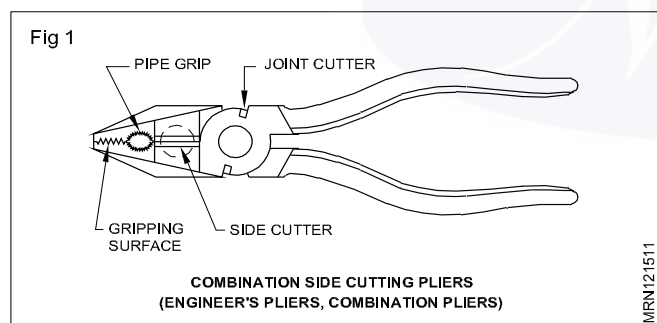
Their specifications and BIS number are given for your reference. Proper method of care and maintenance will result in prolonged tool life and improved working efficiency.

PLIERS

They are specified with their overall dimensions of length in mm. The pliers used for electrical work will be of insulated grip.

- 1 **Combination pliers with pipe grip, side cutter and insulated handle.** BIS 3650 (Fig 1)

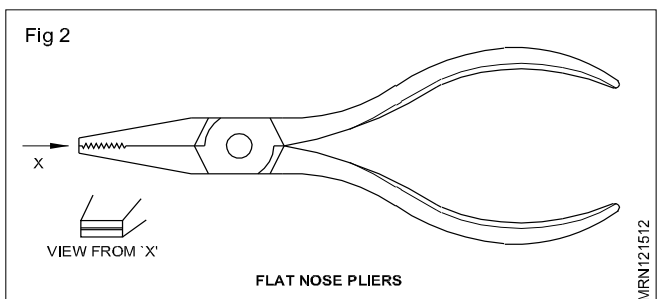
Size 150 mm, 200 mm etc.



It is made of forged steel. It is used for cutting, twisting, pulling, holding and gripping small jobs in wiring assembly and repairing work. A non-insulated type is also available. Insulated pliers are used for work on live lines.

- 2 **Flat nose pliers** BIS 3552 (Fig 2)

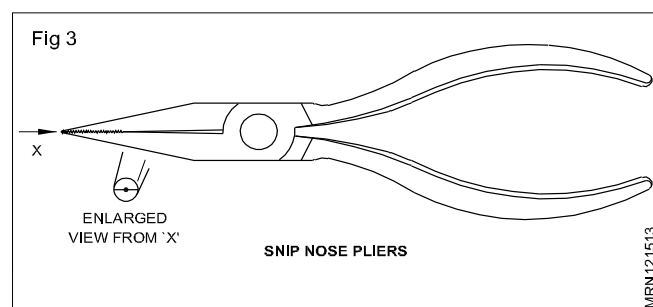
Size 100 mm, 150 mm, 200 mm etc.



Flat nose pliers are used for holding flat objects like thin plates etc.

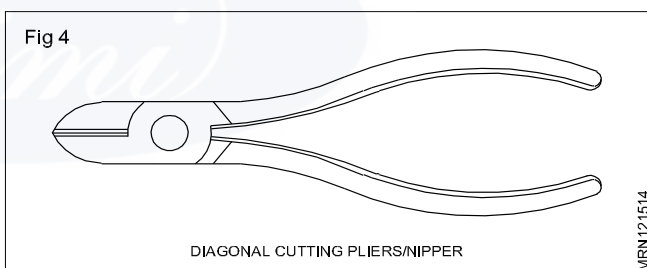
- 3 **Long nose pliers** or (snip nose pliers) with side cutter. BIS 5658 (Fig 3)

Size 100 mm, 150 mm etc.



Long nose pliers are used for holding small objects in places where fingers cannot reach.

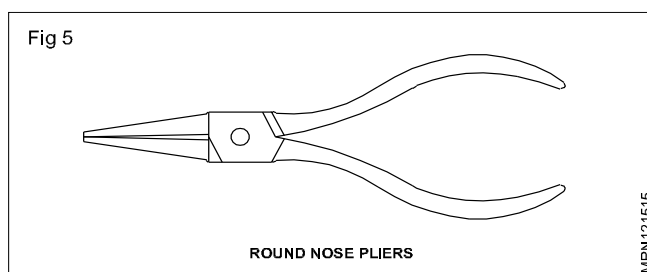
- 4 **Side cutting pliers** (Diagonal cutting pliers) BIS 4378 (Fig 4) Size 100 mm, 150 mm etc.



It is used for cutting copper and aluminium wires of smaller diameter (less than 4mm dia).

- 5 **Round nose pliers** BIS 3568 (Fig 5)

Size 100 mm, 150 mm etc.



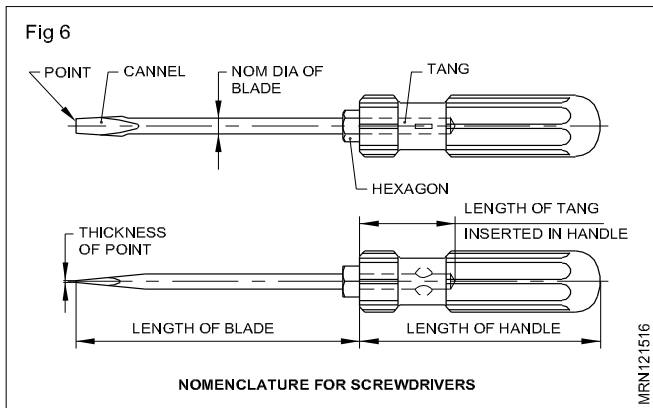
Wire hooks and loops could be made using the round nose pliers.

Care and maintenance of pliers

- Do not use pliers as hammers.
- Do not use pliers to cut large sized copper or aluminium wires and hard steel wires of any size.

- While using the pliers avoid damages to the insulation of hand grips.
- Lubricate hinged portions.

6 Screwdriver BIS 844 (Fig 6)



The screwdrivers used for electrical works generally have plastic handles and the stem is covered with insulating sleeves. The size of the screw driver is specified by its blade length in mm and nominal screwdriver's point size (thickness of tip of blade) and by the diameter of the stem.

eg. 75 mm x 0.4 mm x 2.5 mm
150 mm x 0.6 mm x 4 mm
200 mm x 0.8 mm x 5.5 mm etc.

The handle of screwdrivers is either made of wood or cellulose acetate.

Screwdrivers are used for tightening or loosening screws. The screwdriver tip should snugly fit the grooves of the screw to have maximum efficiency and to avoid damage to the screw heads.

As the length of the screw driver is proportional to the turning force, for small work choose a suitable small sized screwdriver and vice versa.

Screwdriver - Philips

It is used for driving star headed screws.

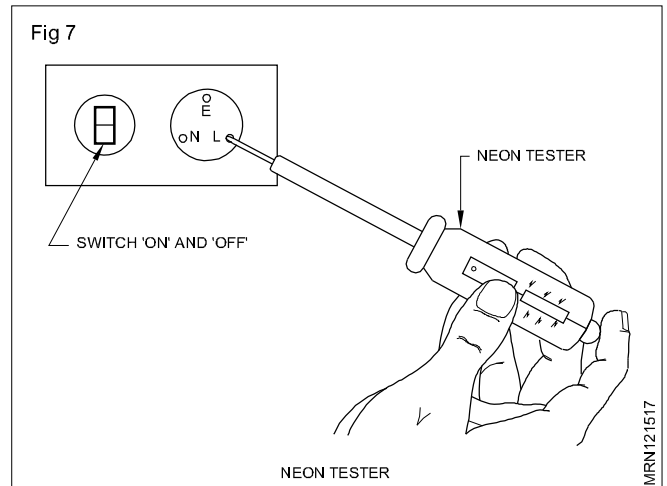
Care and maintenance

- Never use a screwdriver as a lever to apply force as this action will make the stem to bend and the use of the screw driver will be lost.
- Keep the tip in correct shape and in rare cases it could be grinded to shape.

7 Neon tester BIS 5579 - 1985 (Fig 7)

It is specified with its working voltage range 100 to 250 volts but rated to 500 V.

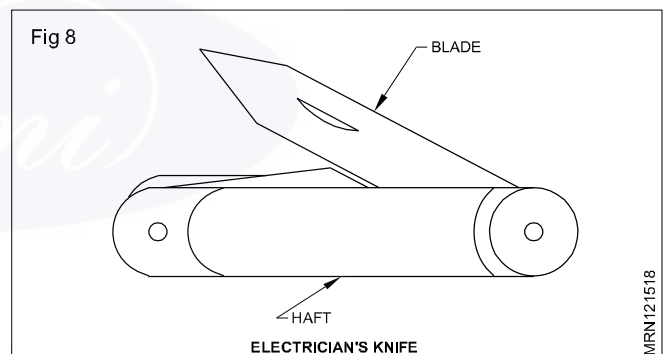
It consists of a glass tube filled with neon gas, and electrodes at the ends. To limit the current within 300 micro-amperes at the maximum voltage, a high value resistance is connected in series with one of the electrodes. It may have a tip like a probe or screwdriver at one end. The presence of supply is indicated by the glow of the lamp when the tip is touched on the live supply and the brass contact in the other end of neon tester is touched by hand.



Care and maintenance

- Never use the neon tester for voltage higher than the specified range.
- While testing see the circuit is completed through the body. In case if you are using rubber soled shoes, the earthing of the body could be provided by touching the wall by one hand.
- Use the screwdriver tipped neon tester for light duty work only.

8 Electrician's knife (Double blade) (Fig 8)



The size of the knife is specified by its largest blade length eg. 50 mm, 75 mm.

It is used for skinning the insulation of cables and cleaning the wire surface. One of the blades which is sharp is used for skinning the cable and the rough edged blade is used for cleaning the surface of the wires.

Care and maintenance

- Do not use the knife for cutting wires.
- Keep it free from rust.
- Keep one of the blades in a sharp condition.
- Fold the knife blade when not in use.

Joints in electrical conductors

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

- **state the necessity of joints, their types and uses.**

Joints in electrical conductors are necessary to extend the cables, overhead lines and also to tap the electricity to other branch loads wherever required.

Definition

Joints in electrical conductor mean connecting/tying or interlacing together of two or more conductors such that the union/junction becomes secured both electrically and mechanically.

Types of joints

In electrical work, different types of joints are used based on the requirement. The service to be performed by a joint determines the type to be used.

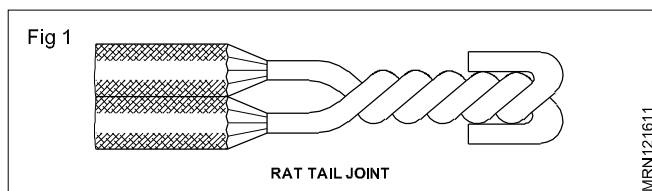
Some joints may require to have good electrical conductivity. They need not necessarily be mechanically strong. For example: the joints made in junction boxes and conduit accessories.

On the otherhand, the joints made in overhead conductors, need to be not only electrically conductive but also to be mechanically strong to withstand the tensile stress due to the weight of the suspended conductor and wind pressure.

Some of the commonly used joints are listed below.

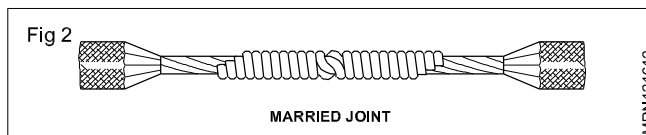
- Pig-tail or rat-tail or twisted joints.
- Married joint
- Tee joint
- Britannia straight joint
- Western union joint
- Scarfed joint
- Tap joint in single stranded conductor.

Pig-tail / rat-tail / twisted joint (Fig 1)



This joint made in either single or multi-strand conductors is suitable for places where there is no mechanical stress on the conductors as found in junction boxes or conduit accessories boxes. However, the joint should maintain good electrical conductivity.

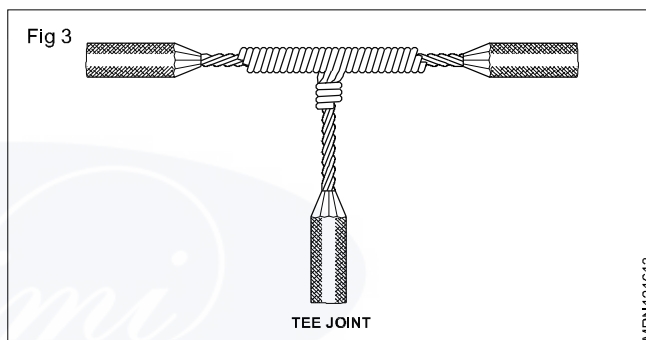
Married joint (Fig 2)



A married joint made with stranded conductors is used in places where appreciable electrical conductivity is required along with compactness.

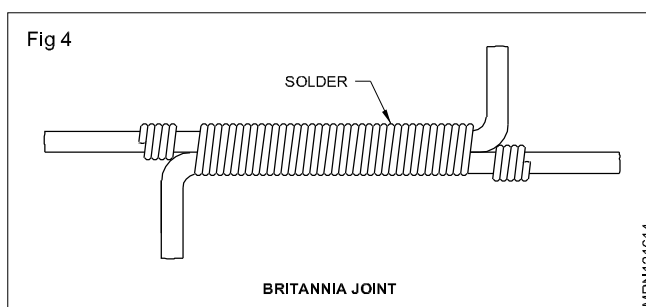
As the mechanical strength is less, this joint could be used at places where the tensile stress is not too great.

Tee joint (Fig 3)



This joint in the stranded conductors could be used in overhead distribution lines where the electrical energy is to be tapped for the service connections.

Britannia joint (Fig 4)

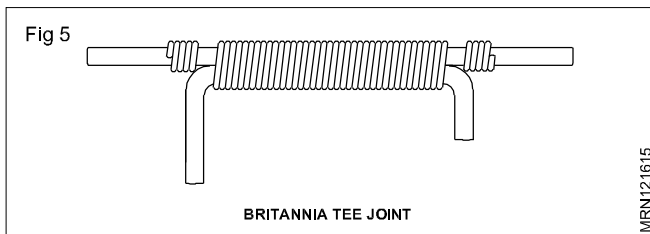


This joint made in a single strand conductor of 4 mm dia. or more is used in overhead lines where considerable tensile strength is required.

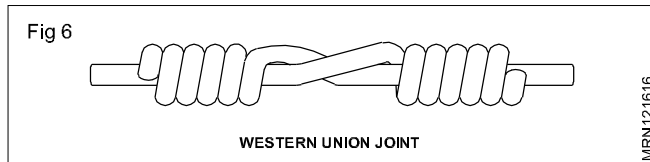
It is also used both for inside and outside wiring.

Britannia Tee joint (Fig 5)

This joint made in single strand conductors of 4 mm dia. or more is used for overhead lines for tapping the electrical energy perpendicular to the service lines.

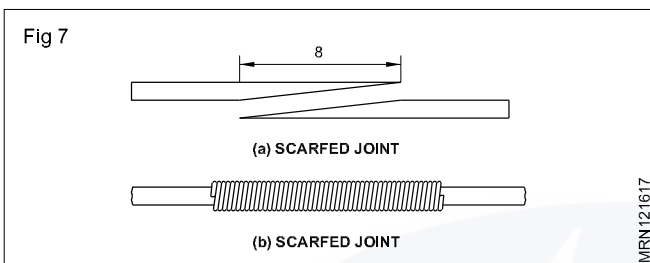


Western union joint (Fig 6)



This joint made in single strand conductors of 4 mm dia. or more is used in overhead lines for extending the length of the wire where the joint is subjected to considerable tensile stress.

Scarfed joint (Fig 7)



This joint made in single strand conductors is used in large single conductors where good appearance and compactness are the main considerations, and where the joint is not subjected to appreciable tensile stress as in earth conductors used in indoor wiring. It is preferable to solder this joint to increase the reliability.

Tap joint in single stranded conductors of diameter 2 mm or less.

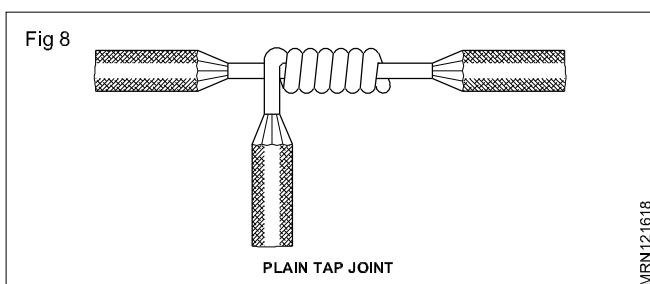
By definition, a tap is the connection of the end of one wire to some point along the run of another wire.

The following types of taps are commonly used.

- Plain
- Aerial
- Knotted
- Cross - Double - Duplex

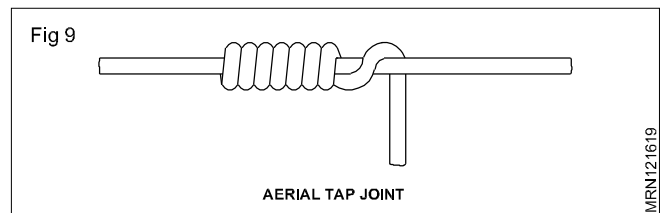
Plain tap joint (Fig 8)

This joint is the most frequently used and is quickly made. Soldering makes the joint more dependable.



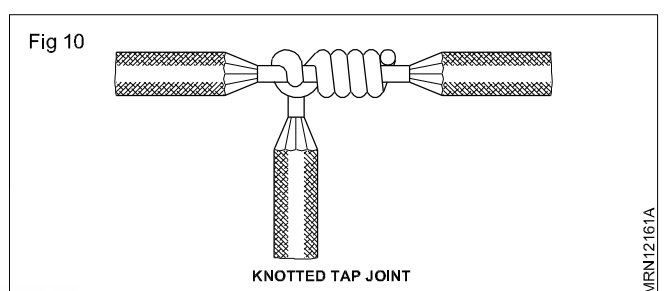
Aerial tap joint (Fig 9)

This joint is intended for wires subjected to considerable movement and it is left without soldering for this purpose. This joint is suitable for low current circuits only. It is similar to the plain tap except that it has a long or easy twist to permit the movement of the tap wire over the main wire.



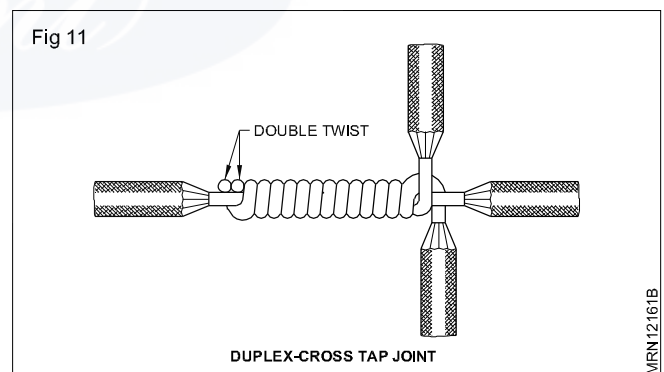
Knotted tap joint (Fig 10)

A knotted tap joint is designed to take considerable tensile stress.



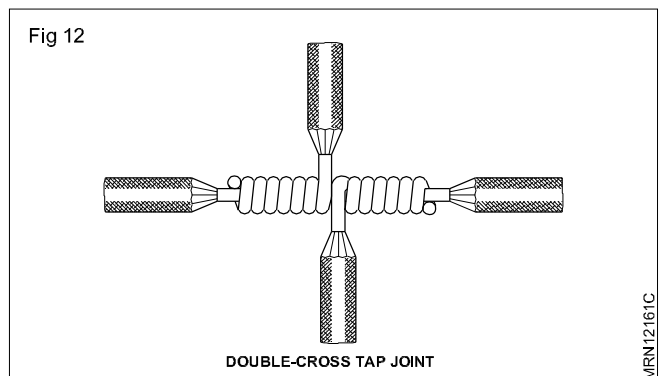
Duplex-cross tap joint (Fig 11)

This joint is used where two wires are to be tapped at the same time. This joint could be made quickly.



Double-cross tap joint (Fig 12)

This joint is simply a combination of two plain taps.



Simple electrical circuit and its elements

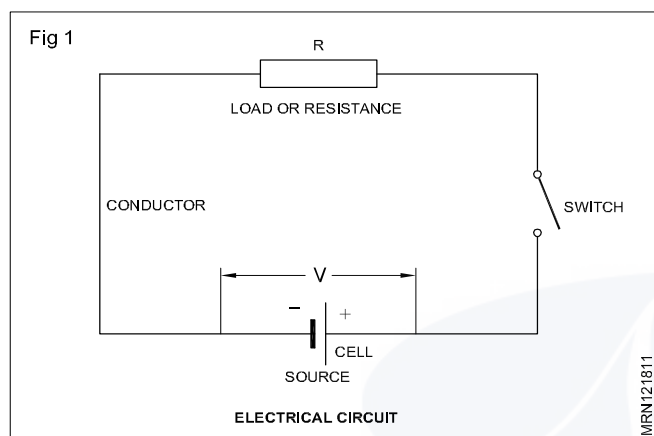
Objectives: At the end of this lesson you shall be able to

- describe a simple electric circuit
- explain the current, its units and method of measurement (Ammeter)
- explain the emf, potential difference, their units and method of measurement (Voltmeter)
- explain resistance and its unit, and quantity of electricity.

Simple electric circuit

A simple electrical circuit is one in which the current flows from the source to a load and reaches back the source to complete the path.

As shown in Fig 1, the electrical circuit should consist of the following.



- An energy source (cell) to provide the voltage needed to force the current through the circuit.
- Conductors through which the current can flow.
- A load (resistor) to control the amount of current and to convert the electrical energy to other forms.
- A control device (switch) to start or stop the flow of current.

In addition to the above, the circuit may have insulators (PVC or rubber) to confine the current to the desired path, and a protection device (fuse) to interrupt the circuit in case of malfunction of the circuit (excess current).

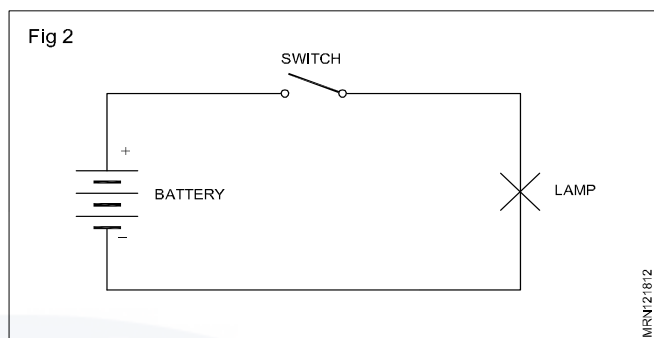
Electric current

Fig 2 shows a simple circuit which consists of a battery as the energy source and a lamp as the resistance. In this circuit, when the switch is closed, the lamp glows because of the electric current flows from the +ve terminal of the source (battery) via the lamp and reaches back the –ve terminal of the source.

Flow of electric current is nothing but the flow of electrons. Actually the electrons flow is from the negative terminal of the battery to the lamp and reaches back to the positive terminal of the battery.

However direction of current flow is taken conventionally from the +ve terminal of the battery to the lamp and back

to the –ve terminal of the battery. Hence, we can conclude that conventional flow of current is opposite to the direction of the flow of electrons. Throughout the Trade Theory book, the current flow is taken from the +ve terminal of source to the load and then back to the –ve terminal of the source.



Ampere

The unit of current (abbreviated as I) is an ampere (symbol A). If 6.24×10^{18} electrons pass through a conductor per second, then we can say one ampere current has passed through the conductor.

Ammeter

We know the electrons cannot be seen and no human being can count the electrons. As such an instrument called ammeter is used to measure the current in a circuit.

As an ammeter measures the flow of current in amperes it should be connected in series with the resistance (Load) as shown in Fig 3. For the decimal and decimal sub-multiples of the ampere we use the following expressions.

$$1 \text{ kilo-ampere} = 1 \text{ kA} = 1000 \text{ A} = 1 \times 10^3 \text{ A}$$

$$1 \text{ milli-ampere} = 1 \text{ mA} = 1/1000 \text{ A} = 1 \times 10^{-3} \text{ A}$$

$$1 \text{ micro-ampere} = 1 \text{ } \mu\text{A} = 1/1000000 \text{ A} = 1 \times 10^{-6} \text{ A}$$

- Measuring the current drawn by the circuit.
- Testing capacitors, diodes and transistors to know their condition.

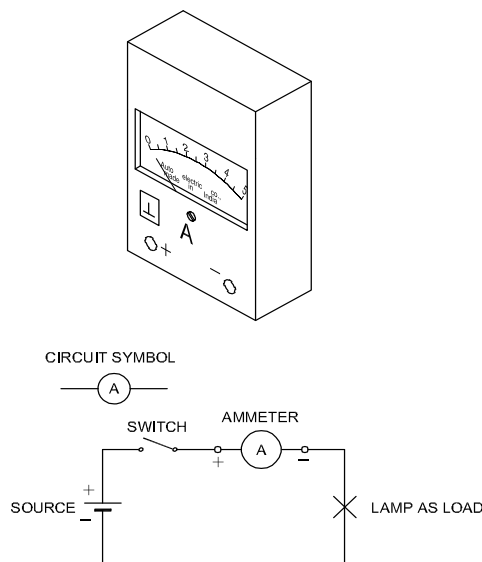
Transformer

Transformers change the voltage in AC circuits. A transformer has two coils of wire close enough to each other for the magnetic field of one coil to affect the other coil.

Electromotive force

In order to move the electrons in a circuit- that is to make the current to flow, a source of electrical energy is required.

Fig 3



In a torch light, the battery is the source of electrical energy.

The terminals of the battery are indicated in the circuit symbol by two lines, the longer line for the *positive* and the shorter for the *negative* terminal.

Within the battery the negative terminal contains an excess of electrons whereas the positive terminal has a deficit of electrons. The battery is said to have an electromotive force (emf) which is available to drive the free electrons in the closed path of the electrical circuit. The difference in the distribution of electrons between the two terminals of the battery produces this emf.

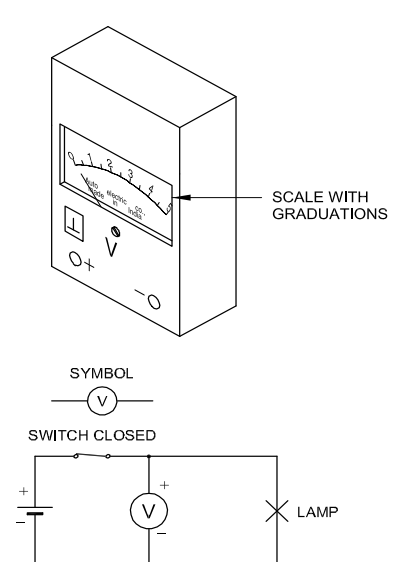
Potential difference (PD)

The unit of electromotive force is the volt (symbol V) and the emf is commonly referred as 'voltage'. When the battery is connected to any load, the voltage measured across the terminals is called potential difference (PD) and this will be slightly less than the value of emf.

Voltmeter

Electrical voltage is measured with a voltmeter. In order to measure the voltage of a source, the terminals of the voltmeter must be connected to the terminals of the source. Positive to the positive terminal and negative to the negative terminal, as shown in Fig 4. The voltmeter connection is across or it is a parallel connection.

Fig 4



For the decimal or decimal sub-multiples of the volt, we use the following expressions.

$$1 \text{ kilo-volt} = 1 \text{ kV} = 1000 \text{ V}$$

$$= 1 \times 10^3 \text{ V}$$

$$1 \text{ milli-volt} = 1 \text{ mV} = 1/1000 \text{ V}$$

$$= 1 \times 10^{-3} \text{ V}$$

$$1 \text{ micro-volt} = 1 \text{ } \mu\text{V} = 1/1000000 \text{ V}$$

$$= 1 \times 10^{-6} \text{ V}$$

Resistance

In addition to the current and voltage there is a third quantity which plays a role in a circuit, called the electrical resistance. Resistance is the property of a material by which it opposes the flow of electric current.

Ohm

The unit of electrical resistance (abbreviated as R) is ohm (symbol Ω).

For the decimal multiples or decimal sub-multiples of the ohm we use the following expressions:

$$1 \text{ megohm} = 1 \text{ M}\Omega = 1000000\Omega = 1 \times 10^6\Omega$$

$$1 \text{ kilo-ohm} = 1 \text{ k}\Omega = 1000\Omega = 1 \times 10^3\Omega$$

$$1 \text{ milli-ohm} = 1 \text{ m}\Omega = 1/1000\Omega = 1 \times 10^{-3}\Omega$$

$$1 \text{ micro-ohm} = 1 \text{ } \mu\Omega = 1/1000000\Omega = 1 \times 10^{-6}\Omega$$

Types of electrical supply

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

- explain the different types of electrical supply
- differentiate between alternating current and direct current
- differentiate between alternating voltage and direct voltage, and their sources
- identify AC and DC supply by the terminal markings.

Working with electricity requires making accurate measurements. Measurements are done by using instruments (meters).

There are various types of instruments working on different principles. Each instrument is designed to measure a particular electrical quantity or more than one quantity with

suitable modification and necessary instruction. Further they may be designed to measure AC or DC supply quantities or can be used in either supply.

To enable proper use of the instruments, the wireman should be able to identify the type of supply with the help of the details given below.

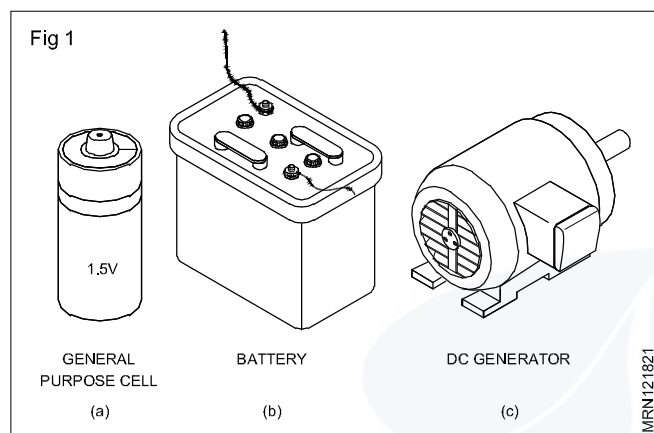
Type of electrical supply (Voltage)

There are two types of electrical supply in use for various technical requirements. The alternating current supply (AC) and the direct current supply (DC).

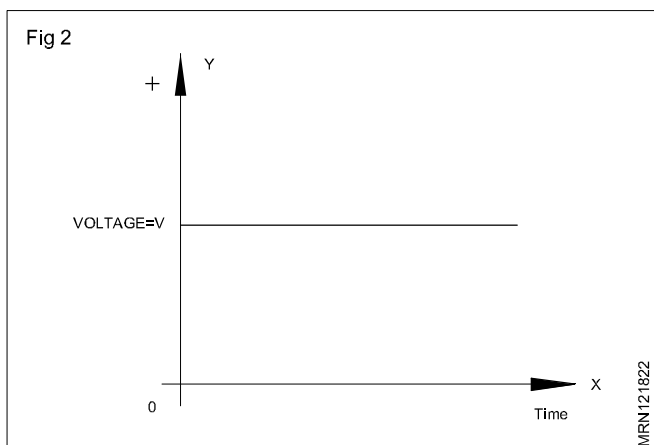
- DC is represented by this symbol.
- AC is represented by this symbol.

DC Supply

The most common sources of DC supply are the cells/batteries (Figs 1a and 1b) and DC generators (dynamos). (Fig 1C)



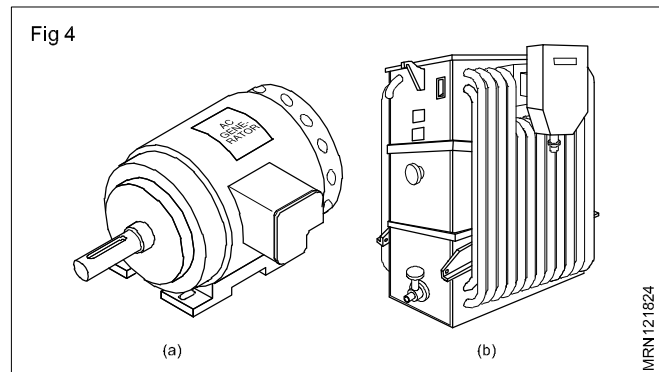
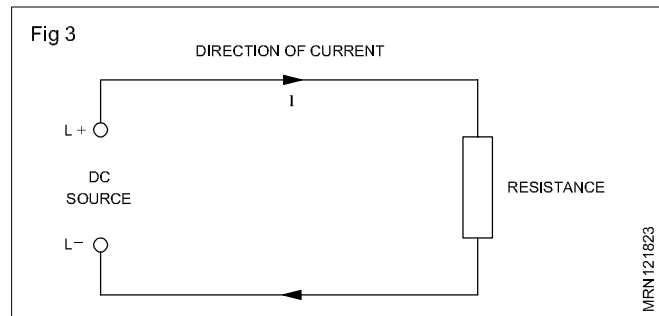
Direct voltage is of constant magnitude (amplitude). It remains at the same amplitude from the moment of switching on to the moment of switching off. The polarity of the voltage source does not change. (Fig 2)



The polarity of direct voltage (commonly known as DC voltage) is positive (+ve) and negative (–ve). The direction of conventional flow of current is taken as from the positive to the negative terminal outside the source. (Fig 3)

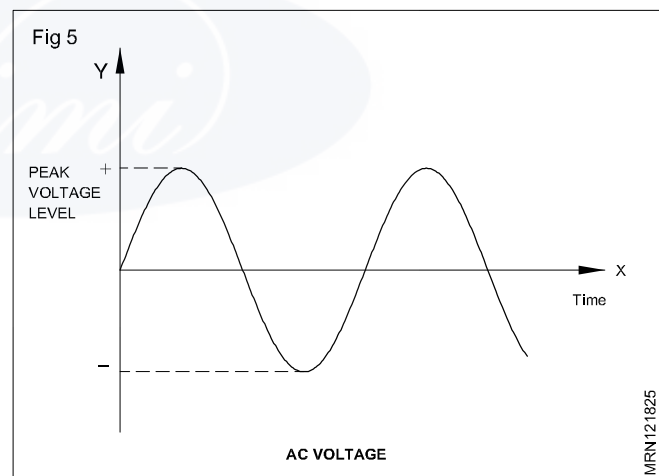
AC Supply

The source of AC supply is AC generators (alternators). (Fig 4a) The supply from a transformer (Fig 4b) is also AC.



Alternating voltage

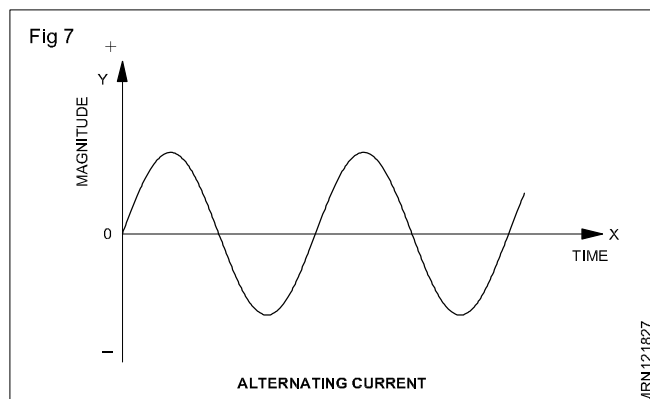
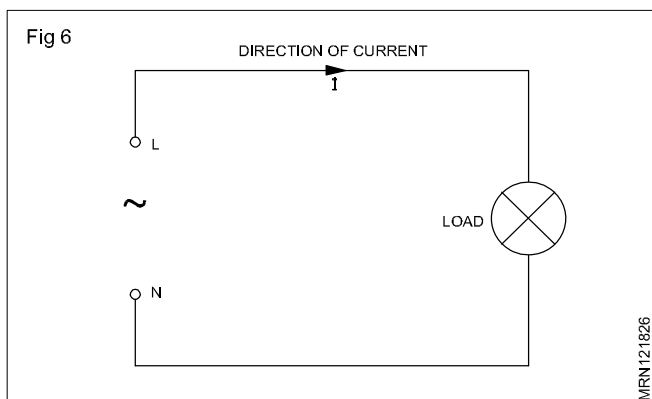
AC supply sources change their polarity constantly, and consequently the direction of voltage. The voltage supplied to our homes by power plants is alternating. Fig 5 shows a sinusoidal alternating voltage over time (wave-form).



AC supply is expressed by the effective value of the voltage, and the number of times it changes in one second is known as frequency. Frequency is represented by 'F' and its unit is in Hertz(Hz).

For example, the AC supply used for lighting is 240V 50 Hz. (Alternating voltage in common use is known as AC voltage.) AC supply terminals are marked as phase/line(L) and neutral(N).

Current is caused in an electric circuit due to the application of voltage. If an alternating voltage is applied to an electrical circuit, an alternating current (commonly known as AC current) will flow. (Figs 6 and 7)



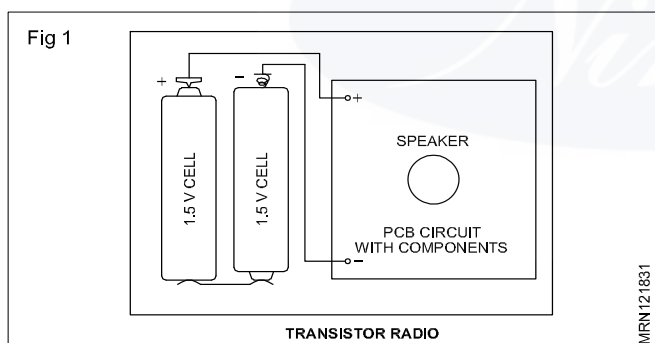
Polarity test in DC

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

- state the importance of polarity
- explain the method of identifying the polarity of DC sources by MC voltmeter
- explain how to use a neon lamp/indicator for testing polarity.
- state the effects of electric current.

Polarity

The polarity of a DC supply source should be identified as positive or negative. We can also use the term to indicate how an electric device is to be connected to the supply. For example, when putting new cells in a transistor radio we must put the cells correctly such that the positive terminal of one cell connects to the positive terminal of the radio and the negative terminal of the other cell connects to the negative terminal of the radio as shown in Fig 1.

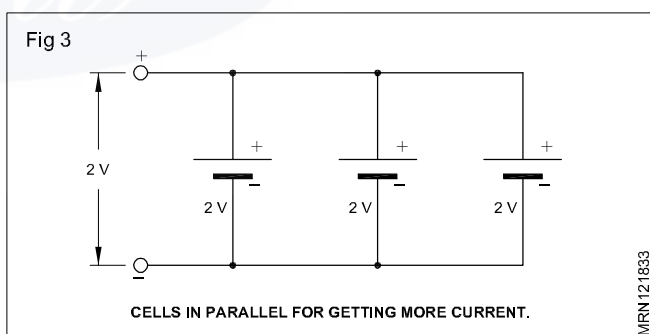
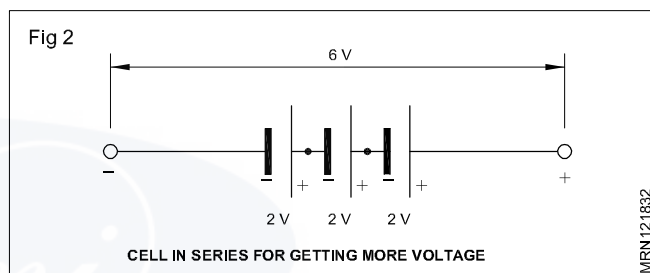


Importance of the polarity

Direct current supply has fixed polarity, positive and negative marked as + and -. Electric devices which have positive and negative identifications on their terminals are said to be polarised. When connecting such devices to a source of voltage (such as a battery or DC supply) we must observe the correct polarity markings. That is the positive terminal of the device must be connected to the positive terminal of the source, and the negative to the negative. If the polarity is not observed correctly (that is, if +ve is connected to -ve) the device will not function and may be damaged.

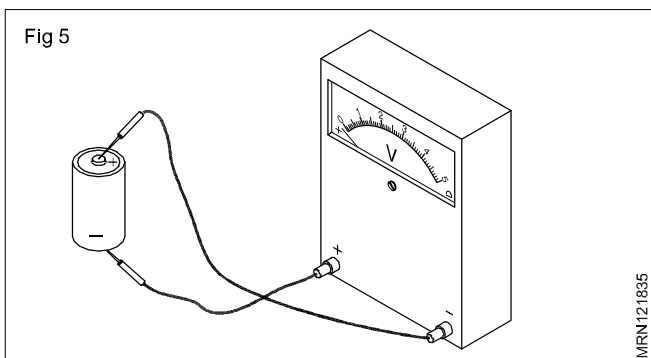
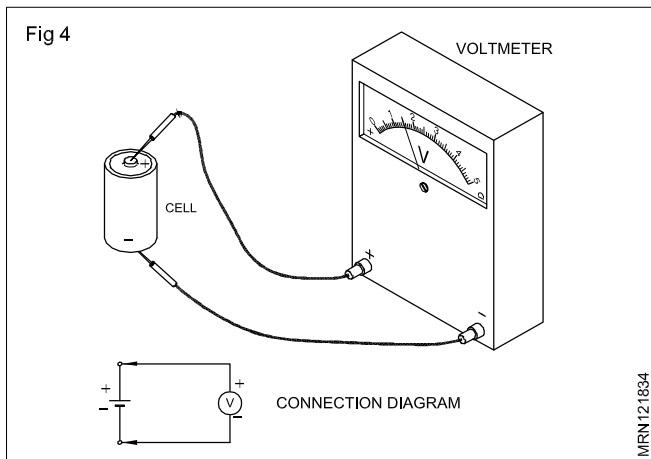
To get more voltage, current and power, the voltage sources like cells, batteries and generator are often connected in series, or in parallel or in series/parallel combination circuit. To connect them in such a manner we must know the correct polarity of the source. Fig 2 shows the method of connecting 3 cells in series to get more

voltage. Fig 3 shows connection of 3 cells in parallel for getting more current.



Testing polarity by MC meter

The polarity of a cell is determined by the use of a moving coil volt-meter. The terminals of the MC meter are marked as +ve and -ve. MC meters are called as polarised as they have to be connected as per the polarity marking. By using a low range (0-3V) MC voltmeter we can find out the voltage of a cell. The connections are made as per Fig 4 the voltmeter reads 1.5 volts. The polarity of the cell is correct as per the marked polarity on the meter terminals. If the pointer of the voltmeter deflects as in Fig 5, below zero, the polarity is not correct. From this we conclude that the meter reads in forward direction only if the instrument is connected with correct polarity as per the markings on the instrument terminals.



Polarity of the battery

To determine the polarity of the terminals of an unmarked battery, that is +ve and -ve we can use a low range MC voltmeter. If the voltmeter reads positive reading, say 10 or 12 volts then the polarity of the terminals are correct as per the markings on the meter terminals. If the meter reading is negative, that is below zero, the battery polarity is not correct with respect to the meter.

Polarity of DC supply

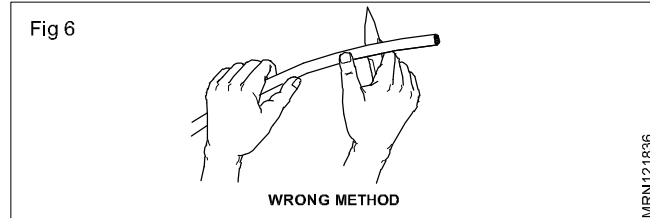
In the same way to find out the polarity of DC generator or a DC source it is advisable to use a moving coil type voltmeter with a suitable range, of say 0-300 volts. To protect the meters, always use higher range meters above the rated voltage of the generator or DC source supply.

Accordingly, while, using aluminium cables proper care is to be taken regarding the following.

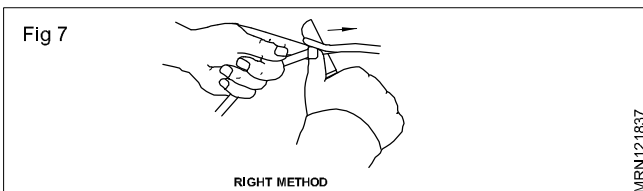
- Handling
- Skinning of the cables
- Connecting the cable ends

Handling: Remember that aluminium conductors when compared to copper conductors have less tensile strength and less resistance to fatigue. As such, bending or twisting of aluminium conductors while laying the cables should be avoided as far as possible.

Skinning of cables: While skinning the insulation from the cables, knicks and scratches should be avoided. As shown in Fig 6, the insulation should not be ringed as there is a danger of nicking the aluminium conductor while ringing the insulation with a knife.



Using the knife as shown in Fig 7 at an angle of 20° to the axis of the core will avoid nicking of the conductor.



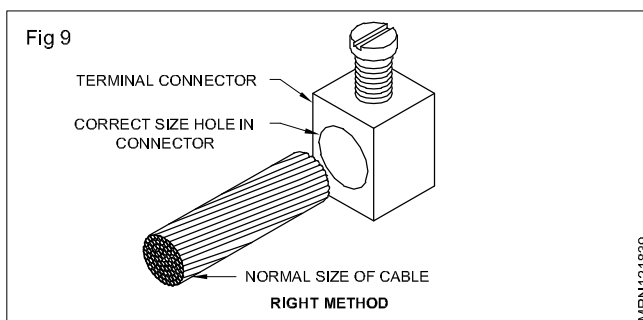
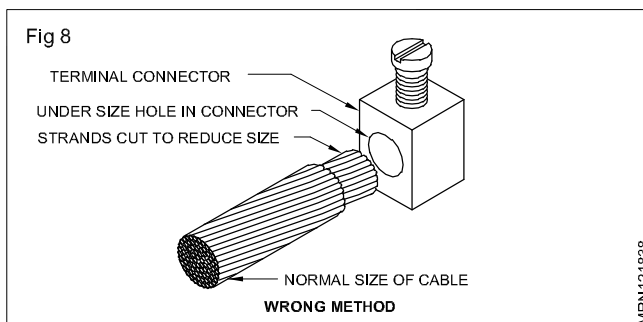
Connecting the cable ends

The following problems are encountered while connecting aluminium cables to the accessories.

The termination holes in the accessories may be undersized.

This normally happens in old accessories as they are designed for copper cable ends. Hence, while selecting accessories, a thorough check is necessary of all accessories to ensure whether the holes in the terminating connectors as shown in Fig 9 are suitable to accommodate the specified aluminium conductors. In any case, the strands should not be cut or the conductor filed as shown in Fig 8 to enable insertion in the undersized hole as this operation results in the heating of the cable end on load condition.

Joints in electrical conductors are necessary to extend the cables, overhead lines, and also to tap the electricity to other branch loads wherever required.



Measurement of energy in single phase circuit

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

- describe the construction and working principle of a single phase energy meter
- name the different dial systems for recording and the method of reading dials
- name the different errors in the energy meter
- identify and use the meter constant of a kWh meter
- state the modification required of the induction type energy meter to read as wattmeters
- identify the different dial systems of reading.

Necessity of energy meter

The electrical energy supplied to different consumers by the electrical supply companies should be billed, based on the actual amount of energy utilised. We need a device to measure the energy supplied to a consumer. Electrical energy is measured in kilowatt-hour in practice. The meter used for this is the energy meter. Symbolically it is represented as Wh.

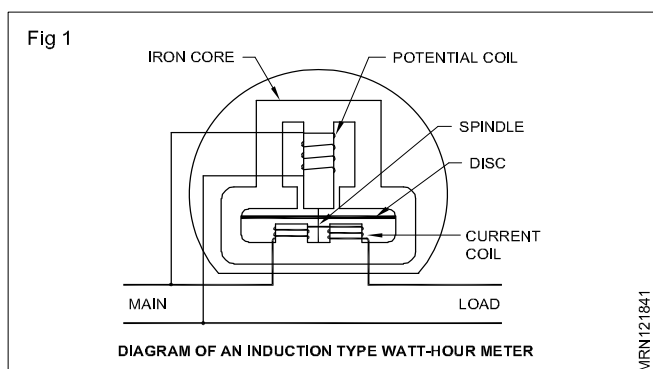
In AC, an induction type of energy meter is universally used for measurement of energy in domestic and industrial circuits.

Principle of a single phase induction type energy meter

The operation of this meter depends on the induction principle. Two alternating magnetic field produced by two coils induce current in the disc and produce a torque to rotate it (disc). One coil (potential coil) carries current proportional to the voltage of the supply and the other (current coil) carries load current (Fig 1). Torque is proportional to the power as in a wattmeter. The watt-hour meter must take both power and time into consideration. The instantaneous speed of the disc is proportional to the power passing through it. The total number of revolutions in a given time is proportional to the total energy that passes through the meter during that time.

Parts and function of energy meter

The parts of the induction type single phase energy meter are as shown in Fig 1.



Iron core

It is specially shaped to direct the magnetic flux in the desired path. It gives path for magnetic lines of force, reduces leakage flux and also magnetic reluctance.

Potential coil (voltage coil)

The potential coil is connected across the main and is wound with many turns of fine wire. When alternating current passes through the potential coil, it produces an alternating magnetic flux, which, in turn, induces eddy current in the aluminium disc.

Current coil

The current coils, connected in series with load, are wound with a few turns of heavy wire, since they must carry the full line current.

Disc

The disc is made of aluminium and it is the rotating element in the meter. This is mounted on a vertical spindle. The disc is positioned in the air gap between the potential and current coil magnets.

Spindle

The spindle has a hardened steel pivot, at both ends. The pivot is supported by a jewel bearing. There is a worm gear at one end of the spindle. The gear turns the dials that indicate the amount of energy passing through the meter.

Permanent magnet/braking magnet

The permanent magnets restrain the aluminium disk from racing at a high speed. This produces an opposing torque that acts against the turning torque of the aluminium disc. It also acts as a brake to the disc when the load is off. Fig 2 shows the arrangement of parts in an energy meter.

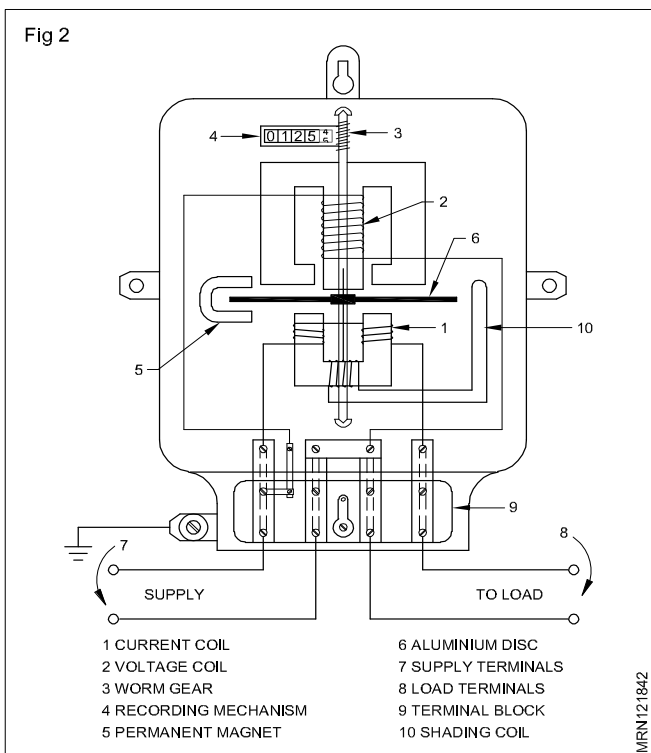
Functioning of energy meter

The rotation of the aluminium disc is accomplished by an electromagnet, which consists of a potential coil and current coils. The potential coil is connected across the load. It induces an eddy current in the rotating aluminium disc. The eddy current produces a magnetic field which reacts with the magnetic field produced by the current coils to produce a driving torque on the disc.

The speed of rotation of the aluminium disc is proportional to the product of the amperes (in the current coils) and the volts (across the potential coil). The total electrical energy that is consumed by the load is proportional to the number of revolutions made by the disc during a given time period.

A small copper coil (shading coil) called friction compensator is placed in the core to produce a forward torque large

enough to counteract any friction produced against the rotating aluminium disc.



Meter constant

It is the number of revolutions the disc makes for one kWh of energy consumed.

Number of revolutions per kWh = 3600×1000 watt sec.

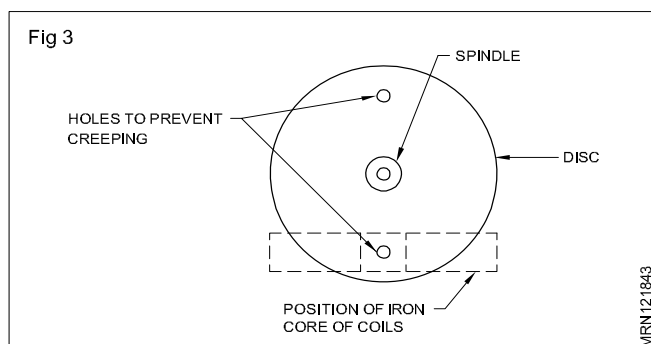
$$\text{One rev.} = \frac{3600 \times 1000}{\text{Meter constant}}$$

Creeping error and adjustment

In some meters the disc rotates continuously even when there is no current flow through the current coil i.e. when only pressure coil is energised. This is called creeping.

The major cause for creeping is over-compensation for friction. The other causes for creeping are excessive voltage across the pressure coil, vibrations and stray magnetic fields.

In order to prevent creeping, two diametrically opposite holes are drilled in the disc (Fig 3). The disc will come to rest with one of the holes under the poles of the brake magnet, the rotation being thus limited to a maximum of half a revolution.



CAUSES OF ERRORS IN METERS

Incorrect magnitude of fluxes

The shunt magnet flux may be in error due to changes in the resistance of the coil or due to abnormal frequencies.

Incorrect phase angles

There may be phase difference between voltage and current, though they may be actually in phase. This may be due to improper power factor adjustment, abnormal frequencies, change in resistance with temperature etc.

Lack of symmetry in magnetic circuits

If the magnetic circuit is not symmetrical, a driving torque is produced which makes the meter to creep.

ERRORS CAUSED BY THE BRAKING SYSTEM

They are:

- changes in the strength of the brake magnet
- improper positioning of the brake magnet in the disc edge
- abnormal friction of the moving parts.

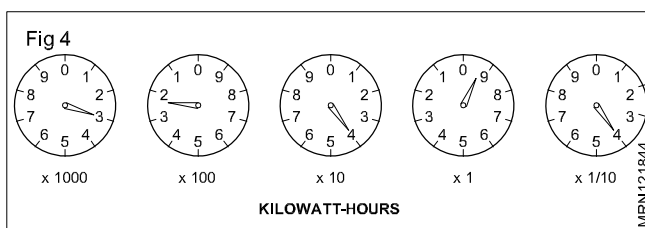
Adjustments are provided for correcting the errors in the energy meters so that they read correctly and their errors are within acceptable limits.

Induction type meter as wattmeter

In the induction type energy meter, the disc is made to rotate and the train of gears attached to the spindle registers the energy consumed. When the induction type meter is used as a wattmeter, the spindle movement is controlled by two phosphor bronze springs and the train of gears is removed. With this arrangement and an addition of a pointer in the spindle, the pointer indicates the power consumed in an AC circuit over a graduated scale of watts or kilowatts.

Types of energy meter dials

In earlier energy meters, the reading of energy had to be done by cyclometer type dials as shown in Fig 4.



In this type there are five dials each having its own pointer. Initially all the pointers will be at zero. The first dial in the left registers in 1000, 2nd dial in 100s, 3rd dial in 10s, 4th dial in ones and the fifth dial in 1/10th of the KWH. When the fifth dial pointer completes one revolution, the fourth dial (one's dial) pointer moves from zero to one, further if the fourth dial (one's dial) completes one revolution, the third dial (10's dial) pointer moves from zero to one and so on.

While reading start from right to left being careful to note the direction of rotation.

Read the right hand dial. If the pointer has moved away from one figure, read the figure behind the pointer in the direction of rotation.

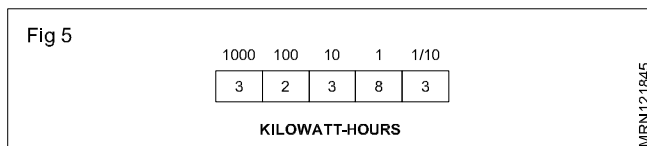
Read the remaining dials in order, taking care to read the figures behind the pointer on these dials. When one of the pointers is directly on a number, the procedure is to look back at the dial on the right. Has it passed the zero? If it has not passed the zero, the correct figure to read is the one behind the pointer.

Meters are read once each month or once in two months. The earlier reading is subtracted from the present reading to know the consumption in KWH.

Example

The reading shown by the energy meter as per Fig 4 will be 3239.3 KWH

In the latest type of energy meters these scales have been changed from cyclometer type to direct reading system as shown in Fig 5.



Frequency meter

The digital frequency meter is commonly called a counter since it determines the frequency by electronically counting the number of cycles of an unknown signal in a standard time interval usually second.



Earthing – Terms and methods

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

- describe the necessity of earthing
- explain the reasons for system and equipment earthing
- explain the various terms used in earthing electrical system
- differentiate between an earthed and non-earthed electrical equipment towards human safety
- state and explain the methods of preparing pipe earthing and plate earthing according to BIS recommendations
- explain the procedure of reducing the resistance of earth electrodes to an acceptable value.

Necessity of earthing

While working in electrical circuits, the most important consideration for a wireman is the safety factor - safety not only for himself but also for the consumer who uses the electricity.

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

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

System earthing

Equipment earthing

Special requirement earthing

System earthing

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

System earthing is done at generating stations and substations. The following are the purposes of system earthing.

- Maintain the ground as zero reference potential, thereby ensuring that the voltage on each live conductor is restricted to such a value with respect to the potential of the general mass of the earth as is consistent with the level of the insulation applied.
- Protect the system when any fault occurs against which earthing is designed to give protection, by making the protective gear to operate and make the faulty portion of the plant harmless.

In most cases, such operation involves isolation of the faulty main or plant by circuit breakers or fuses. Earthing may not give protection against faults which are not essentially earth faults.

For example, if a phase conductor on an overhead spur line breaks, and a part remote from the supply falls to the ground, it is unlikely that any protective gear relying on earthing, other than current balance protection at the substation will operate since the earth fault current circuit includes the impedance of the load that would be high relative to the rest of the circuit which will not allow the earth's protective gear to operate and cut off the supply.

Equipment earthing

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

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

Special requirements earthing

'Static earthing' is provided to prevent building up of static charges, by connections to earth at appropriate locations. Example, operation theatres in hospitals. (For details, please refer to BIS 7689 - 1974 and the National Electrical Code.)

'Clean earth' may be needed for some of the computer data processing equipments. These are to be independent of any other earthing in the building. (For details, please refer to BIS: 10422 - 1982 and BIS: 3043 - 1987.)

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

TERMINOLOGY

The following terms are to be understood, which are often used while referring to earthing in electrical installations.

Apparatus

Electrical apparatus including all machines, appliances and fittings in which conductors are used or of which they form a part.

Bonding

Bonding is a method to connect together electrically two or more conductors or metal parts.

Dead

'Dead' means at or about earth potential and disconnected from any live system.

Earth

A connection to the general mass of earth by means of an earth electrode. An object is said to be 'earthed' when it is electrically connected to an earth electrode and a conductor is said to be 'solidly earthed' when it is electrically connected to an earth electrode without intentional addition of resistance or impedance in the earth connection.

Earth continuity conductor (ECC)

The conductor, including any clamp, connecting to the earthing lead or to each other parts of an installation which are required to be earthed. It may be in whole or in part the metal conduit or the metal sheath or armour of the cables, or a special continuity conductor, cable or flexible cord incorporating such a conductor.

Earth current

A current flowing to earth.

Earth electrode

A metal plate, pipe or other conductor or an array of conductors electrically connected to the general mass of the earth.

Earth fault

Live portion of a system getting accidentally connected to earth.

Earth wire

A conductor connected to earth and usually situated in proximity to the associated line conductors.

Earthed circuit

A circuit having one or more points which are intentionally connected to earth.

Earthed system

A system in which the neutral or any one conductor is deliberately connected to earth directly or through an impedance.

Earthing lead

The conductor by which the connection to the earth electrode is made.

Earthing ring (or earth bus)

A ring or bus formed by connecting earth electrodes.

Fault

Any defect in plant, apparatus or conductor, which impairs normal operation or safety.

Fault current

A current flowing from a conductor to earth, or to another conductor, owing to a fault in the insulation.

Double insulation

Denotes insulation comprising both functional insulation and supplementary insulation.

Functional insulation

Denotes the insulation necessary for the proper functioning of equipment and for basic protection against electric shock.

Supplementary insulation (Protective insulation)

Denotes an independent insulation provided in addition to the functional insulation in order to ensure protection against electric shock in case of failure of the functional insulation.

Leakage

The passage of electricity in a path, other than that desired, due to imperfect insulation.

Leakage current

A fault current of relatively small value, as distinguished from that due to a short circuit.

Live

An object is said to be 'live' when a difference of potential exists between it and earth.

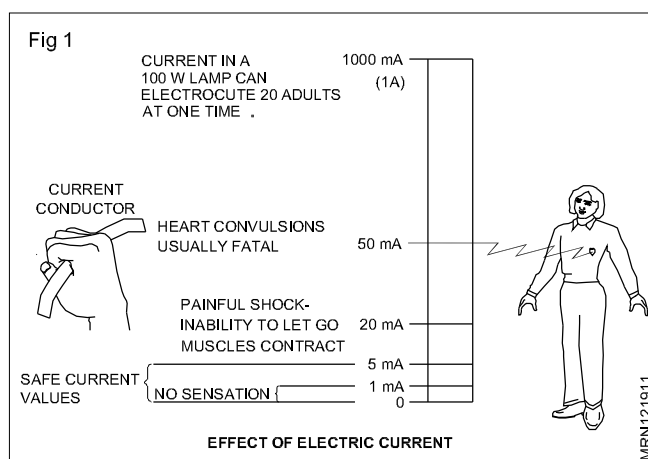
Multiple earthed neutral system

A system of earthing in which the parts of an installation specified to be earthed are connected to the general mass of earth, and in addition, are connected within the installation to the neutral conductor of the supply system.

Reasons for earthing

The basic reason for earthing is to prevent or minimize the risk of shock to human beings and livestock. The reason for having a properly earthed metal part in an electrical installation is to provide a low resistance discharge path for earth leakage currents which would otherwise prove injurious or fatal to any person touching the metal part.

An electric shock is dangerous only when the current through the body exceeds beyond certain milliampere value. In general any current flowing through the body beyond 5 milliamperes is considered dangerous. Fig 1 shows the magnitude of current and its effect.



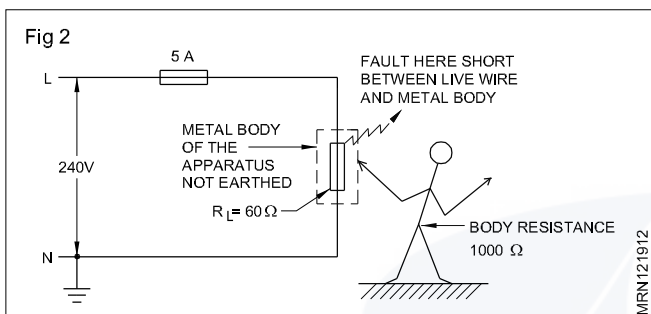
However, the degree of danger is dependent not only on the current through the body but also on the duration of time it flows. The applied voltage is in itself only important in producing this minimum current through the resistance of the body. In human beings, the resistance between hand and hand or between hand and foot, can easily be as low as 400 ohms under certain conditions. Table 1 shows the body resistance at specified area of contact.

Let us consider the effect of earthing of the body of the apparatus through two extreme cases.

CASE 1 Metal body of apparatus when not earthed

Let us consider a 240 V AC circuit connected to an apparatus having a load resistance of 60 ohms. Assume that the defective insulation of the cable makes the metal body to be live and the metal body is not earthed.

As shown in Fig 2, when a person whose body resistance is 1000 ohms comes in contact with the metal body of the apparatus which is at 240 V, a leakage current may pass through the body of the person.



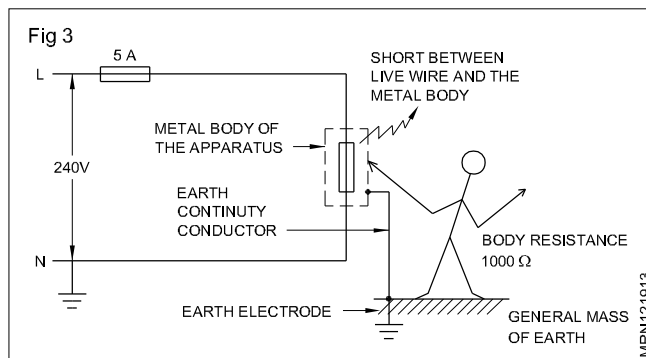
The value of current through the body =

$$\frac{V}{R_{\text{BODY}}} = \frac{240}{1000} = 0.24 \text{ amps or } 240 \text{ milliamps.}$$

This current according to Table 1 is highly dangerous and will prove to be fatal. On the other hand, the 5 amps fuse in the circuit will not blow for this additional leakage current of 240 milliamperes. As such the metal body will have 240 V supply and may electrocute any person touching it.

CASE 2 Metal body of apparatus when earthed

In case the metal body of the apparatus is earthed as shown in Fig 3 the moment the metal body comes in contact with the live wire, a higher amount of leakage current will flow through the metal body to earth.



Assuming that the sum of the resistance of the main cable, metal body, earth continuity conductor and the general mass of earth to a tune of 10 ohms.

The leakage current =

$$\frac{V}{R_{\text{Total}}} = \frac{240}{10} = 24 \text{ amps.}$$

This leakage current is 4.8 times higher than the fuse rating, and hence, the fuse will blow and disconnect the supply from the mains. The person touching will not get any shock due to two reasons. Firstly, before the fuse operates, the metal body and earth are in the same zero potential, and across the person there is no difference of potential. Secondly within a short (milli-seconds) time the fuse blows to open the defective circuit.

By studying the above two cases, it is clear that a properly earthed metal body eliminates shock hazards to persons and also prevents fire hazards in the system by blowing the fuse quickly in case of ground faults.

General

In general all parts of the apparatus, other than the live parts shall be at earth potential. For this purpose, earth electrodes are used. These earth electrodes shall be provided at generating stations, substations and consumer premises. Sometimes a number of earth electrodes in parallel is necessary to bring down the earth resistance to acceptable low value such that the system's protective devices like earth fault relays and fuses operate properly in case of fault. As far as possible these earth electrodes shall be visible.

Earth resistance tester

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

- state the meaning of earth system resistance
- analyse low and high values of earth system resistance
- state the minimum size of the earth continuity conductor
- state the method of measuring the resistance of the earth continuity conductor
- state the necessity of measuring of earth electrode resistance
- explain the principle of an earth resistance tester (earth Megger)
- explain the construction and working of the earth resistance tester (earth Megger)
- explain the method of measuring earth resistance
- state the other uses of an earth resistance tester.

Earth system resistance

This is the sum of the resistance of the general mass of earth and the resistance of the earth continuity conductor. (E C C)

If the resistance of the general mass of earth is high it can be brought to a low value by the methods suggested in Ex.3.10 Related Theory of Wireman 1st year.

The resistance of the earth continuity conductor also can be lowered by using a larger area of cross-section conductor or by replacing the existing conductor to a higher conductivity metal wire of the same cross-section.

Protection by lower earth resistance

In accordance with the recommendations of B.I.S: 3043-1966, the earthing arrangement of the consumer's installation shall be such that, on the occurrence of a fault of negligible impedance from a phase or non-earthed conductor to adjacent exposed metal, a current corresponding to not less than three and a half times the rating of the fuse or one and a half times the setting of the overload leakage earth circuit breaker will flow (except where voltage operated earth leakage circuit breakers are used) and make the faulty circuit dead.

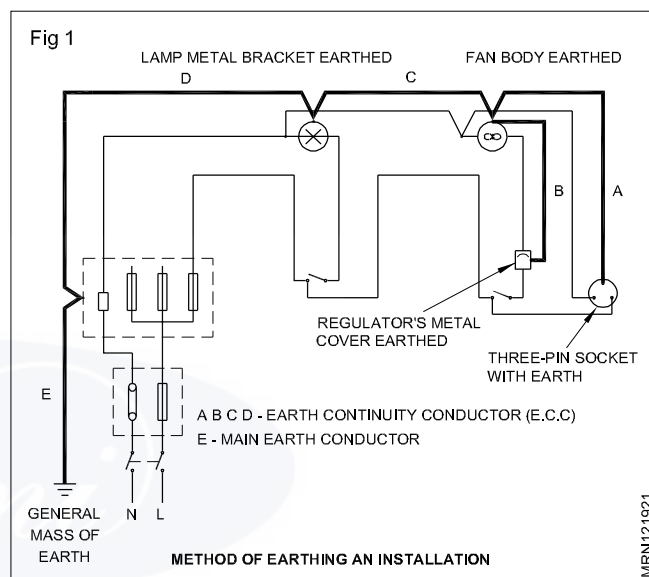
To facilitate easy flow of faulty current through the earth and, thereby, to blow the fuse or activate the circuit breakers, the sum of the resistance of the general mass of earth and earth continuity conductor (ECC) resistance should be of low value such that the faulty current is atleast $3 \frac{1}{2}$ times or more than the fuse rating to blow the fuses. (Fig 1)

Let us say that the general mass of earth has a resistance (impedance) of 30 ohms and the earth continuity conductor (Route A,B,C,D and E) has a resistance of 20 ohms. Then the faulty current in a 240 V supply system will be

$$= \frac{\text{Supply volts}}{\text{Earth resistance} + \text{ECC resistance}}$$

$$= \frac{240}{30 + 20} = \frac{240}{50} = 4.8 \text{ amps}$$

If the circuit fuse is of 5 amps, this faulty current of 4.8 amps will not blow the fuse. As such if anybody touches the regulator or fan or lamp bracket or appliance connected to the 3-pin socket he will get a shock.



The earth tester, has to be placed horizontally and is rotated at a rated speed (normally 160 r.p.m.). The resistance of the electrode under test is directly read on the calibrated dial. To ensure correct measurement, the spikes are placed at a different position around the electrode under test, keeping the distance the same as in the first reading. The average of these readings is the earth resistance of the electrodes.

Effectiveness of earth resistance

To ensure whether the earth electrode resistance is below the safe value please refer to the earlier part of this lesson.

Applications

There are several uses of the earth Megger as listed below.

- 1 Earth electrode resistance measurement
- 2 Soil resistivity
- 3 Earth continuity testing
- 4 Neutral earth test
- 5 Direct resistance measurement.

Resistance of earth electrode to earth at generating stations, substations etc. - soil resistivity measurements to find optimum sitting for new earth electrodes - positioning and testing of ground beds of cathodic protection systems - geophysical surveying - bedrock depth assessment for dam foundations.

Single phase motors- types- resistance/induction-start, induction-run motor

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

- explain briefly the types of AC single phase motors
- explain the necessity and methods of split-phasing the single phase to obtain a rotating magnetic field
- explain the principle, construction, operation characteristic and application of single phase resistance / induction-start/induction-run motors.

Single phase motors perform a great variety of useful services at home, office, farm, factory, and in business establishments. These motors are generally referred to as fractional horsepower motors with a rating of less than 1 H.P. Most single phase motors fall into this category. Single phase motors are also manufactured in 1.5, 2, 3 and up to 10 H.P. as a special requirement.

Single phase motors may be broadly classified as split-phase induction motors and commutator motors according to their construction and method of starting.

Split-phase induction motors can be further classified as:

- resistance-start, induction-run motors
- induction-start, induction-run motors
- permanent capacitor motors
- capacitor-start, induction-run motors
- capacitor-start, capacitor-run motors
- shaded pole motors.

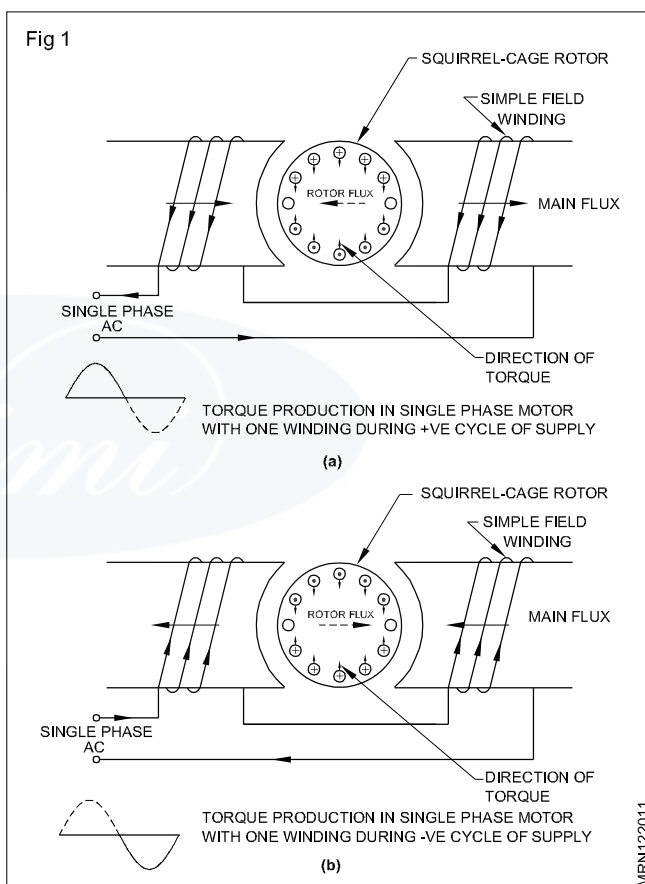
Commutator motors can be classified as:

- repulsion motors
- series motors.

The basic principle of operation of a split-phase induction motor is similar to that of a polyphase induction motor. The main difference is that the single phase motor does not produce a rotating magnetic field but produces only a pulsating field. Hence to produce the rotating magnetic field, phase-splitting is to be done to make the motor to work as a two-phase motor for starting.

First, let us examine the behaviour of the magnetic field as set up by an AC current in a single-phase field winding. With reference to Fig 1, at a particular instant, the current flowing in the field winding produces the magnetic field as shown in Fig 1a. Since the produced magnetic field is varying, it will induce currents in the rotor bars which in turn will create a rotor flux. This stator-induced flux, according to Lenz's law, opposes that of the main field. By applying this principle, the current direction in the rotor bars can be determined as shown in Fig 1a, as well as the torque created between the field and rotor currents. It is apparent that the downward torque produced by the upper rotor conductors is counteracted by the upward torque produced by the lower rotor conductors; hence no rotation results. In the next instant, as shown in Fig 1b, the voltage in the input supply changes its polarity, creating a main field with a

change in direction. This main field produces a torque, downward in upper conductors, and upwards in bottom conductors resulting in the cancellation of torque with no movement of the rotor, in this case also. Since the field is pulsating, the torque is pulsating although no net torque is produced over a full cycle.



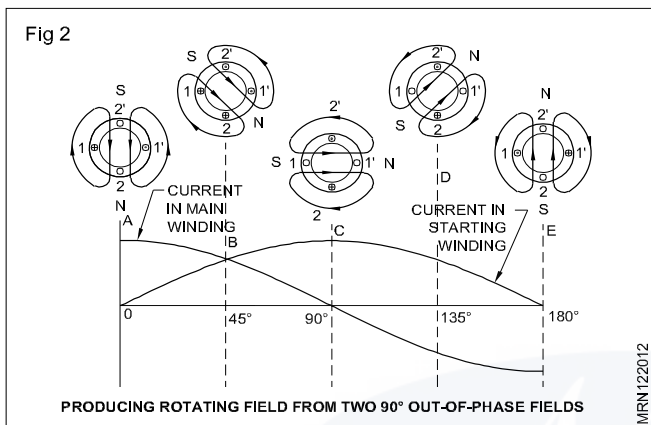
If the rotor is given a small jerk in any direction in the above mentioned cases, it will go on revolving, and will develop a torque in that particular direction due to interaction between the rotor and stator fluxes. Because of this effect, the split-phase motor, once started, needs only one winding to be connected to the supply for running. It is clear that a single phase induction motor, when having only one winding, is not self-starting. If the main field is made revolving instead of pulsating, a rotational torque could be produced in the rotor.

Producing a rotating field from two 90° out-of-phase fields: One of the methods of producing a rotating magnetic field is by split-phasing. This could be done by providing a second set of winding in the stator called the starting

winding. This winding should be kept physically at 90 electrical degrees from the main winding, and should carry a current out of phase from the main winding. This, out of phase current, could be achieved by making the reactance of the starting winding being different from that of the main winding. In case both the windings have similar reactance and impedance, the resulting field, created by the main and starting windings, will alternate but will not revolve and the motor will not start.

By split-phasing, the two (main and starting) fields would combine to produce a rotating magnetic field as stated below.

Fig 2 shows that the main (1,1') and starting (2,2') windings are kept in the stator at 90° to each other. For consideration, only, one half cycle is shown with the effects at 45° increments.



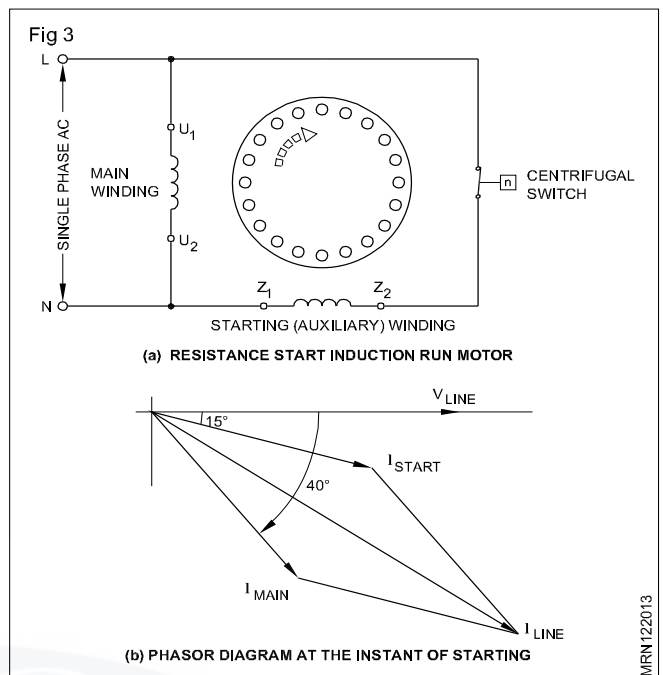
At position 'A', only the main winding is producing flux, and the net flux will be in a vertical direction, as shown in the stator diagram. At instant 'B', 45° later, both windings are producing flux, and the net flux direction will also have rotated 45°. At position 'C', the maximum flux is now in a horizontal direction because only the starting winding is producing flux. At instant 'D', the current from the main winding is building up again, but in a new direction, while that from starting winding is now decreasing. Therefore, the net flux at this instant will be as shown in position D. At position 'E', the maximum flux is just the opposite of what it was at instant 'A'. It should now be evident that the two out-of-phase fields are combining to produce a net rotating field effect.

Working of split-phase motor: At the time of starting, both the main and starting windings should be connected across the supply to produce the rotating magnetic field. The rotor is of a squirrel cage type, and the revolving magnetic field sweeps past the stationary rotor, inducing an emf in the rotor. As the rotor bars are short-circuited, a current flows through them producing a magnetic field. This magnetic field opposes the revolving magnetic field and will combine with the main field to produce a revolving field. By this action, the rotor starts revolving in the same direction of the rotating magnetic field as in the case of a squirrel cage induction motor, which was explained earlier.

Hence, once the rotor starts rotating, the starting winding can be disconnected from the supply by some mechanical means as the rotor and stator fields form a revolving magnetic field.

Resistance-start, induction-run motor: As the starting torque of this type of motor is relatively small and its starting current is high, these motors are most commonly used for rating up to 0.5 HP where the load could be started easily.

The essential parts are as shown in Fig 3a.



- Main winding or running winding
- Auxiliary winding or starting winding
- Squirrel cage type rotor
- Centrifugal switch

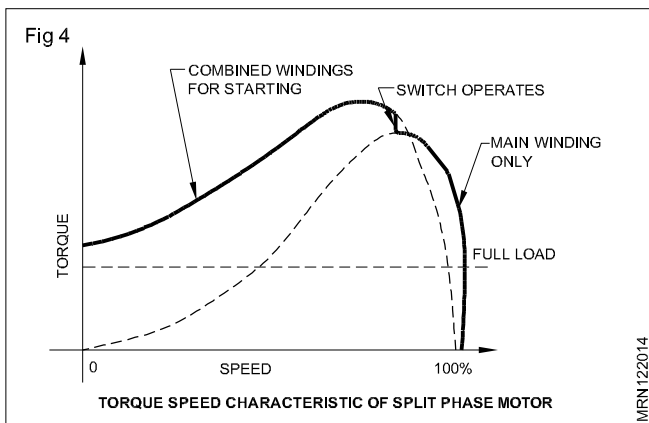
The starting winding is designed to have a higher resistance and lower reactance than the main winding. This is achieved by using smaller conductors in the auxiliary winding than in the main winding. The main winding will have higher inductance when surrounded by more iron, which could be made possible by placing it deeper into the stator slots. It is obvious that the current would split as shown in Fig 3b. The starting current 'I start' will lag the main supply voltage 'V' line by 15° and the main winding current 'I main' lags the main voltage by about 40°. Therefore, these currents will differ in time phase and their magnetic fields will combine to produce a rotating magnetic field.

When the motor has come up to about 75 to 80% of synchronous speed, the starting winding is opened by a centrifugal switch, and the motor will continue to operate as a single phase motor. At the point where the starting winding is disconnected, the motor develops nearly as much torque with the main winding alone as with both windings connected.

This can be observed from the typical torque-speed characteristics of this motor, as shown in Fig 4.

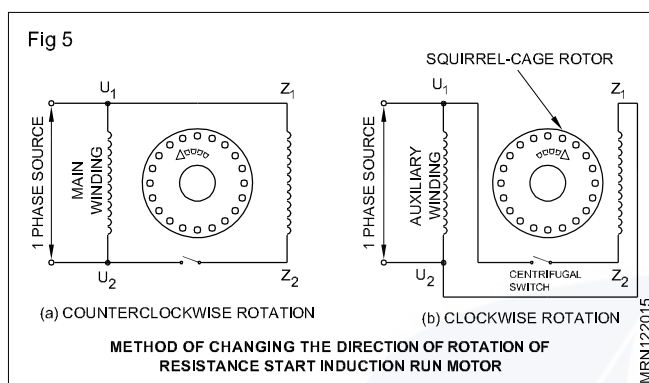
The direction of rotation of a split-phase motor is determined by the way the main and auxiliary windings are connected. Hence, either by changing the main winding terminals or by changing the starting winding terminals, the reversal of

direction of rotation could be obtained. Rotation will be, say counter-clockwise, if Z_1 is joined to U_1 and Z_2 is joined to U_2 as per Fig 5a. If Z_1 is joined to U_2 and Z_2 is joined to U_1 , then the rotation will be clockwise, as shown in Fig 5b.



Application of resistance-start, induction-run motor: As the starting torque of this type of motors is relatively small and its starting current is high, these are manufactured for a rating up to 0.5 HP where the starting load is light. These motors are used for driving fans, grinders, washing machines and wood working tools.

Induction-start, induction-run motor: Instead of resistance start, inductance can be used to start the motor through a highly inductive starting winding. In such a case, the starting winding will have more number of turns, and will be imbedded in the inner areas of the stator slots so as to have high inductance due to more number of turns, and the area will be surrounded by more iron. As the starting and main windings in most of the cases are made from the same gauge winding wire, resistance measurement has to be done to identify the windings. This motor will have a low starting torque, higher starting current and lower power factor.

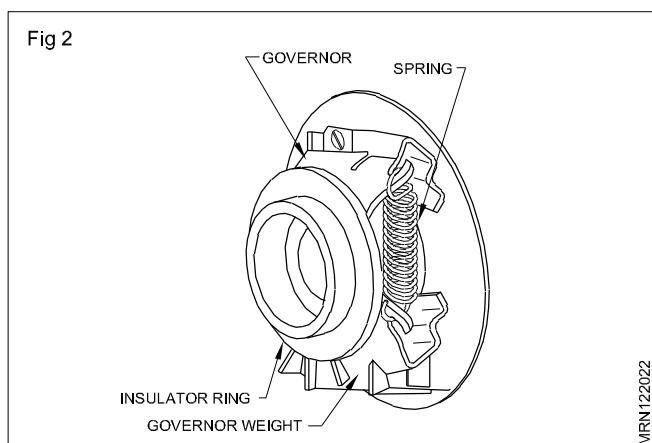
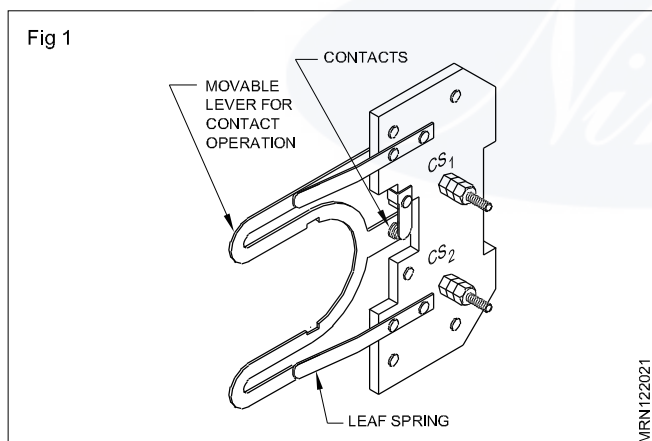


Centrifugal switch

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

- explain the working, the method of maintenance and testing of a centrifugal switch
- explain the necessity of a manual D.O.L. starter and its working.

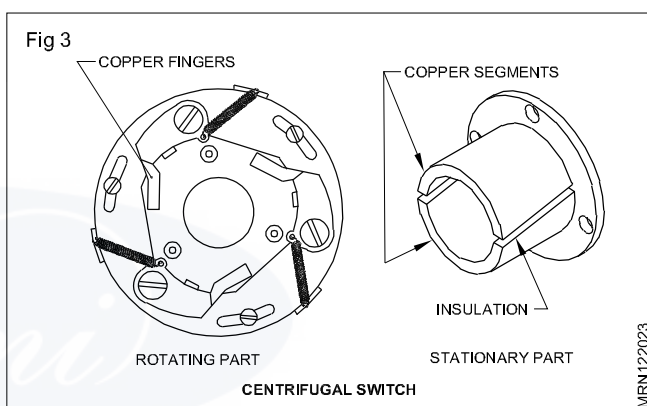
The centrifugal switch: The centrifugal switch is located inside the motor and is connected in series with the starting winding in the case of capacitor-start, induction-run motors, and for disconnecting the starting capacitor in the case of a two value, capacitor-start, capacitor-run motor. Its function is to disconnect the starting winding after the rotor has reached 75 to 80% of the rated speed. The usual type consists of two main parts. Namely, a stationary part as shown in Fig 1, and a rotating part as shown in Fig 2. The stationary part is usually located on the front-end plate of the motor and has two contacts, so that it is similar in action to a single-pole, single-throw switch. When the rotating part is fitted in the rotor, it rotates along with it. When the rotor is stationary, the insulator ring of the rotating part is in an inward position due to spring tension. This inward movement of the insulator ring allows the stationary switch contacts to be closed which is due to the movable lever pressure against the leaf-spring tension in the switch.



When the rotor attains about 75% of the rated speed, due to centrifugal force, the governor weights fly out, and this makes the insulator ring to come outward. Due to this

forward movement of the insulated ring, it presses the movable lever, and the contacts connected through terminals CS_1 and CS_2 open the starting winding.

In older types of centrifugal switches, the stationary part consists of two copper, semicircular segments. These are insulated from each other and mounted inside the front-end plate. The centrifugal switch connections are given to these segments. The rotating part is composed of three copper fingers that ride around the stationary segments, while the motor is at rest or running at lower than 75% of the rated speed. These parts are illustrated in Fig 3.

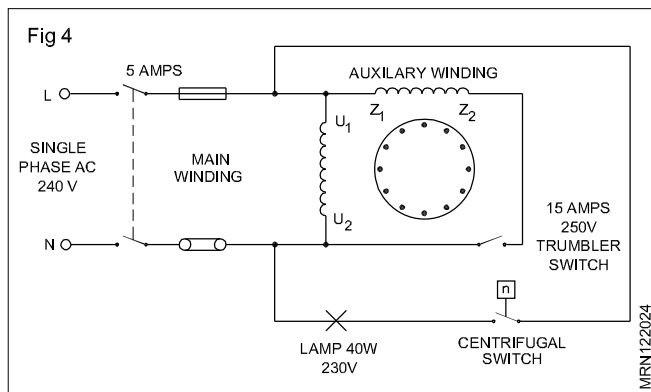


At the time of starting, the segments are shorted by the copper fingers, thus causing the starting winding to be included in the motor circuit. At approximately 75 percent of the full speed, the centrifugal force causes the fingers to be lifted from the segments, thereby disconnecting the starting winding from the circuit.

Maintenance of centrifugal switch: Access to the centrifugal switch could be had by removing the inspection plate, located in the end covers of the motor. In very many cases, the switch is accessible only when the end plate is removed. These switches need to be checked at least once in six months to ensure their proper operation. Look for broken or weak springs, for improper movement, for dirt or corrosion or pittings in the contact points. Make sure all parts work freely without binding. Replace the switch, if found defective.

Testing the operation of a centrifugal switch: Though the centrifugal switch could be tested in a static condition, it will be very difficult to assess its operation at dynamic condition. As most of these switches cannot be checked without opening the end plate, the procedure becomes lengthy and cumbersome. To check the dynamic operation of the switch the following method is suggested. Disconnect the interconnecting terminals of the centrifugal switch from the supply and the starting winding. Connect the starting (auxiliary)

winding through a 15 amps, single-pole, tumbler switch to the rated supply as shown in Fig 4, and keep the tumbler switch in the 'ON' position.



Connect the terminals of the centrifugal switch, through a lamp as shown in Fig 4. Switch 'ON' the motor. When the centrifugal switch is in the closed position, the lamp will light. As the motor picks up speed, say in about 20 seconds, open the tumbler switch to disconnect the starting winding. When the speed of the motor attains about 75% of the rated value, the centrifugal switch, if it operates correctly, will open its contacts which could be observed from the lamp going 'off'. Soon after switching 'on' the main supply, if the lamp is not lighted, or if it lights up but does not go out after 30-40 seconds (75 % of the rated speed) then the centrifugal switch is deemed to be not working, and should be repaired or replaced.

Manual D.O.L. starter: A starter is necessary for starting and stopping the motor, and for providing overload protection.

A manual starter, as it appears, is shown in Fig 5, an open view of the starter is shown in Fig 6, and the internal parts are shown in Fig 7, as a schematic diagram. A manual starter is a motor controller with a contact mechanism operated by hand. A push-button operates the mechanism through a mechanical linkage. As shown in Figs 6 & 7, the starter may have both a thermal overload relay and a magnetic overload relay for overload protection and short circuit protection respectively. Both the relays are made to operate independently, in case of overload or short circuit, to release the start-button for disconnecting the motor from supply. Most of the present day, manual starters have either of the two relays only. Basically, a manual starter is an ON-OFF switch with overload relay only.

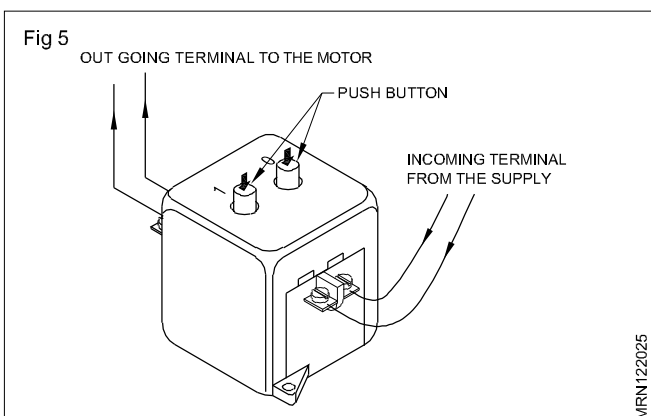


Fig 6

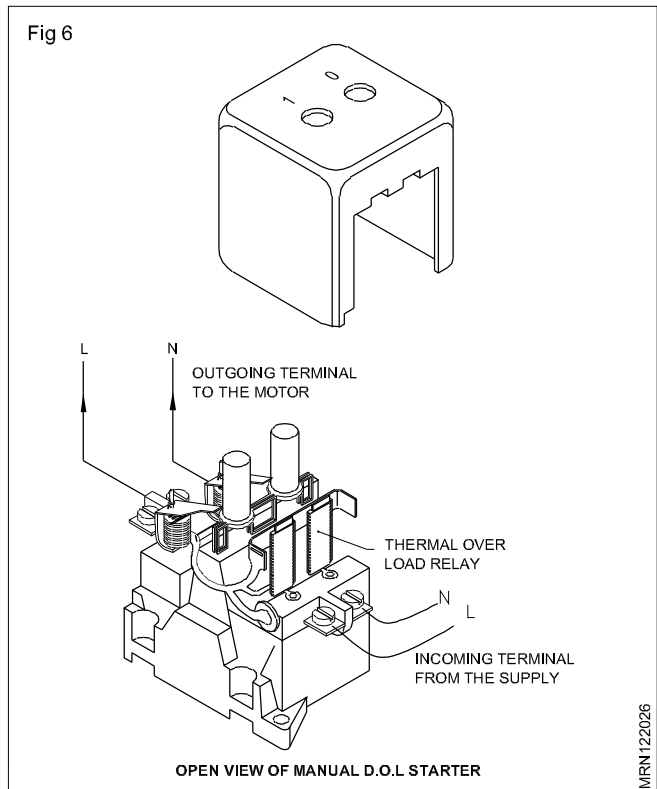
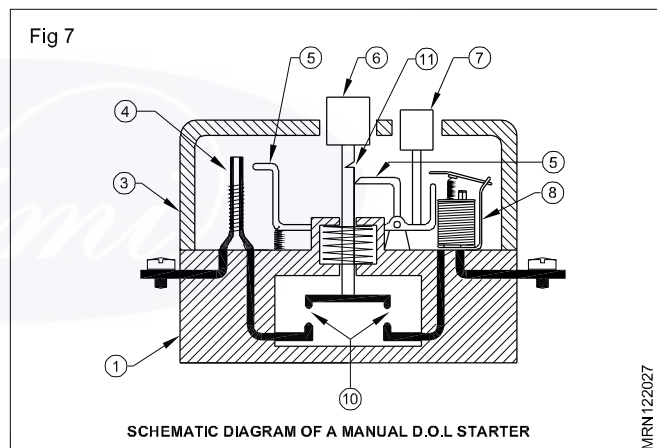


Fig 7



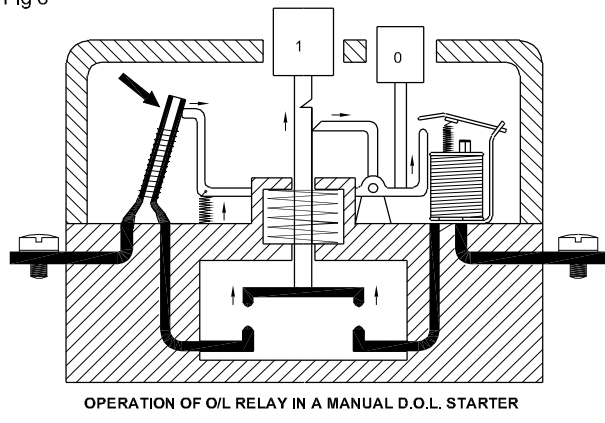
Manual starters are simple and they provide quiet operation

Operation: Pushing the 'ON' button closes the contacts. The contacts remain closed until the STOP button is pushed or the overload relay or the short circuit relay trips the starter.

As shown in Fig 7, when the 'ON' push-button (6) is pressed, the switching contact (10) gets closed, and remains in a closed position, as the mechanical lever system (5) holds the stem of the 'ON' button by the cavity (11) against the spring tension. By operating the stop button (7), the mechanical lever system (5) gets disengaged from the stem cavity, making the stem of the 'ON' button to spring back, thereby opening the switching contacts (10).

Operation of overload relay: In the case of sustained overloads, the heavy currents passing through the heating element of the thermal overload relay heats up the bimetallic strip, making it to bend as shown by the arrow in Fig 8, thereby activating the mechanical lever system to open the switching contacts.

Fig 8



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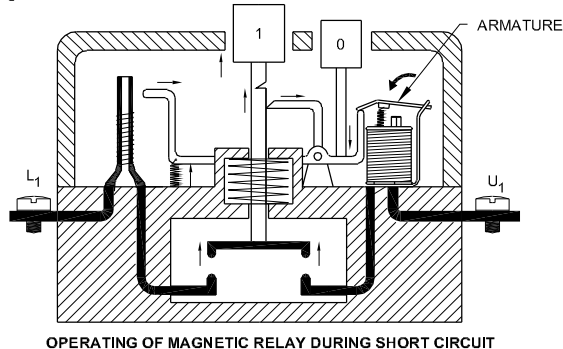
The current setting of the thermal overload relay can be changed by adjusting the setting screw, provided for this purpose (not shown in the figure.)

Operation of short-circuit relay: In the case of a short circuit in the motor circuit, the short circuit current will be very high in value. Though the thermal overload relay is also in series with such a short circuit current, it is sluggish in operation and takes considerable time to operate. On the other hand, the short circuit current within such time of delayed operation, will sufficiently damage the motor winding, power cables or the connected supply line.

The magnetic relay will operate faster than the thermal overload relay in such cases.

During normal load current the magnetic field produced by the coil will not have sufficient pull to attract the armature. But in case of short circuit, the current will be very high and the coil produces sufficient magnetism to attract the armature. Downward movement of the armature activates the mechanical lever mechanism as shown by the arrow in Fig 9 and the switching contact opens. These contacts cannot be reclosed until the starter mechanism has been reset by pressing the Stop button.

Fig 9

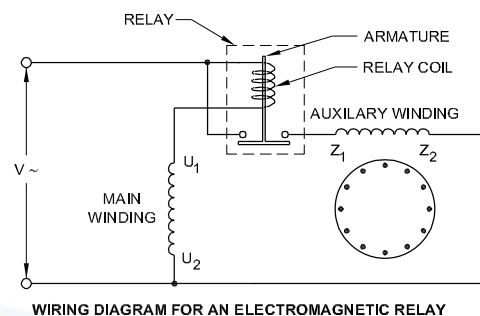


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Manual starters are used for fractional horsepower motors. They usually provide across-the-line starting. Manual starters cannot provide low-voltage protection or no-volt release. If power fails, the contacts remain closed, and the motor will restart when the power returns. This may be an advantage for pumps, fans, compressors, and oil burners. But in the case of machinery it can be dangerous to people operating the equipment, and hence, such manual starters are not recommended to be used in these places.

Electromagnetic relay: Single phase induction motors, like poly phase induction motors takes heavy current from the time during starting when started direct on line Advantage of this high starting current is taken to operate electromagnetic type relay which performs the same function as the centrifugal device. Connection diagram for such a relay is shown in Fig 10.

Fig 10



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The relay has a coil which is connected in series with the main winding. The auxiliary winding is connected across the supply through a normally open contact of the relay. Since split-phase motors are usually started direct on line, the initial current inrush may be as high as five to six times the rated current. During the starting period, when the main winding current is high, the armature of the relay will be drawn upwards, thereby closing the relay contacts. The auxiliary winding will, therefore, get connected across the supply, thus helping the motor to start rotating. As the rotor starts rotating, the line current gradually goes on decreasing. After the motor reaches proper speed, the main winding current drops to a low value and causes the armature of the relay to fall downwards and open the contacts, thereby cutting out the auxiliary winding from the supply. Such relays are located outside the motor so that they can be easily serviced or replaced. As centrifugal switches are mounted internally, their servicing or replacement is not as simple as an externally mounted over-current relay.

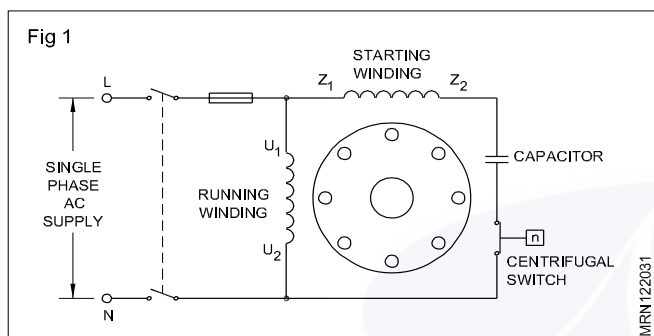
Capacitor-start, induction-run motor

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

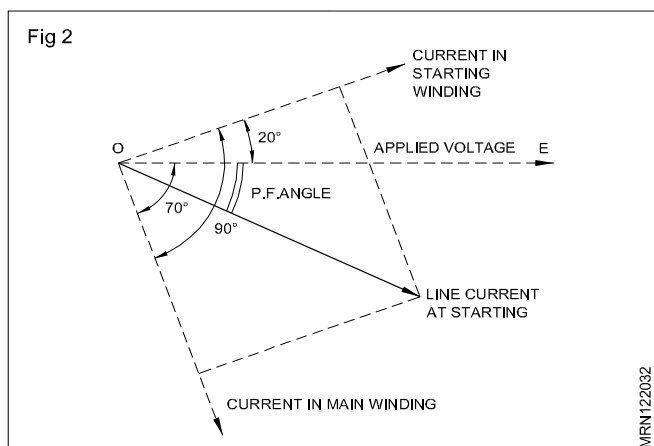
- explain with a diagram the working of an AC single phase, capacitor-start, induction-run motor
- explain the characteristic and application of a capacitor-start, induction-run motor.

A drive which requires a higher starting torque may be fitted with a capacitor-start, induction-run motor as it has excellent starting torque as compared to the resistance-start, induction-run motor.

Construction and working: Fig 1 shows the schematic diagram of a capacitor-start, induction-run motor. As shown, the main winding is connected across the main supply, whereas the starting winding is connected across the main supply through a capacitor and a centrifugal switch. Both these windings are placed in a stator slot at 90° electrical degrees apart, and a squirrel cage type rotor is used.



As shown in Fig 2, at the time of starting, the current in the main winding lags the supply voltages by about 70° degrees, depending upon its inductance and resistance. On the other hand, the current in the starting winding due to its capacitor will lead the applied voltage, by say 20° degrees.

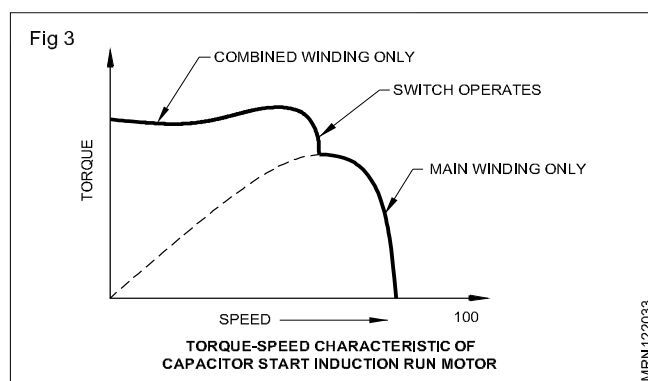


Hence, the phase difference between the main and starting winding becomes near to 90 degrees. This in turn makes the line current to be more or less in phase with its applied voltage, making the power factor to be high, thereby creating an excellent starting torque.

However, after attaining 75% of the rated speed, the centrifugal switch operates opening the starting winding, and the motor then operates as an induction motor, with only the main winding connected to the supply.

Reversing the direction of rotation: In order to reverse the direction of rotation of the capacitor start, induction-run motor, either the starting or the main winding terminals should be changed. This is due to the fact that the direction of rotation depends upon the instantaneous polarities of the main field flux and the flux produced by the starting winding. Therefore, reversing the polarity of any one of the fields will reverse the torque.

Characteristic: As shown in Fig 2, the displacement of current in the main and starting winding is about 80/90 degrees, and the power factor angle between the applied voltage and line current is very small. This results in producing a higher power factor and an excellent starting torque, several times higher than the normal running torque, as shown in Fig 3. The running torque adjusts itself with load by varying inversely with respect to speed as shown in the characteristic curve in Fig 3.



Application: Due to the excellent starting torque and easy direction-reversal characteristic, these machines are used in belted fans, blowers, dryers, washing machines, pumps and compressors.

Capacitors used in single phase capacitor motors

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

- state the precautions to be followed while using a capacitor in a single phase capacitor motor
- explain the methods of testing capacitors.

A capacitor is a device which can store electrical energy in the form of electrostatic charge. However the main purpose

of the capacitor in the single phase motors is to split the phase for producing the rotating magnetic field.

In addition, they also draw the leading current, thereby improving the power factor.

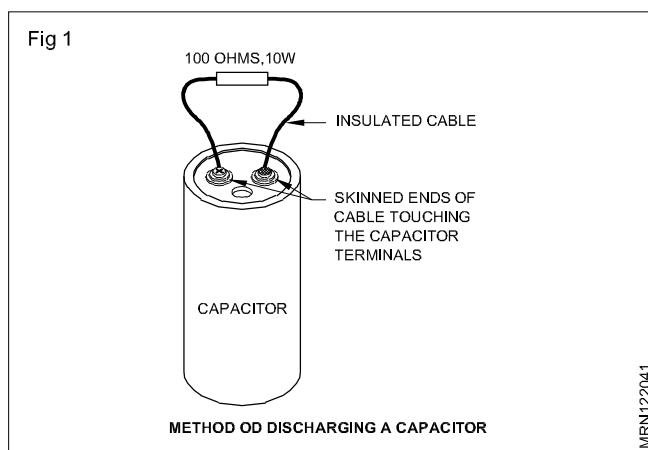
Precautions to be followed while using a capacitor in a single phase capacitor motor: Paper or electrolytic capacitors of non-polarized types are used for starting AC capacitor type motors. These capacitors have special marking for use in AC circuits, and will not have polarity marking. Paper or electrolytic capacitors for use in DC circuits have polarity markings. They must not be used in AC circuits as the reversal of AC voltage will heat up the capacitor, producing enormous gas inside the can, thereby blowing it into pieces.

The AC voltage rating inscribed on the capacitor will have two ratings. One for working voltage and another for the maximum value of voltage. Working voltage refers to the normal R.M.S. rating of the supply mains while the maximum rating will be AC peak voltage which will be $\sqrt{2}$ times the rated R.M.S. voltage. Hence, while replacing a capacitor, a careful scrutiny of voltage rating is essential, as otherwise the capacitor may fail and may also explode.

The duty cycle is another important point to be checked. In most of the capacitors, the marking will indicate whether it is for intermittent (short duty) or continuous (long duty) rating. Though continuous rated capacitors can be used for intermittent rating, never an intermittent (short duty) rating capacitor should be used for continuous rating. This has some relation with the centrifugal switch operation, frequency of starting and stopping and load. When the load is heavy or the centrifugal switch is not proper, there will be a chance for the starting winding, along with the capacitor, to be in the main circuit for a long time. In such cases the capacitor, which is intermittent rated, will fail due to overheating. This should be checked when the capacitor fails often in a specified capacitor-start motor.

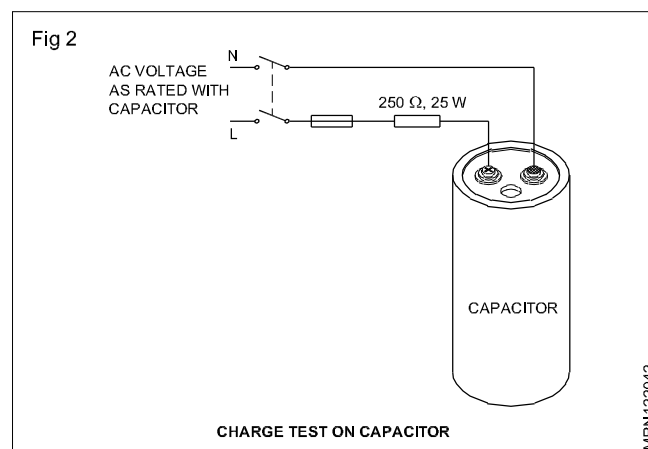
The capacity of the capacitor, which is given in microfarads, should be the same as is specified by the manufacturer of the motor. A lower value will result in poorer starting torque and high starting currents, whereas a higher rating may not allow the speed to reach the rated value resulting in the starting winding to be in main line for a long time thereby ending in poor operation and efficiency. In capacitor-start, capacitor-run motors, there will be two capacitors. As the starting capacitor will be 5 to 15 times of the rating of the running capacitor, and will also be of intermittent-rated electrolytic type, when compared to the running capacitor, which will be of continuous-rated, oil-filled type. Due care should be taken while connecting these capacitors in the motor, avoiding wrong selection and connection.

While handling a capacitor, due care should be taken to avoid shocks. A good capacitor can hold its charge for several days, and when touched, may give a severe shock. Hence, before touching any terminal of the capacitor, which is in use, the electrical charge should be discharged through a test lamp or through a 100 ohms 10 watts resistor as shown in Fig 1. Direct shorting of the capacitor terminals for discharging should be avoided as far as possible as this results in creating an enormous strain to the inner parts of the capacitor and it may fail.



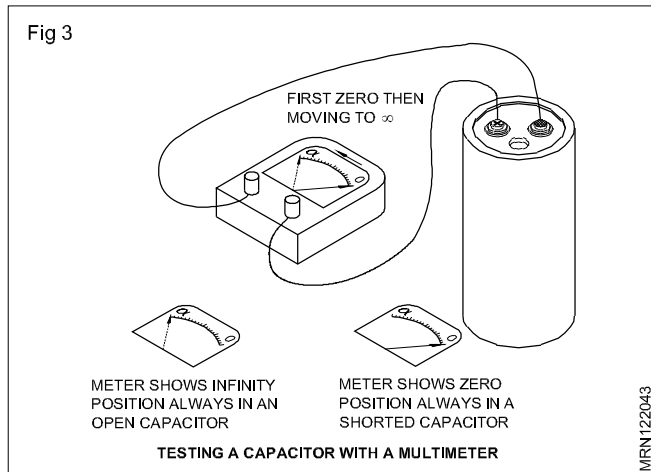
Method of testing capacitors: Before removing a capacitor from the motor connection for testing, it should be discharged to avoid fatal shocks. The following methods are recommended for testing the large value paper, electrolytic or oil-filled capacitors.

Charge-discharge test: Check the working voltage indicated on the capacitor. If the value is equal or more than that of the usual, single phase voltage, say 230V AC 50 Hz, we can connect it to the supply through a 100 ohms, 25 watts resistor as shown in Fig 2. Preferably, keep the capacitor, while testing on line voltage, inside a covered cardboard box or in a wooden box. Sometimes, if the capacitor is defective, it may explode and cause injury to you. Switch on the circuit for about 3-4 seconds. Then switch 'OFF' the supply, and remove the supply terminals carefully with the help of an insulated pliers, without touching the capacitor terminals. Then, short the capacitor terminals with the help of a screwdriver. A bright spark is an indication that the capacitor is working. A dull spark or no spark indicates the capacitor is weak or open. On the other hand, no sparks while touching with the supply terminals indicate that the capacitor is opened. In the case of low capacity capacitors, the spark will be very feeble even if the capacitor is in good condition. Further, this check or the ohmmeter test described in the next para, does not indicate the de-rated value of the capacitor. Hence a capacity check is necessary as will be explained later.



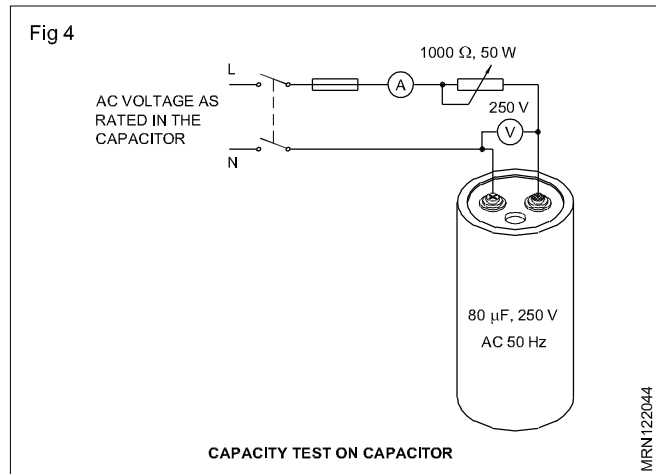
Ohmmeter test: Before using the ohmmeter, the capacitor should be thoroughly discharged to avoid damage to the ohmmeter. Set the range of the ohmmeter to resistance and adjust to zero ohms. Touch the terminals of the

capacitor and watch the deflection of the meter. If the needle deflects towards zero and then moves towards infinity, the capacitor is working. Reverse the test leads and test it again, the needle will do the same thing again in a good capacitor. If the capacitor is open, the needle will not go to zero position but will remain in infinity side. On the other hand, in a shorted capacitor, the needle will be in zero position but will not go to infinity side at all. These results are illustrated in Fig 3.



Capacity test: Connection should be as shown in Fig 4. Keep the resistance value maximum at the time of switching 'on' to protect the ammeter. Keep the capacitor inside a cardboard or wooden box to avoid injury in case of explosion. The ammeter (I) and voltmeter (V) readings are to be taken when the resistor is completely cut out from the circuit. From the meter readings, the capacity rating of the capacitor in microfarads can be calculated.

If the capacity is 20 percent more or less than the notified value, replace it.



$$\text{Capacity of capacitor in CF Farad} = \frac{I}{2\pi FV}$$

$$\begin{aligned} \text{Capacity in microfarad } C_{mf} &= \frac{I \times 10^6}{2\pi FV} \\ &= \frac{3182 \times I}{V} \text{ microfarads.} \end{aligned}$$

Insulation test on capacitors: According to BIS 1709-1984 recommendations, the insulation test conducted between the shorted capacitor terminals and the metal can, when measured by a 500V megger/insulation tester, should not be less than 100 megohms. If the can is of insulating material, the measurement could be made between the capacitor terminals and the metal strap holding the can.

Capacitor-start, capacitor-run motor

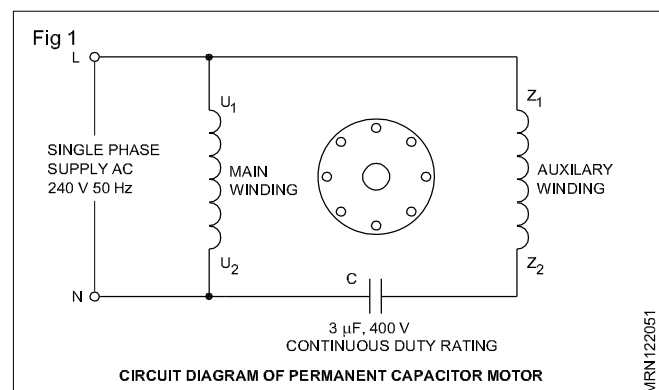
Objectives: At the end of this lesson you shall be able to

- distinguish between the single and two-value, capacitor-start, capacitor-run motors
- draw the schematic diagram of a permanent capacitor motor, state its characteristic and use
- draw the schematic diagram of a capacitor-start, capacitor-run motor, state its characteristic and use.

Capacitor-start, capacitor-run motors are of two types as stated below.

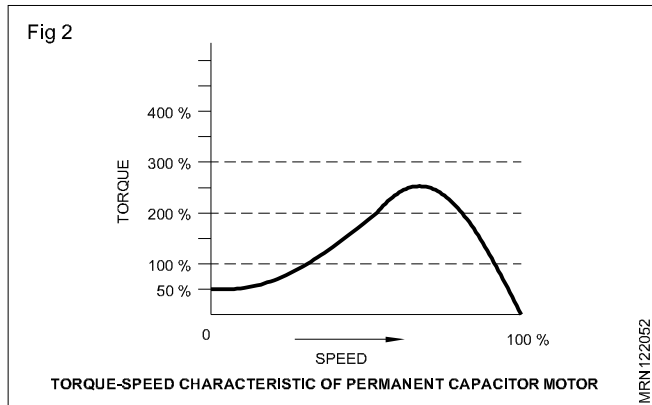
- Permanent capacitor motor (Single value capacitor motor)
- Capacitor-start, capacitor-run motor (Two-value capacitor motor)

Permanent capacitor motor: This type of motor is shown in Fig 1 which is most commonly used in fans. This motor is preferred in drives where the starting torque is not required to be high, while at the same time elimination of the centrifugal switch in the motor is necessary for easy maintenance. The capacitor is connected in series with the auxiliary winding, and remains so throughout the operation. These capacitors should be of oil-type construction and have continuous duty rating.



To avoid low efficiency, the capacity of the condensers is kept low, which, in turn, brings down the starting torque to about 50 to 80% of the full-load torque.

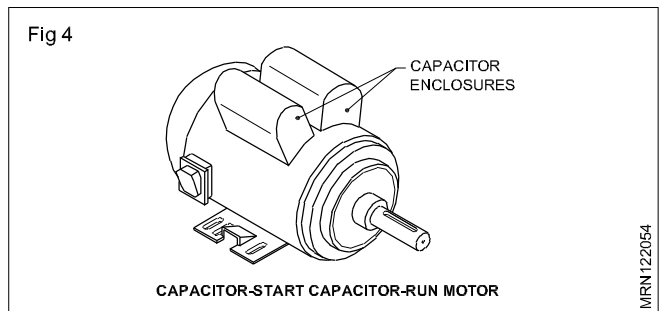
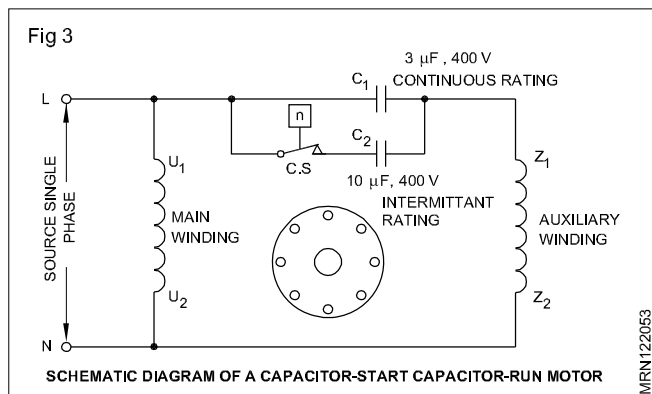
The torque-speed characteristic of the motor is shown in Fig 2. This motor works on the same principle as the capacitor-start, induction-run motor with low starting torque but with higher power factor, during starting as well as in running.



This motor is most suitable for drives, which require a lower torque during start, easy changes in the direction of rotation, stable load operation and higher power factor during operation. *Examples* - fans, variable rheostats, induction regulators, furnace control and arc welding controls. This motor is cheaper than the capacitor-start, induction-run motor of the same rating.

Capacitor-start, capacitor-run motors: As discussed earlier capacitor-start, induction-run motors have excellent starting torque, say about 300% of the full load torque, and their power factor during starting is high. However, their running torque is not good, and their power factor, while running, is low. They also have lesser efficiency and cannot take overloads.

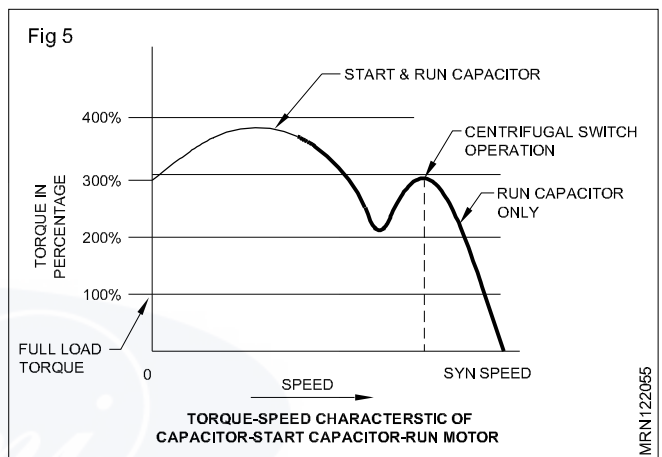
These problems are eliminated by the use of a two-value capacitor motor in which one larger capacitor of electrolytic (short duty) type is used for starting, whereas a smaller capacitor of oil-filled (continuous duty) type is used for running, by connecting them with the starting winding as shown in Fig 3. A general view of such a two-value capacitor motor is shown in Fig 4. This motor also works in the same way as a capacitor-start induction-run motor, with the exception, that the capacitor C1 is always in the circuit, altering the running performance to a great extent.



The starting capacitor which is of short-duty rating will be disconnected from the starting winding with the help of a centrifugal switch, when the starting speed attains about 75% of the rated speed.

Characteristic

The torque-speed characteristic of this motor is shown in Fig 5. This motor has the following advantages.



- The starting torque is 300% of the full load torque.
- The starting current is low, say 2 to 3 times of the running current.
- Starting and running P.F. are good.
- Highly efficient running.
- Extremely noiseless operation.
- Can be loaded up to 125% of the full-load capacity.

Application

These motors are used for compressors, refrigerators, air-conditioners etc. where the duty demands a higher starting torque, higher efficiency, higher power factor and overloading. These motors are costlier than the capacitor-start, induction-run motors of the same capacity.

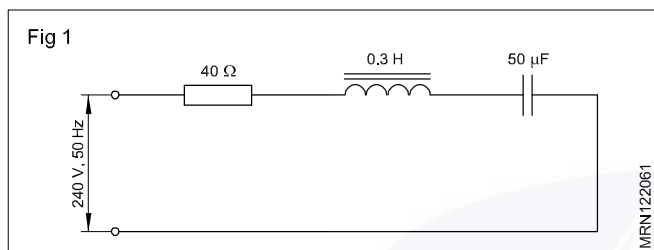
R L C series circuit

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

- calculate the resulting reactance in the RLC series circuit
- calculate the impedance of the RLC series circuit.

Assume an AC single phase circuit consisting a resistance, inductor and capacitor in series. Various parameters could be calculated as shown in the example.

Example : The value of the components shown in Fig 1 is $R = 40 \text{ ohms}$ $L = 0.3 \text{ H}$ and $C = 50 \text{ mf}$. The supply voltage is $240 \text{ V } 50 \text{ Hz}$. Calculate the inductive reactance, capacitive reactance, net reactance, impedance, current in the circuit, voltage drops across the R, L and C power factor, active power, reactive power and apparent power. Also draw the impedance triangle, voltage triangle and power triangle.



Calculate the resulting reactance in RLC circuit :

Inductance and capacitance have directly opposite effects in an AC circuit. The voltage drop caused by the inductive reactance of the coil leads the line current by 90° . The voltage drop across the inductor coil and the capacitor are 180 degrees apart and oppose each other. To calculate the net reactance in the above example:

Inductive reactance

$$X_L = 2\pi fL = 314 \times 0.3 = 94.2 \Omega$$

Capacitive reactance

$$X_C = \frac{1}{2\pi fC} = \frac{1}{314 \times 0.00005} = \frac{1}{0.0157} = 63.69 \Omega$$

$$\text{Net reactance} = X_L - X_C = 94.2 - 63.69 = 30.51 \Omega$$

Calculate the impedance: From the circuit given above the impedance can be found. The impedance is the resultant combination resistance and reactance. In this circuit, the impedance is the combination of the 40 ohms resistance and 30.51Ω resultant reactance. The impedance for this circuit is

$$\begin{aligned} Z &= \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{40^2 + 30.51^2} \\ &= \sqrt{1600 + 930.86} = \sqrt{2530.86} = 50.30 \Omega \end{aligned}$$

Power and power factor in AC single phase system

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

- state the relationship between power and power factor in single phase circuits
- state the principle and function of AC single phase wattmeter(dynamometer type).

The power in a DC circuit can be calculated by using the formulae.

- $P = E \times I$ watts
- $P = E^2/R$ watts.

The use of the above formulae in AC circuits will give true power only if the circuit contains pure resistance. Note that the effect of reactance is present in AC circuits.

Power in AC circuit: There are three types of power in AC circuits.

- Active power (True power)
- Reactive power
- Apparent power

Active power (True power): The calculation of active power in an AC circuit differs from that in a direct current circuit. The active power to be measured is the product of $V \times I \times \cos \phi$ where $\cos \phi$ is the power factor (cosine of the phase angle between current and voltage). This indicates that with a load which is not purely resistive and where the current and voltage are not in phase, only that part of the current which is in phase with the voltage will produce power. This can be measured with a wattmeter.

Reactive power: With the reactive power (wattless power)

$$P_q = V \times I \times \sin \phi$$

only that part of the current which is 90° out of phase (90° phase shift) with the voltage is used in this case. Capacitors and inductors, on the other hand, alternatively store energy and return it to the source. Such transferred power is called reactive power measured in volt/ampere reactive or vars. Unlike true power, reactive power can do no useful work.

Apparent power: The apparent power, $P_a = V \times I$.

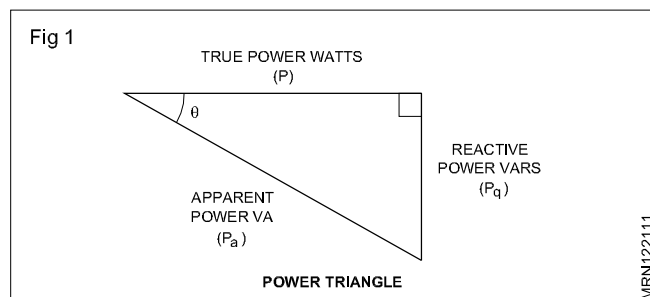
The measurement can be made in the same way as for direct current with a voltmeter and ammeter.

It is simply the product of the total applied voltage and the total circuit current and its unit is volt-ampere (VA).

The power triangle: A power triangle identifies three different types of power in AC circuits.

- True power in watts (P)
- Reactive power in vars (P_q)
- Apparent power VA (P_a)

The relationship among the three types of power can be obtained by referring to the power triangle. (Fig 1)



Therefore

$$P_a^2 = P^2 + P_q^2 \text{ volt-amperes (VA)}$$

where ' P_a ' is the apparent power in volt-ampere (VA)

'P' is the true power in watts (W)

P_q is the reactive power in volt-amperes reactive. (VAR)

Wattmeter

A power measuring meter, called a wattmeter, can be connected into a circuit to measure power instead of making two measurements and then calculating the power. The power dissipated can be read directly from the scale of the meter.

The wattmeter takes the power factor of the circuit into account and always indicates true power.

Principle: A wattmeter consists of two stationary coils connected in series, and one moving coil. (Fig 2) The stationary coils, wound with many turns of thick wire, have a low resistance. The moving coil. (Fig 2) wound with many turns of fine wire, has high resistance. For power measurements, the moving coil is connected across the source voltage with a series resistance of high value which determines the current through this coil in phase and proportional to voltage. The fixed coil is connected in series with the load, which can carry the load current.

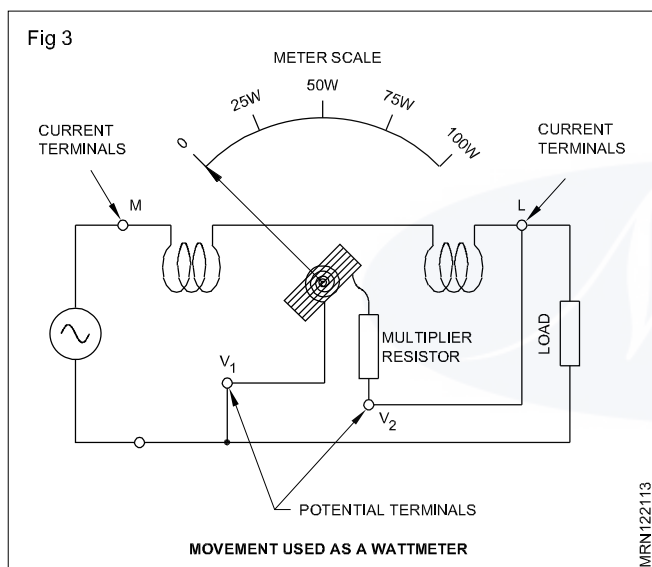
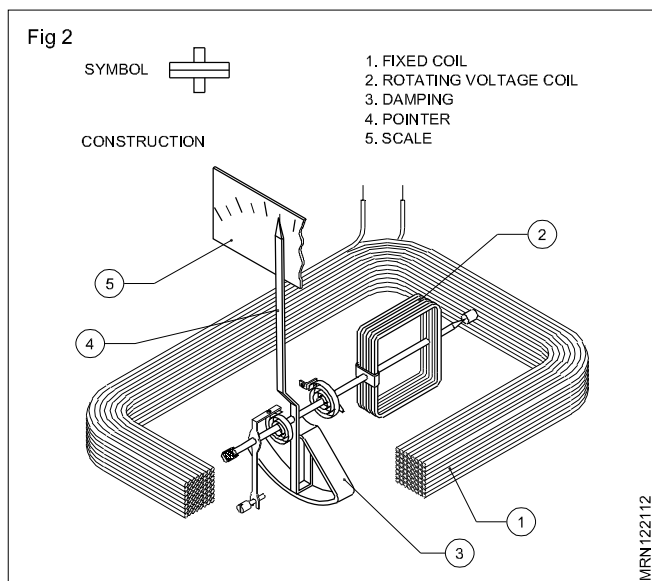
The interaction of the two magnetic fields, produced by the fixed and moving coils, will cause the moving coil and its pointer to rotate in proportion to the voltage (across the load) and current (through the load).

Wattmeter types

- Dynamometer type
- Induction type
- Electrostatic type

Electro-dynamometer type wattmeter: The wattmeter has got four terminals, and they are marked as 'M' 'L' for the

current coils and 'V₁ V₂' for the pressure coils (Fig 3). Generally the current coil terminals 'M' and 'L' are thick in size compared to the pressure coil terminals 'V₁' and 'V₂'.

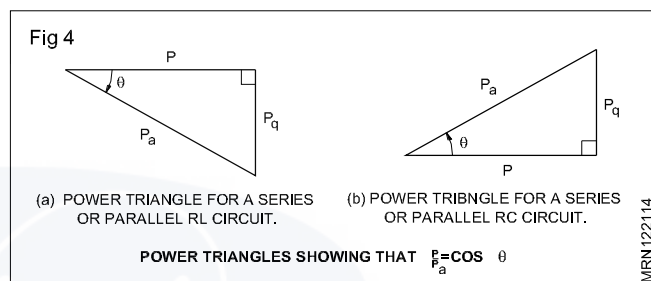


The dynamometer type of wattmeter can be used for both AC and DC power measurements, whereas the induction type wattmeter is used for AC power measurement only. The electrostatic type wattmeter is used for DC power measurements only.

Power factor: The ratio of the true power delivered to an AC circuit compared to the apparent power that the source must supply is called the power factor of the load. If we examine any power triangle (Fig 4), you may see the ratio of the true power to the apparent power is the cosine of the angle θ .

$$\text{Power factor} = \frac{P}{P_a} = \cos \theta$$

From the equation, you can observe that the three powers are related and can be represented in a right-angled power triangle, from which the power factor can be obtained as the ratio of true power to apparent power. For inductive loads, the power factor is called lagging to distinguish it from the leading power factor in a capacitive load. (Fig 4)



A circuit's power factor determines how much current is necessary from the source to deliver a given true power. A circuit with a low power factor requires a higher current than a unity power factor circuit.

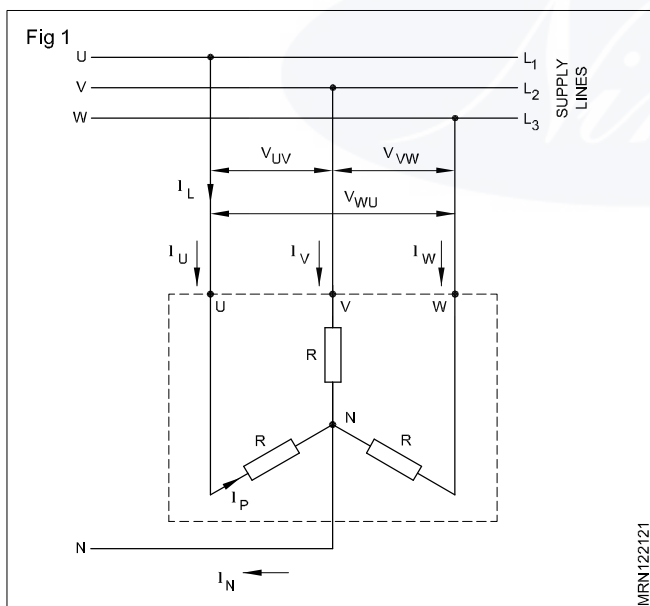
Systems of connection in 3-phase AC

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

- explain the star and delta systems of connection
- state phase relationship between line and phase voltages in a star connection
- state and describe the relationship between phase and line current in a star connection
- state the relationship between phase and line voltage in a delta connection
- state and describe the relationship between phase and line current in a delta connection.

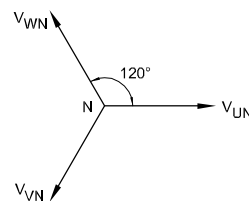
Methods of 3-phase connection: If a three-phase load is connected to a three-phase network, there are two basic possible configurations. One is 'star connection' (symbol Y) and the other is 'delta connection' (symbol D).

Star connection: In Fig 1 the three-phase load is shown as three equal magnitude resistances. From each phase, at any given time, there is a path to the terminal points U, V, W of the equipment, and then through the individual elements of the load resistance. All the elements are connected to one point N: the 'star point'. This star point is connected to the neutral conductor N. The phase currents i_U , i_V , and i_W flow through the individual elements, and the same current flows through the supply lines, i.e. in a star connected system, the supply line current (I_L) = phase current (I_P).



The potential difference for each phase, i.e. from a line to the star point, is called the phase voltage and designated as V_P . The potential difference across any two lines is called the line voltage V_L . Therefore, the voltage across each impedance of a star connection is the phase voltage V_P . The line voltage V_L appears across the load terminals U-V, V-W and W-U and designated as V_{UV} , V_{VW} and V_{WU} in the Fig 2. The line voltage in a star-connected system will be equal to the phasor sum of the positive value of one phase voltage and the negative value of the other phase voltage that exist across the two lines.

Fig 2

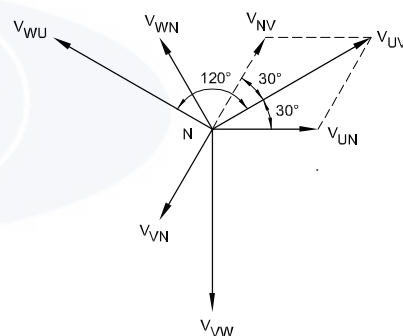


Thus

$$V_L = V_{UV} = (\text{phasor } V_{UN}) - (\text{phasor } V_{VN}) \\ = \text{phasor } V_{UN} + V_{VN'}$$

In the phasor diagram (Fig 3)

Fig 3



$$V_L = V_{UV} = V_{UN} \cos 30^\circ + V_{VN'} \cos 30^\circ$$

$$\text{But } \cos 30^\circ = \frac{\sqrt{3}}{2}$$

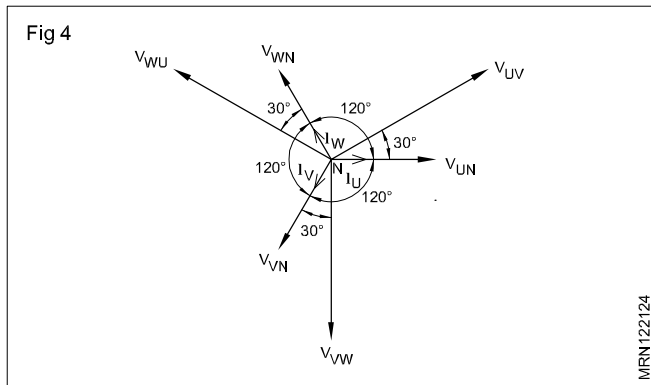
$$\text{Thus as } V_{UN} = V_{VN} = V_P$$

$$V_L = \sqrt{3} V_P$$

This same relationship is applied to V_{UV} , V_{VW} and V_{WU} .

In a three-phase star connection, the line voltage is always $\sqrt{3}$ times the phase-to-neutral voltage. The factor relating the line voltage to the phase voltage is $\sqrt{3}$.

The voltage and current relationship in a star connection is shown in the phasor diagrams. (Fig 4) The phase voltages are displaced 120° in phase with respect to each other.

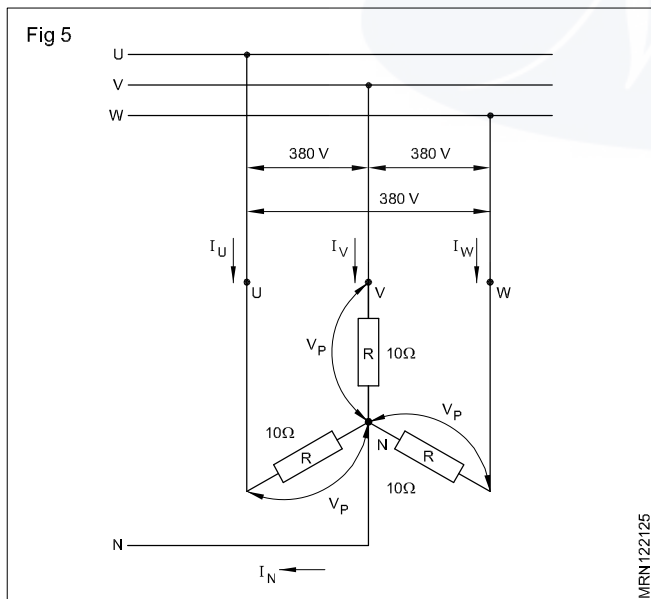


Derived from these are the corresponding line voltages. The line voltages are displaced 120° in phase with respect to each other. Since the loads in our example are provided by purely resistive impedances, the phase currents I_P (I_U , I_V , I_W) are in phase with the phase voltages V_P (V_{UN} , V_{VN} and V_{WN}). In a star connection, each phase current is determined by the ratio of the phase voltage to the load resistance R .

Example 1: What is the line voltage for a three-phase, balanced star-connected system, having a phase voltage of 240V?

$$V_L = \sqrt{3} V_P = \sqrt{3} \times 240 \\ = 415.7V.$$

Example 2: What is the magnitude of each of the supply line currents for the circuit shown in Fig 5?



Because of the arrangements of a star connection there is a voltage

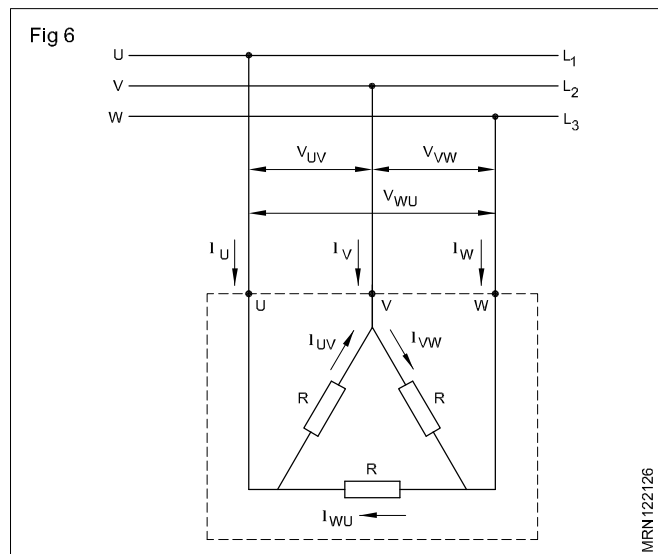
$$V_P = \frac{380}{1.73} = 220V$$

across each of the purely resistive loads R .

The three-supply line currents have the same magnitude since the star-connected load is balanced, and they are given by

$$I_U = I_V = I_W = \frac{V_P}{R} = \frac{220}{10} = 22A = I_L = I_P$$

Delta connection: There is a second possible arrangement for connecting a three-phase load in a three-phase network. This is the delta or mesh connection (D). (Fig 6)



The load impedances form the sides of a triangle. The terminals U, V and W are connected to the supply lines of the L_1 , L_2 and L_3 .

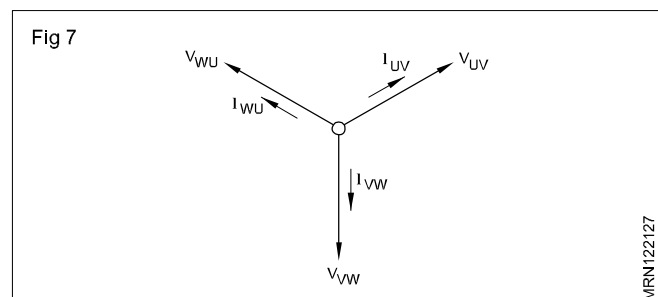
In contrast to a star connection, in a delta connection the line voltage appears across each of the load phases.

The voltages, with symbols V_{UV} , V_{VW} and V_{WU} are, therefore, the line voltages.

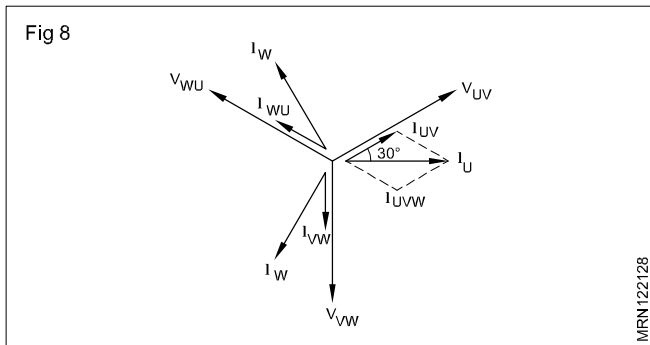
The phase currents through the elements in a delta arrangement are composed of I_{UV} , I_{VW} and I_{WU} . The currents from the supply lines are I_U , I_V and I_W , and one line current divides at the point of connection to produce two phase currents.

The voltage and current relationships of the delta connection can be explained with the aid of an illustration. The line voltages V_{UV} , V_{VW} and V_{WU} are directly across the load resistors, and in this case, the phase voltage is the same as the line voltage. The phasors V_{UV} , V_{VW} and V_{WU} are the line voltages. This arrangement has already been seen in relation to the star connection.

Because of the purely resistive load, the corresponding phase currents are in phase with the line voltages. (Fig 7) Their magnitudes are determined by the ratio of the line voltage to the resistance R .



On the other hand, the line currents I_U , I_V and I_W are now compounded from the phase currents. A line current is always given by the phasor sum of the appropriate phase currents. This is shown in Fig 8. The line current I_U is the phasor sum of the phase currents I_{UV} and I_{UW} . (See also Fig 8)



$$\text{Hence, } I_U = I_{UV} \cos 30^\circ + I_{UW} \cos 30^\circ$$

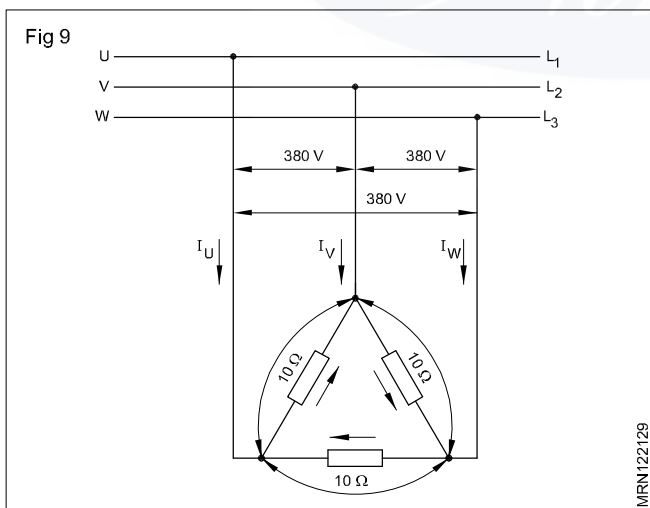
$$\text{But } \cos 30^\circ = \frac{\sqrt{3}}{2}.$$

$$\text{Thus } I_L = \sqrt{3} I_{ph}$$

Thus, for a balanced delta connection, the ratio of the line current to the phase current is $\sqrt{3}$.

Thus, line current = $\sqrt{3}$ x phase current.

Example 3: What are the values of the line currents, I_U , I_V and I_W in the above example? (Fig 9)



Solution

Since the load is balanced (i.e. the resistance of each phase is the same), the phase currents are of equal magnitude, and are given by the ratio of the line voltage to the load phase resistance

$$I_{UV} = I_{VW} = I_{WU} = \frac{V_P}{R} = \frac{V_L}{R} = \frac{380}{10} = 38A.$$

Thus, the phase current in the case of delta is 38A. Expressed in words:

$$\text{Phase current} = \frac{\text{line or phase voltage}}{\text{phase resistance}}$$

The line current is $\sqrt{3}$ times the phase current.

Therefore the line current is

$$I_U = I_V = I_W = \sqrt{3} \times 38A = 1.73 \times 38A = 66A.$$

Example 4: Three identical coils, each of resistance 10 ohms and inductance 20mH is delta connected across a 400-V, 50Hz, three-phase supply. Calculate the line current.

For a coil,

$$\text{reactance } X_L = 2\pi fL = 2 \times 3.142 \times 50 \times \frac{20}{1000} = 6.3 \text{ ohms.}$$

Impedance of a coil is thus given by

$$Z = \sqrt{R^2 + X^2} = \sqrt{(10^2 + 6.3^2)} = 11.8 \text{ ohms.}$$

For a delta connected system, according to equation

$$V_L = V_P.$$

$$\text{Thus } V_P = 400V.$$

Hence the phase current is given by

$$I_P = \frac{V_P}{Z} = \frac{400}{11.8} = 33.9 \text{ A.}$$

But for a delta connected system, according to equation,

$$I_L = \sqrt{3} I_P = \sqrt{3} \times 33.9 = 58.7A.$$

Application of star and delta connection with balanced loads

An important application is the 'star-delta change over switch' or star-delta starter.

For a particular three-phase load, the line current in a delta connection is three times as great as for a star connection for a given line voltage, i.e. for the same three-phase load (D line current) = 3 (Y - line current).

This fact is used to reduce the high starting current of a 3-phase motor with a star-delta change over switch.

Application of star connection: Alternators and secondary of distribution transformers, have their three, single-phase coils interconnected in star.

Neutral in 3-phase system

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

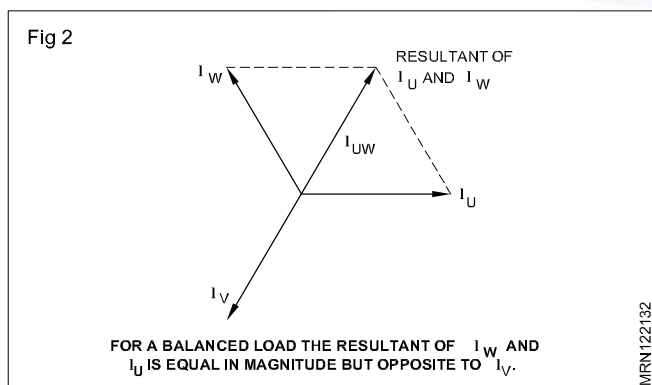
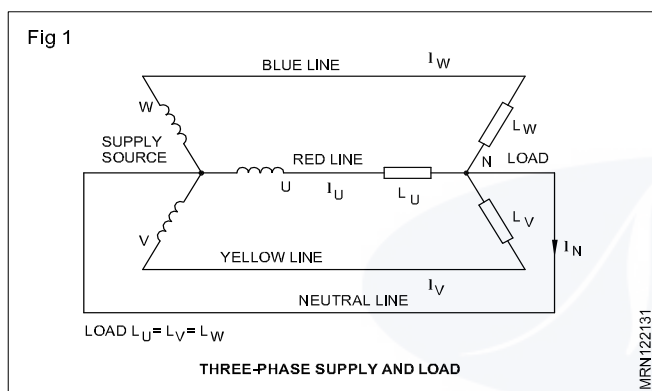
- explain the current in neutral of a 3-phase star connection
- state the method of producing artificial neutral in a 3-phase delta connection
- state the method of earthing the neutral.

Neutral: In a three-phase star connection, the star point is known as neutral point, and the conductor connected to the neutral point is referred as neutral conductor.

Current in the neutral conductor: In a star-connected, four-wire system, the neutral conductor N must carry the sum of the currents I_U , I_V and I_W . One may, therefore, get the impression that the conductor must have sufficient area to carry a particularly high current. However, this is not the case, because this conductor is required to carry only the phasor sum of the three currents.

$$I_N = \text{phasor sum of } I_U, I_V \text{ and } I_W$$

Fig 2 shows this phasor addition for a situation where the loads are balanced and the currents are equal. The result is that the current in the neutral line I_N is zero.

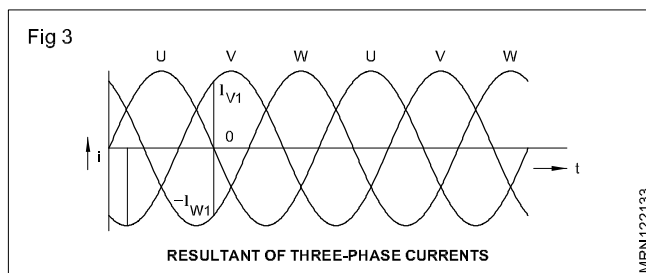


This can also be shown for the other instantaneous values.

At a particular instant in time, t_1 , the instantaneous value $i_U = 0$ (Fig 3), i_V and i_W , have equal magnitudes, but they have opposite signs, i.e. they are in opposition and the phasor sum is zero. Taking the other values of t , it can be seen that the sum of the three phase currents to equal to zero.

Therefore, for a balanced load the neutral conductor carries no current.

With unequal value the phase currents are different in magnitude and the neutral current is not zero. Then a 'neutral' current I_N does flow in the neutral conductor, but this, however, is less than any of the supply line currents.



Thus, neutral conductors, when they are used, have a smaller cross-section than the supply lines.

Effect of imbalance: If the load is not balanced and there is no neutral conductor, there is no return path for the sum of the phase currents which will be zero. The phase voltages will not now be given by the line voltage divided by $\sqrt{3}$, and will have different values.

Earthing of neutral conductor: Supply of electrical energy to commercial and domestic consumers is an important application of three-phase electricity. For 'low voltage distribution' - in the simplest case, i.e. supply of light and power to buildings - there are two requirements.

- 1 It is desirable to use conductors operating at the highest possible voltage but with low current in order to save on expensive conductor material.
- 2 For safety reasons, the voltage between the conductor and earth must not exceed 250V.

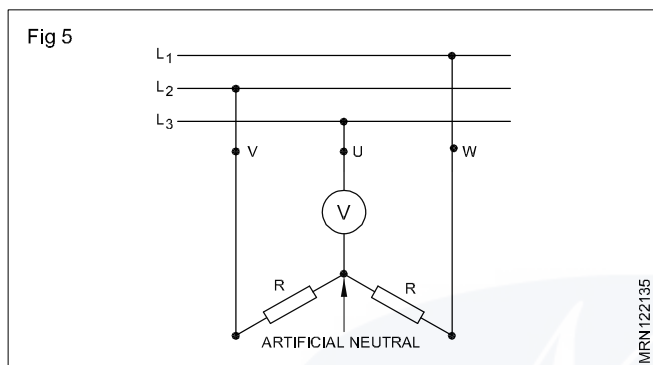
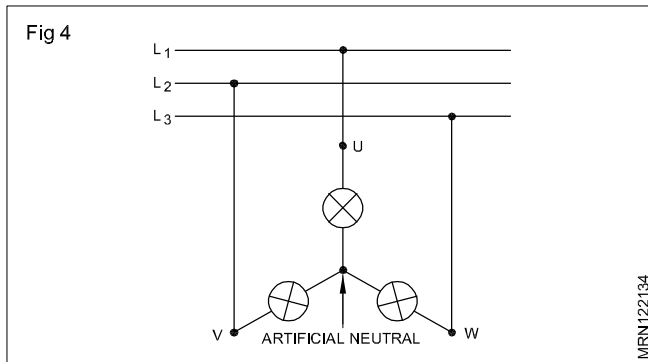
A voltage distribution system according to criterion 2, only possible with a low line voltage below 250 V. However, this is contrary to criterion 1. On the other hand, with a star connection, a line voltage of 400V is available. In this case, there is only 230V between the supply line and the neutral conductor. Criterion 1 is satisfied and, to comply with 2, the neutral conductor is earthed.

Indian Electricity Rules: I.E. Rules insist that the neutral conductor must be earthed by two separate and distinct connections to earth. Rule No.61(1)(a), Rule No.67(1)(a) and Rule No.32 insist on the identification of neutral at the point of commencement of supply at the consumer's premises, and also prevent the use of cut outs or links in the neutral conductor. BIS stipulate the method of earthing the neutral. (Code No.17.4 of IS 3043-1966)

Cross-sectional area of neutral conductor: The neutral conductor in a 3-phase, 4-wire system should have a smaller cross-section. (half of the cross-section of the supply lines).

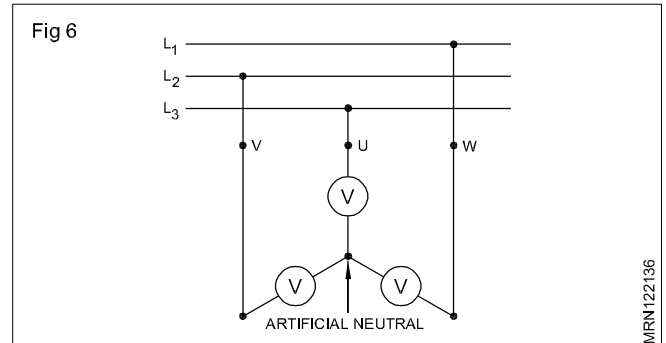
Artificial neutral: Normally neutral conductors are available with a 3-phase, 4-wire system only. Neutral conductors are not drawn for a 3-phase, 3-wire system. Neutral conductors are also not available with the delta-connected supply system.

A neutral conductor is required for measuring phase voltage, energy, power to connect indicating lamps, etc. An artificial neutral for connecting indicating lamps can be formed by connecting them in star. (Fig 4) Artificial neutral for instruments can be formed by connecting additional resistors in star. (Fig 5)



In this method, the value of R must be equal to the resistance of the voltmeter. The same method can be used while measuring power or energy by connecting resistors of equal resistance as of potential coil.

When three instruments of a similar kind are in use, their pressure coils can be connected to form an artificial neutral. (Fig 6)



This type of neutral cannot allow a large current. When earthing of a delta-connected system is required, neutral earthing compensators are used. These can sink or source large currents while keeping neutral to phase voltages constant.

IS 3043 Code No. 17, provide a method to obtain neutral for earthing purposes by an earthing compensator.

Introduction to electronics

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

- describe about electronics
- explain the types of resistors and induction
- explain the active components
- state the coding of semiconductor devices.

Electronics is the discipline dealing with the development and application of devices and systems involving the flow of electrons in a vacuum, in gaseous media, and in semiconductors. Electronics deals with electrical circuits that involve active electrical components such as vacuum tubes, transistors, diodes, integrated circuits, optoelectronics, and sensors, associated passive electrical components, and interconnection technologies. Commonly, electronic devices contain circuitry consisting primarily or exclusively of active semiconductors supplemented with passive elements; such a circuit is described as an electronic circuit.

Electronics is considered to be a branch of physics and electrical engineering.

The nonlinear behaviour of active components and their ability to control electron flows makes amplification of weak signals possible. Electronics is widely used in information processing, telecommunication, and signal processing. The ability of electronic devices to act as switches makes digital information processing possible. Interconnection technologies such as circuit boards, electronics packaging technology and varied forms of communication infrastructure complete circuit functionality and transform the mixed components into a regular working system.

This Electronic sensors and signals are very much useful in Refrigeration & Air conditioning process.

Electrical and electro-mechanical science and technology deals with the generation, distribution, switching, storage and conversion of electrical energy to and from other energy forms (using wires, motors, generators, batteries, switches, relays, transformers, resistors and other passive components). This distinction started around 1906 with the invention by Lee De Forest of the triode, which made electrical amplification of weak radio signals and audio signals possible with a non-mechanical device. Until 1950 this field was called "radio technology" because its principal application was the design and theory of radio transmitters, receivers and vacuum tubes.

Today, most electronic devices use semiconductor components to perform electron control. The study of semiconductor devices and related technology is considered a branch of solid-state physics, whereas the design and construction of electronic circuits to solve practical problems come under electronics engineering. This article focuses on engineering aspects of electronics.

Branches of electronics

Electronics has branches as follows:

- | | |
|-------------------------|------------------------|
| 1 Digital electronics | 2 Analogue electronics |
| 3 Microelectronics | 4 Circuit design |
| 5 Integrated circuits | 6 Optoelectronics |
| 7 Semiconductor devices | 8 Embedded systems |

Resistors : The Components used in electronic circuits can broadly grouped under two headings.

- passive components
- active components

Passive components : Components like resistors, capacitors, and inductors used in electronic circuit are called as passive components. These components by themselves are not capable of amplifying or processing an electrical signal. However these components are equally important in electronic circuit as that of active components, without the aid of passive components, a transistor (active components) cannot be made to amplify electrical signal.

Circuits formed with passive components obey the electrical circuits laws such as ohm's law, Kirchoff's Laws etc.,

Active components : In electronic circuit, the components, other than passive are known as active components. Namely, transistors, diodes, SCRs Vacuum tubes etc.,

Resistors : The components whose purpose to introduce resistance in the circuit is called as resistors. Other details of resistors are dealt in earlier lessons.

Capacitor : The components whose purpose to introduce capacitance in the circuit is called as capacitor. The unit of capacitance is 'FARAD'. Commercially capacitors are available in micro farad (mF), nanofarad (nF) & pico farads (pF).

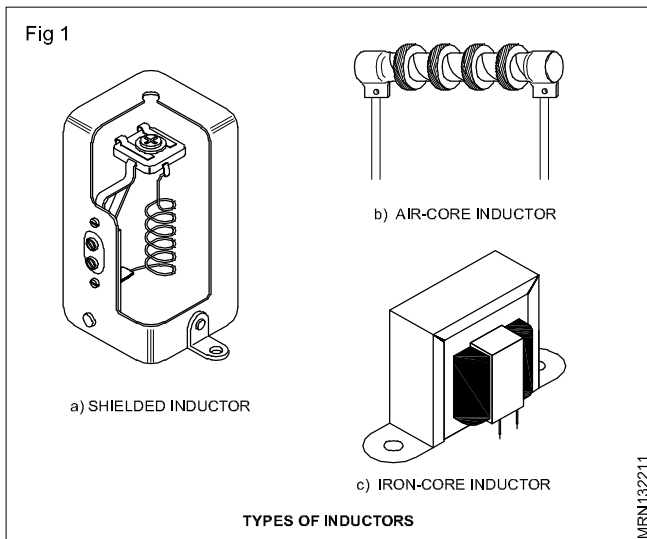
The colour coding of capacitors and resistors are same. Where as, in the case of fixed capacitors, the colour coded unit shall be in pico farads.

For letter coding, in case of capacitor, the letter 'p', 'n', 'm' shall be used as multipliers. Where $p = 10^{-12}$, $n = 10^{-9}$ and $m = 10^{-6}$ farads, and letter code for tolerance on capacitor is the same as in resistor.

Other details about the capacitors are already dealt in 1st year trade theory.

INDUCTOR : The ability of the conductor to induce voltage in itself, when the current changes in it is called as self inductance (or) simply inductance. A coil introduced in a circuit to have inductance is called as inductor.

Different type of inductors are shown in Fig 1. The unit of inductance is “Henry”. Commercially a coil may have inductance in milli henry (10^{-3}H), or in micro henry (10^{-6}H).



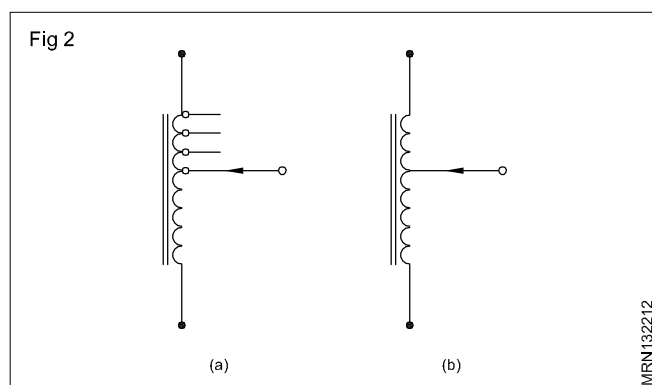
While specifying the inductance the following factors to be considered

- nominal value of inductance in Henry / millihenry / micro (m) henry
- tolerance in percentage ($\pm 5/10/20\%$)
- type of winding like single layer, double layer, multilayer and pie (p) etc.
- type of core like air core, iron core, ferrite core
- type of application like audio frequency (AF), Radio frequency (RF) coupling coil, filter coil etc.,

In an electronic circuit some time, it is also required to vary the inductance.

The inductance of a coil can be varied by:-

- providing tapped inductive coil, as shown in Fig 2 or

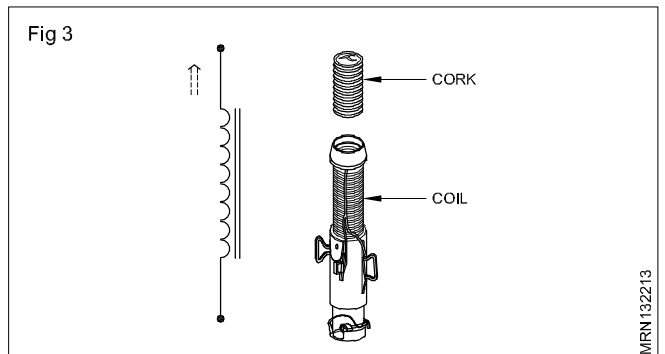


- adjusting the core of a coil as shown in Fig 3.

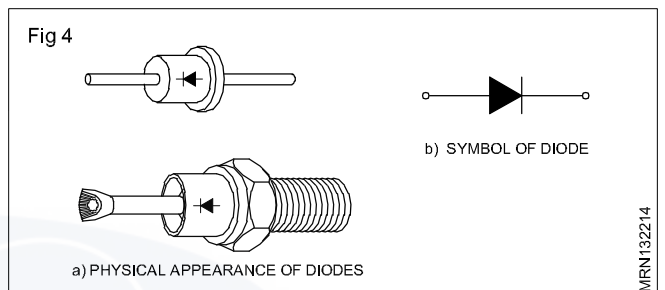
However, all inductor coils have inherent resistance due to the resistance of the winding wire in the coil. Further the maximum current that can be safely carried by an inductor depends upon the size of the winding wire used.

Active components : In electronic circuits, components other than resistors, capacitors and inductors are also used. Namely, transistors, diodes, vacuum tubes, SCRs,

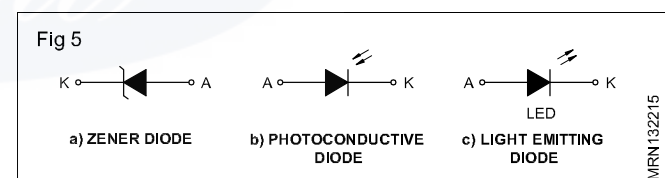
diacs, zener-diode etc. The application of electrical circuit laws (Ohm's law etc.) in the circuit containing the above components will not give correct results. i.e. these components do not obey. Ohm's law, Kirchoff's law etc. These components are called active components.



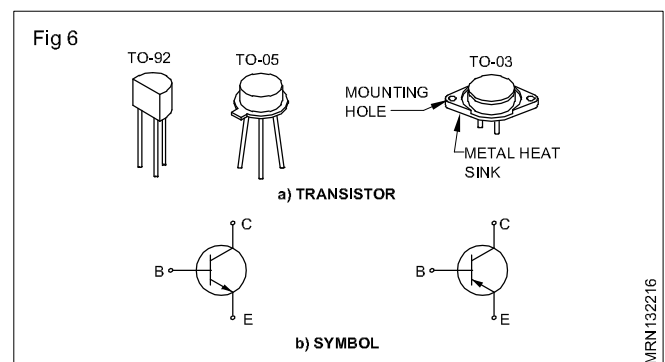
The different active components and the method of representing them by symbols in the circuit diagram are given below. (Fig 4)



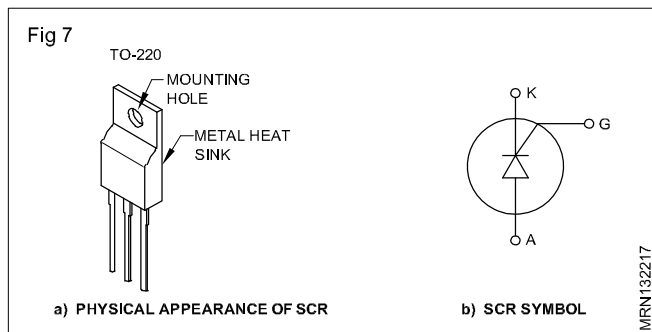
The different types of diodes (Fig 5) used for specific purposes are represented by the symbols given.



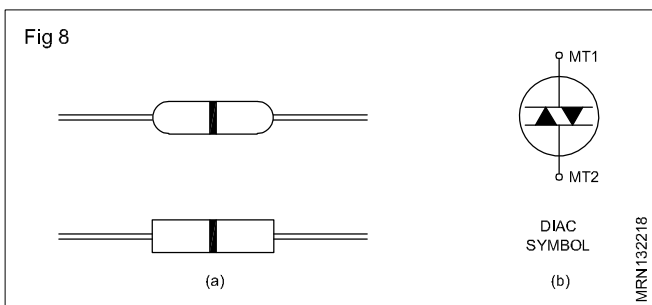
Transistor : Figure 6a shows the physical appearance of transistors. There are two symbols to represent a transistor. (Fig 6b). The selection of a symbol is based on either the NPN or the PNP type of transistor.



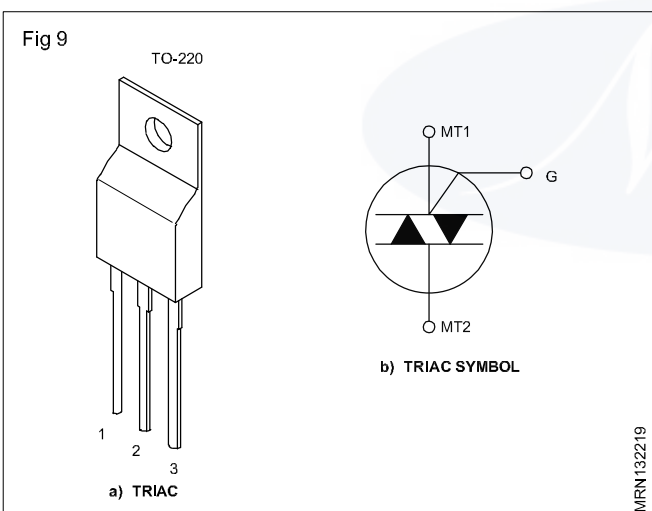
SCR (Silicon controlled rectifier) : Figure 7a shows the physical appearance of one type of SCR and the symbol is shown in Fig 7b. SCRs are also called thyristors and used as switching devices.



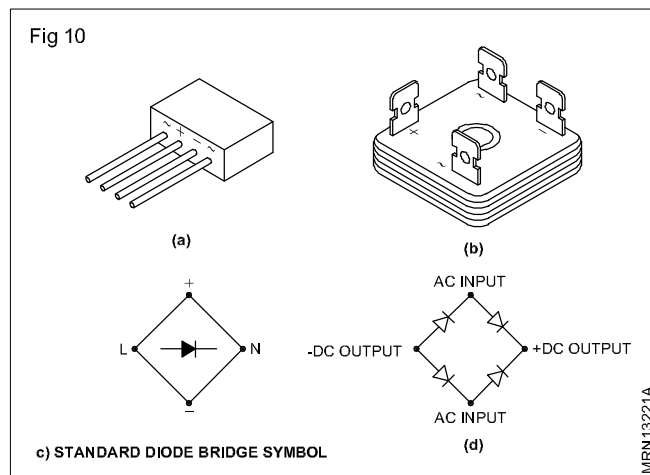
Diac : A diac (Fig 8a) is a two-lead device like a diode. It is a bidirectional switching device. Its symbol is shown in Fig 8b.



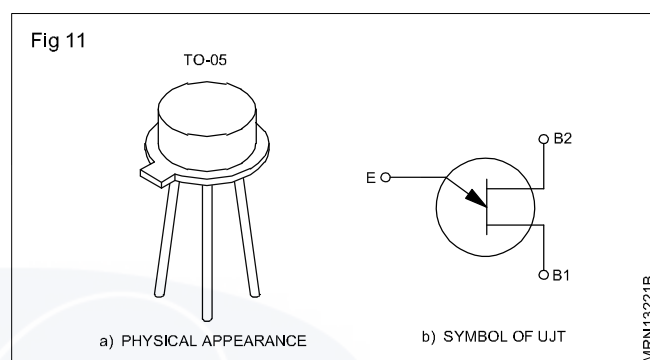
Triac : A triac is also a semiconductor device with three leads like two SCRs in parallel. The triac can control the circuit in either direction. (Fig 9)



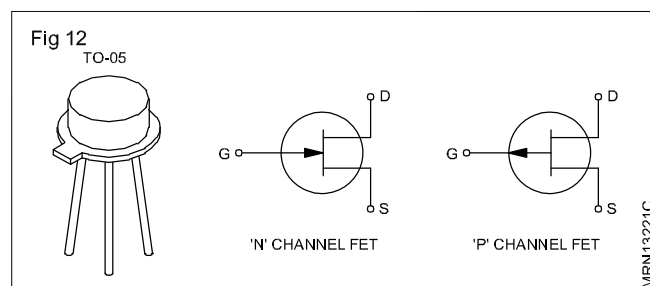
Bridge rectifier or diode bridge : It is a single package of four semiconductor diodes connected in bridge circuit. The input AC and the output DC leads are marked and terminated as shown in the Figure 10.



UJT (Uni-junction transistor) : It has two doped regions with three leads and has one emitter and two bases. (Fig 11)



FET (Field effect transistor) : Fig 12a give a pictorial view of the component, and the related symbol to represent the field effect transistor is shown in Fig 12b. The selection of the symbol is based on whether the FET is a 'N' channel or a 'P' channel one.



Note:- The devices like transistor, SCR triac, UJT & FET may look alike due to similarity in encapsulation. They can be identified only by the code numbers and relevant data books.

Coding of semiconductor devices

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

- state the purpose of letters used in the old systems of coding semiconductors, by referring to the manual
- describe the meaning of 1N, 2N, 3N in semiconductor coding.

Old system : Some earlier semiconductor diodes and transistors have type numbers, consisting of two or three letters followed by group of one, two or three figures. The first letter is always 'O', indicating a semiconductor device.

The second (and third) letter(s) indicate the general class of the device.

- A – diode or rectifier
- AP – photo-diode
- AZ – voltage regulator diode
- C – transistor
- CP – phototransistor

The group of figures in a serial number indicating a particular design or development.

Present system : This system consists of two letters followed by a serial number. The serial number may consist of three figures of one letter and two figures depending on the main application of the device.

The first letter indicates the semiconductor material used.

- A Germanium
- B Silicon
- C Compound materials such as gallium arsenide
- R Compound materials such as cadmium sulphide

The second letter indicates the general function of the device.

- A detection diode, high speed diode, mixer diode
- B variable capacitance diode
- C transistor for I.F. applications (not power types)
- D power transistor for A.F. applications (not power types)
- E tunnel diode
- F transistor for A.F. applications (not power types)
- G multiple of dissimilar devices, miscellaneous devices
- L power transistor for a.f. applications
- N photo-coupler

- P radiation sensitive device such as photo-diode, photo-transistor, photo-conductive cell, or radiation detector diode
- Q radiation generating device such as light-emitting diode
- R controlling and switching devices (e.g. thyristor) having a specified breakdown characteristic (not power types)
- S transistor for switching applications (not power types)
- T controlling and switching power device (e.g. thyristor) having a specified breakdown characteristic.
- U power transistor for switching applications
- X multiplier diode such as varactor or step recovery diode
- Y rectifier diode, booster diode, efficiency diode
- Z voltage reference or voltage regulator diode, transient suppressor diode.

The remainder of the type number is a serial number indicating a particular design or development, and is in one of the following two groups.

- a Devices intended primarily for use in consumer applications (radio and television receivers, audio-amplifiers, tape recorders, domestic appliances, etc.) The **serial number** consists of three figures.
- b Devices intended mainly for applications other than (a) e.g. industrial, professional and transmitting equipments.

The serial number consists of one letter (Z, Y, X, W etc) followed by two numbers (digits)

The international system follows letters 1N, 2N, 3N etc followed by four numbers.

- 1N indicates single junction
- 2N indicates two junction
- 3N indicates three junctions.

The number indicates internationally agreed manufacturer's code e.g. 1N 4007, 2N 3055, 3N 2000.

Again, manufacturers use their own codes for semiconductor devices. Manufacturers in Japan use 2SA, 2SB, 2SC, 2SD etc. followed by a group of numbers e.g. 2SC 1061, 2SA 934, 2SB 77. Indian manufacturers have their own codes too.

Resistors

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

- state the function of a resistor in a circuit and unit of resistance
- name and list the classifications of resistors
- brief constructional details of important resistor types
- state the meaning of tolerance in resistor and power rating.

Resistors

Resistors are electronic components, used to reduce, or limit, or resist the flow of current in any electrical or electronic circuit.

Resistors are made of materials whose conductivity fall in-between that of conductors and insulators. This means, the materials used for making resistors have free electrons, but not as many as in conductors. Carbon is one such material used most commonly for making resistors.

When a large number of electrons are made to flow through a resistor, there is opposition to the free flow of electrons. This opposition results in generation of heat.

Unit of resistance

The property of the resistor to limit the flow of current is known as *resistance*. The value, or quantity of *resistance* is measured in units called **ohms** denoted by the symbol Ω .

Resistors are called *passive devices* because, their resistance value does not change even when the level of applied voltage or current to it is changed. Also, the resistance value remains same when the applied voltage is AC or DC.

Resistors can be made to have very small or very large resistance. Very large values of resistances can be represented as given below;

$$\begin{aligned}1000 \Omega &= 1 \times 1000 \Omega = 1 \times \text{kilo}\Omega = 1 \text{ K } \Omega \\10,000 \Omega &= 10 \times 1000 \Omega = 10 \times \text{kilo}\Omega = 10 \text{ K } \Omega \\100,000 \Omega &= 100 \times 1000 \Omega = 100 \times \text{kilo } \Omega = 100 \text{ K } \Omega \\1000,000 \Omega &= 1000 \times 1000\Omega = 1000 \times \text{kilo}\Omega = 1000 \text{ K}\Omega \\&= 1000\text{k}\Omega = 1\text{M}\Omega\end{aligned}$$

Classification of resistors

Fixed value resistors

Its ohmic value is fixed. This value cannot be changed by the user. Resistors of standard fixed values are manufactured for use in majority of applications.

Fixed resistors are manufactured using different materials and by different methods. Based on the material used and their manufacturing method/process, resistors carry different names.

Fixed value resistors can be classified based on the type of material used and the process of making as follows.

Physical appearance of some types of fixed value resistors is shown in Chart 1 at the end of this lesson.

Power rating

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

Resistor values - coding schemes

For using resistors in circuits, depending upon the type of circuit in which it is to be used, a particular type, value and wattage of resistor is to be chosen. Hence before using a resistor in any circuit, it is absolutely necessary to identify the resistor's type, value and power rating.

Selection of a particular type of resistor is possible based on its physical appearance. The resistance value of a resistor will generally be printed on the body of the resistor either directly in ohms or using a typographic code or using a colour code.

Colour band coding of resistors

Colour band coding is most commonly used for carbon composition resistors. This is because the physical size of carbon composition resistor is generally small, and hence, printing resistance values directly on the resistor body is difficult.

Tolerance

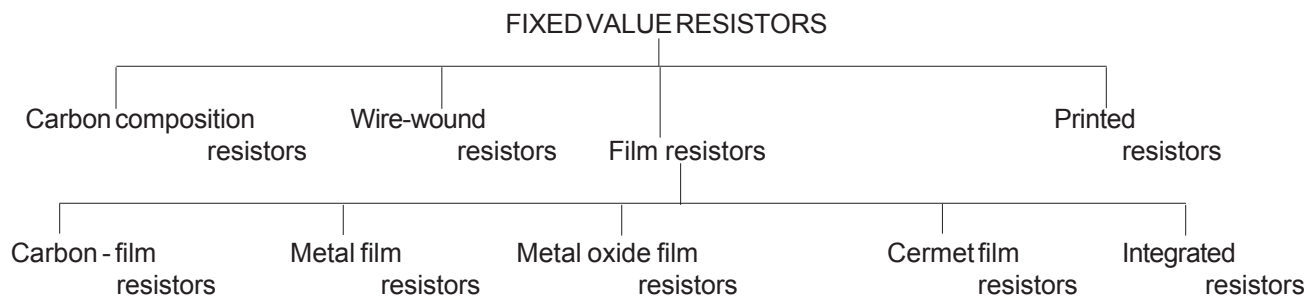
In bulk production/ manufacturing of resistors, it is difficult and expensive to manufacture resistors of particular exact values. Hence the manufacturer indicates a possible variation from the standard value for which it is manufactured.

This variation will be specified in percentage tolerance. Tolerance is the range(max -to- min) within which the resistance value of the resistor will exist.

Typo graphical coding of resistors

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

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



Applications

Carbon composition, fixed value resistors are the most widely used resistors in general purpose electronic circuits such as radio, tape recorder, television etc. More than 50% of the resistors used in electronic industry are carbon resistors.

Brief constructional details of a few important types of fixed value resistors is given in Chart-2 at the end of this lesson.

Measuring ohmic value of resistors

It is not possible to read the *exact ohmic value* of a resistor from colour/other coding schemes due to manufacturing tolerance built into the resistors. To find the exact ohmic value of resistors *ohmmeters* are used. When a resistor is placed between the test prods of an ohmmeter as shown in Fig 6A, the meter shows nearest to the exact resistance of the resistor directly on the graduated meter scale. Multimeters are also used to measure the value of resistors as shown in Fig 6B.

When a multimeter is used for resistance measurement, the resistance range switch on the meter should be put to the most suitable resistance range, depending upon the value of resistance being measured.

Appendix D suggest the meter ranges for measuring different resistor values accurately.

Wire-wound Resistors

Resistors, in addition to having a required ohmic value, should also be capable of dissipating the heat produced. Carbon by its nature has a limitation in the maximum heat it can dissipate. Carbon resistors become too hot when high current flows through them. This increased heat in carbon resistors changes the ohmic value of the resistors. Sometimes the resistors may even burn open due to excessive heat. Hence carbon resistors are suited only in low power circuits safely up to 2 watts.

This limitation in carbon resistors can be overcome by using wires of resistive materials like Nichrome, Manganin etc., instead of carbon. Resistors made using wires of resistive materials are known as *wire-wound* resistors. These resistors can withstand high temperature, and still maintain the exact ohmic values. In addition, wire-wound resistors can also be made to have fractional ohmic values which is not possible in carbon composition resistors.

Resistor values

Wire-wound resistors are available from a fraction of an ohm to 100's of Kilo ohms, with a power ratings of 1 watt to several 100s of watts. The higher the power rating, the thicker the resistive wire used, and bigger will be the physical size of the wire-wound resistor.

Applications

Wire-wound resistors are commonly used in electronic circuits where small values, precision values, high wattage ratings are required. A few applications are : regulated power supplies, amplifiers, motor controls, servo control circuits, TV receivers etc.

Special types of fixed value wire wound resistors

In applications where more than one fixed value wire-wound resistor is required to be used, a tapped wire wound resistor with more than one value, made in a single unit as in Fig 7 can be used.

Tapped resistors, whose tapings can be adjusted by adjusting the position of the sliding collar are also available as shown in Fig 8. This gives the flexibility of varying the resistance value between the tapings.

Ohm's law - Resistors - Measurement of resistance - Laws of resistance

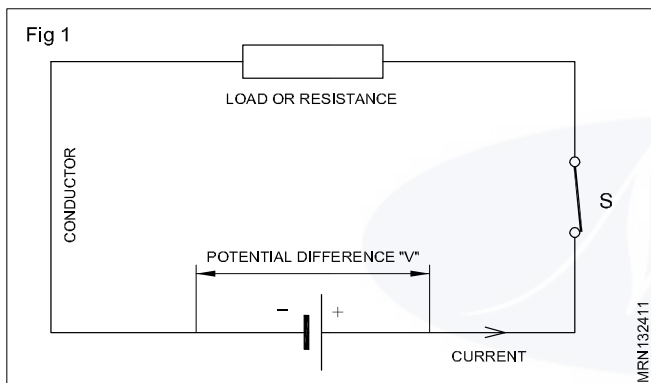
Objectives: At the end of this lesson you shall be able to

- describe the essential factors in an electrical circuit
- state the relation between circuit factors through Ohm's law
- apply Ohm's law in an electric circuit
- explain the working of semi conductors
- state the classification of diodes
- check the diode with multimeter
- state the use of voltmeter amphere meter and multimeter.

Simple electric circuit

In the simple electric circuit shown in Fig 1, the current completes its path from the positive terminal of the battery via the switch and the load back to the negative terminal of the battery.

The circuit shown in Fig 1 is a closed circuit. In order to make a circuit to function normally the following three factors are essential.



- Electromotive force to drive the electrons through the circuit
- Current, the flow of electrons
- Resistance - the opposition to limit the flow of electrons.

Electromotive force (Symbol E)

An electromotive force is essential to drive the electrons in a circuit.

This force is obtained from the source of supply i.e. Torch cells, dynamo.

Systems International (SI) unit of electromotive force is volts (symbol V).

Potential difference (Symbol V)

The difference of voltage across two points in a circuit is called a potential difference and is measured in volts.

In a circuit, when a current flows, there will be a potential difference across the terminals of the resistor/load. In the circuit shown in Fig 1, when the switch is in the open condition, the voltage across the terminals of the cell is called electromotive force (E) whereas when the switch is in the closed position, the voltage across the cell is called potential difference which will be lesser in value than the

electromotive force earlier measured. This is due to the fact that the internal resistance of the cell drops a few volts when the cell supplies current to the load.

Current (Symbol I)

The flow of current through a circuit is essential for energy conversion.

Example

Heat produced in electric kettles/heaters.

Light produced in electric lamps.

Mechanical force produced in electric motors.

The SI unit of electric current is ampere (symbol A).

Resistance- (Symbol R)

The resistance offered by the circuit elements like resistance of the conductor or load is essential to limit the flow of current.

In the absence of resistance in a circuit, the current will reach an abnormally high value endangering the circuit itself.

Example

Filament of a lamp, heater coil of a kettle, winding of a motor.

The SI unit of electrical resistance is ohm. (symbol Ω)

Ohm's law

The relation between the electromotive force, current and resistance of a circuit is given by Ohm's law.

Ohm's law states that the ratio of the voltage (V) across any two points of a circuit to the current (I) flowing through is constant provided physical conditions, namely temperature etc. remain constant. This constant is denoted as resistance (R) of the circuit.

$$\text{Thus } \frac{V}{I} = \text{Constant}$$

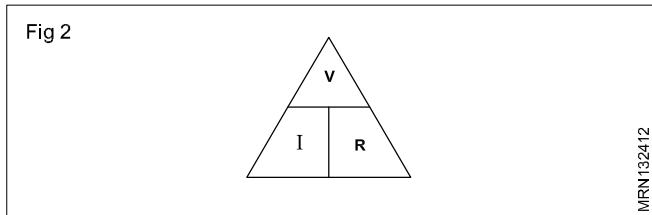
$$\text{or we can say } \frac{V}{I} = R$$

V = Voltage applied to the circuit

I = Current flowing through the circuit

R = Resistance of the circuit

The above relationship can be referred to in a **triangle** as shown in Fig 2. In this triangle whatever the value you want to find out, place the thumb on it then the position of the other factors will give you the required value.



For example for finding 'V' close the value 'V' then readable values are IR , so $V = IR$.

Again for finding 'R', close the value R, then readable values are V/I so $R = V/I$, like that $I = \frac{V}{R}$

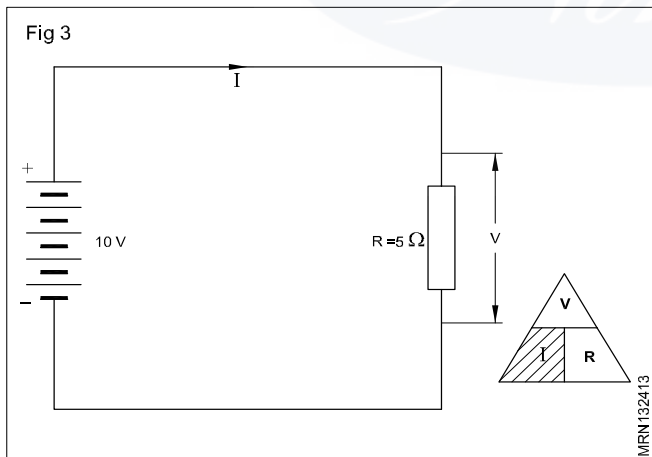
Application of Ohm's law in circuits

Example 1

Let us take a circuit shown in Fig 3 having a source of 10V battery and a load of 5 ohms resistance. Now we can find out the current through the conductor.

$$I = \frac{V}{R}, \text{ applying the value}$$

$$I = \frac{10}{5} = 2 \text{ amperes.}$$



Problem

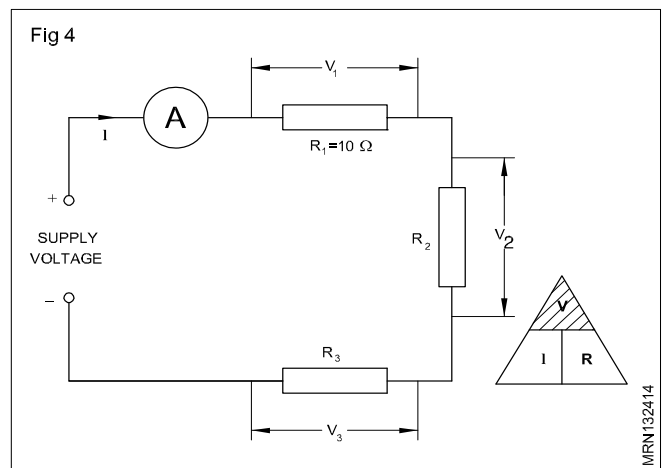
Find the value of voltage across a 10 ohms resistor in the circuit shown (Fig 4) when the current of 2 amps flows through the 10 ohms resistor.

Solution

Voltage across 10 ohms

$$\begin{aligned} V &= I \times R \\ &= 2 \times 10 = 20 \text{ volts.} \end{aligned}$$

Similarly if the value of the other resistance is known we can find the voltage drop across them.



Extreme circuit conditions

Two important extreme conditions can occur in a circuit.

Open circuit

In an open circuit, there is an infinitely high resistance in the circuit. This condition can happen in a circuit when the switch is open. Therefore, no current of flow.

For example, a generator is said to be in an open circuit when the switch is open and running without supplying current to the circuit. A wall socket, too, is an open circuit if the control switch of the wall socket is 'OFF' or 'ON' position provided there is no appliance plugged to the wall socket.

Short circuit

The other important extreme condition is the short circuit. A short circuit will occur, for example, when the two terminals of a cell are joined. A short circuit may also occur if the insulation between the two cores of a cable is defective. The resulting low resistance will cause large currents which can become a hazard.

Identification of rectifier diodes

Semiconductor

Semiconductors are materials whose electrical property lies between that of Conductors and Insulators. Because of this fact, these materials are termed as semiconductors. In conductors the valence electrons are always free. In an insulator the valence electrons are always bound. Whereas in a semiconductor the valence electrons are normally bound but can be set free by supplying a small amount of energy. Several electronic devices are made using semiconductor materials. One such device is known as Diode.

Semiconductor theory

Basic semiconductor materials like other materials have crystal structure. The atoms of this structure, are bonded to each other. This bonding is known as covalent bonding. In such a bonding, the valence electrons of the atoms are shared to form a stable structure.

Intrinsic semiconductors

The most important of the several semiconductor materials are Silicon (Si) and Germanium (Ge). Both these

semiconductor materials have four valence electrons per atom. These valence electrons, unlike in conductors, are not normally free to move. Hence, semiconductors in their pure form, known as Intrinsic semiconductors, behave as insulators.

However, the valence electrons of a semiconductor can be set free by applying external energy. This energy will tear-off the bound electrons from their bond and make them available as free electrons. The simplest method of turning bonded valence electrons into free electrons is by heating the semiconductor.

The higher the temperature to which the semiconductor is heated, more the bound electrons becoming free and will be able to conduct electric current. This type of conduction in an intrinsic semiconductor (pure semiconductor) as a result of heating is called intrinsic conduction.

From the above said phenomena, it is important to note that semiconductors are temperature-sensitive materials.

Extrinsic semiconductor

The number of free electrons set free by heating a pure semiconductor is comparatively small to be used for any useful purpose. It is found experimentally that, when a small quantity of some other materials such as Arsenic, Indium, Gallium etc. is added to pure conductor material, more number of electrons become free in the mixed material. This enables the semiconductor to have higher conductivity.

These foreign materials added to the pure semiconductor are referred to as impurity materials.

The process of adding impurity to an Intrinsic semiconductor material is known as Doping. Since the doped semiconductor materials are no longer pure, they are called impure or **extrinsic semiconductors**.

Depending upon the type of impurity used, extrinsic semiconductors can be classified into two types;

1 N-type semiconductors

When a pentavalent material like Arsenic (As) is added to a pure Germanium or pure Silicon crystal, one free electron results per bond. As every arsenic atom donates one free electron, arsenic is called the donor impurity. Since a free electron is available and since the electron is of a Negative charge, the material so formed by mixing is known as **N type material**.

When a N-type material is connected across a battery, current flows due to the availability of free electrons. As this current is due to the flow of free electrons, the current is called electron current.

2 P-type semiconductors

When a trivalent material like Gallium (Ga) is added to a pure Germanium or pure Silicon crystal, one vacancy or deficit of electron results per bond. As every gallium atom creates one deficit of electron or hole, the material is ready to accept electrons when supplied. Hence gallium is called acceptor impurity. Since vacancy for an electron is available, and as this vacancy is a hole which is of Positive charge,

the material so formed is known as **P-type material**.

When a P-type material is connected across a battery as shown in Fig 4b, current flows due to the availability of free holes. As this current is due to flow of holes, the current is called hole current.

P-N junction

When a P-type and a N-type semiconductors are joined, a contact surface between the two materials called PN-junction is formed. This junction has a unique characteristic. This junction, has the ability to pass current in one direction and stop current flow in the other direction. To make use of this unique property of the PN junction, two terminals one on the P side and the other on the N side are attached. Such a PN junction with terminals attached is called a **Diode**. The typical symbol of a PN-junction diode.

When a P and N material is put together, at the junction of P and N materials, some electrons from the N-material jump across the boundary and recombine with the hole near the boundary of the P-material. This process is called diffusion. This recombination makes atoms near the junction of the P-material gaining electrons and become negative ions, and the atoms near the junction of the N-material, after losing electrons, become positive ions. The layers of negative and positive ions so formed behave like a small battery. This layer is called the depletion layer because there are neither free electrons nor holes present (depleted of free carriers). This depletion region prevents further the movement of electrons from the N-material to the P material, and thus an equilibrium is reached.

The internal voltage set up due to +ve and -ve ions at the junction is called barrier potential. If any more electrons have to go over from the N side to the P side, they have to overcome this barrier potential. This means, only when the electrons on the N side are supplied with energy to overcome the barrier potential, they can go over to the P side.

In terms of voltage applied across the terminals of the PN junction diode, a potential difference of 0.7V is required across the terminals in the case of silicon diode and 0.3V in the case of Germanium diode for the electrons, in order to cancel off the barrier potential and cross over the barrier. Once the barrier potential gets canceled due to external voltage application, current flows through the junction freely. In this condition the diode is said to be forward biased.

Types of diodes

The PN junction diodes discussed so far are commonly referred to as rectifier diodes. This is because these diodes are used mostly in the application of rectifying AC to DC.

Classification of Diodes

1 Based on their current carrying capacity/power handling capacity, diodes can be classified as

- **low power diodes**
can handle power of the order of several milliwatts only

- **medium power diodes**
can handle power of the order of several watts only
- **high power diodes**
can handle power of the order of several 100's of watts.

2 Based on their principal application, diodes can be classified as,

- **Signal diodes**
low power diodes used in communication circuits such as radio receivers etc. for signal detection and mixing
- **Switching diodes**
low power diodes used in switching circuits such as digital electronics etc. for fast switching ON/OFF of circuits
- **Rectifier diodes**
medium to high power used in power supplies for electronic circuits for converting AC voltage to DC.

3 Based on the manufacturing techniques used, diodes can be classified as,

- **Point contact diodes**
a metal needle connected with pressure on to a small germanium(Ge) or silicon(Si) tip.
- **Junction diodes**
made by alloying or growing or diffusing P and N materials on a semiconductor substrate.

Types of diode packaging

The type of packaging given to diodes is mainly based on the current carrying capacity of the diode. Low power diodes have either glass or plastic packaging. Medium power diodes have either plastic or metal can packaging. High power diodes will invariably have either metal can or ceramic packaging. High power diodes are generally of stud-mounting type.

Testing rectifier diodes using ohmmeter

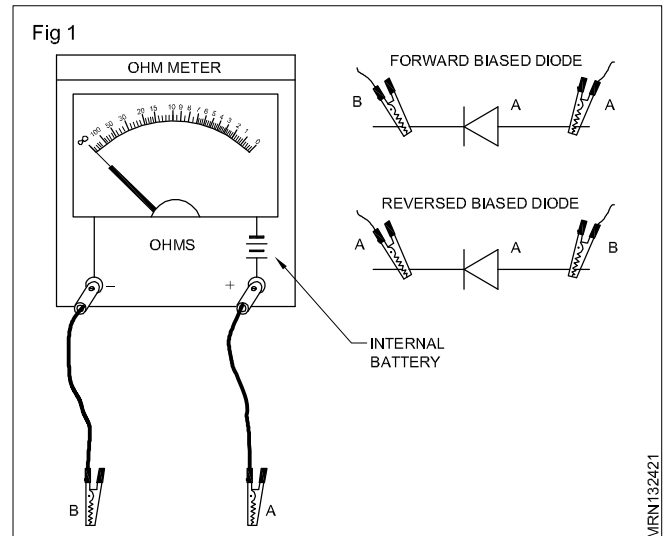
A simple ohmmeter can be used to quickly test the condition of diodes. In this testing method, the resistance of the diode in forward and reverse bias conditions is checked to confirm its condition.

Recall that there will be a battery inside an ohmmeter or a multimeter in the resistance range. This battery voltage comes in series with the leads of the meter terminals. In Fig 10, the lead A is positive, lead B negative.

NOTE: If the polarity of the meter leads are not known at first, the polarity of the meter leads can be determined using a voltmeter across the ohm meter terminals.

If the positive lead of the ohmmeter, lead A in the Fig 1, is connected to the anode of a diode, and the negative (lead B) to the cathode, the diode will be forward-biased. Current will flow, and the meter will indicate low resistance.

On the other hand, if the meter leads are reversed, the diode will be reverse-biased. Very little current will flow because a good diode will have very high resistance when reverse biased, and the meter will indicate a very high resistance.



While doing the above test, if a diode shows a very low resistance in both the forward and reverse biased conditions, then, the diode under test must have got damaged or more specifically shorted. On the other hand, a diode is said to be open if the meter shows very high resistance both in the forward and reverse biased conditions.

Polarity marking on the diodes

The cathode end of a diode is usually marked by a circular band or by a dot or by plus (+) sign as shown in Chart 1. In some diodes the symbol of the diode, which itself indicates the polarities, is printed on the body of the diode.

Type number or diode code number

Unlike resistors, capacitors or inductors, the diodes do not have any value that can be printed or coded on its body. The other reason for this is, there are almost innumerable types of diodes with varied current handling and other specifications. Hence, instead of printing its specifications on its body, all diodes will have a type number printed on their body. This type number carries a set of specifications which can be found out by referring to a diode data manual. Diode data manuals give data of several thousands of diodes from different manufacturers. Some of the popular type numbers of diodes are

OAxx,	xx - from 70 to 95.	examples: OA79, OA85 etc.,
BYxxx,	xxx- from 100 onwards,	examples: BY127, BY128 etc.
DRxxx,	xxx- from 25 onwards.	examples: DR25, DR150 etc.,
1Nxxxx	examples: 1N917	1N4001, 1N4007 etc.

Voltmeter

A voltmeter is an instrument used for measuring electrical potential difference between two points in an electric circuit. Analog voltmeters move a pointer across a scale in proportion to the voltage of the circuit; digital voltmeters give a numerical display of voltage by use of an analog to digital converter.

Ampere meter

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

Multimeter

A multimeter or a multimeter, also known as a VOM (volt-ohm-milliammeter), is an electronic measuring instrument that combines several measurement functions in one unit. A typical multimeter can measure voltage, current, and resistance. Analog multimeters use a microammeter with a moving pointer to display readings.



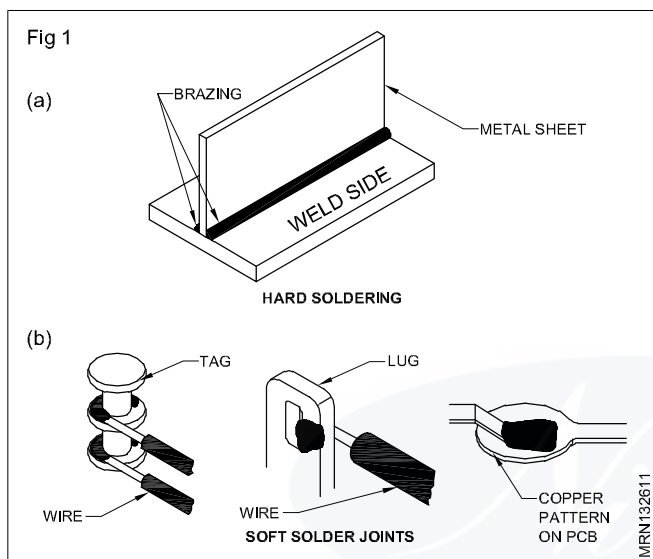
Tinning and soldering of wires

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

- state the meaning of soldering
- list two main types of soldering and its uses
- state the soldering technique.

Soldering

Soldering is a process of connecting any two metallic surfaces such as copper, brass and alloys of these metals. Some types of solder joints are shown in Fig 1



There are two types of soldering,

- 1 **Hard soldering or brazing** used for joining large metal parts as shown in Fig 1a.
- 2 **Soft soldering** used to form good electrical joints/connections between electrical/electronic parts as shown in Fig 1b.

Soft soldering is used extensively for electronic circuit wiring. In this lesson only soft soldering is discussed. Hard soldering or brazing is out of scope of this lesson.

From now on in this book, soldering means soft soldering.

Need for soldering

Requirements of an electrical joint

- 1 The electrical joint must provide ideally zero resistance or at least a very low resistance path, for the flow of current.
- 2 The electrical joint made should be strong enough to withstand vibrations, physical shock, bumps etc, without causing any deterioration to the quality and strength of the joint.
- 3 The electrical joint should be able to withstand corrosion and oxidation due to adverse atmospheric conditions.

All the above requirements of an electrical joint can be achieved by making a solder joints.

Solder

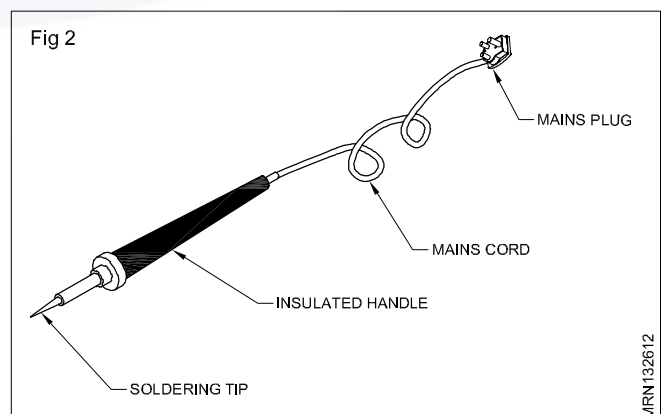
In a soldered joint, the solder is a mixture of metals, generally TIN and LEAD. It is made to melt at a certain temperature. It acts as a filler between the parts of the connection/joint to form a continuous, low resistance metallic path for conduction of electricity.

In soldering, as the metal surface is wetted (free flow of liquid solder over a surface) by the solder, a complex chemical reaction, bonds the solder to the metal surface.

The tin content of the solder diffuses with the metal surface to form a layer of a completely new alloy. The alloy so formed will have the same structure as the constituent metals and retain their metallic properties and strength.

Soldering and soldering irons

While soldering, the solder is made to melt between the metallic surfaces of the joint, using a soldering iron, as shown in Fig 2. A **soldering iron** is an instrument used to produce the required heat to carry out soldering.



Soldering irons of different wattage ratings starting from 10 watts to more than 150 watts are available commercially. Depending on the type, size and heat sensitivity of the components being soldered, the most suitable wattage soldering iron should be chosen. Most of these soldering iron work on 240V, 50Hz ac mains supply. There are special type irons which work on dc supply also. For soldering delicate components, soldering irons with temperature controlling facility are used. These are known as soldering stations.

Soldering iron tips

Soldering irons are designed to take, a variety of tip sizes and shapes. The choice of the iron and the tip to use depends on, the nature of the joint to be soldered. A proper selection of the soldering iron and tip is important for obtaining good quality soldered joint. To solder effectively, the tip of the soldering iron must be kept clean all times.

Types of solders

Solders are available in many forms. The type to be chosen depends on, the type of soldering to be carried out. The wire type solder is the most commonly used solder for hand soldering work, using low wattage soldering iron.

Solders available in the market may have different tin-lead proportion in it. For general electronic circuit soldering work, solder with 60% tin and 40% lead is most suited. This solder is commonly called 60/40 solder. This solder has been specially developed to possess superior properties required for electronic circuit work.

Soldering FLUX

A protective oxide layer forms on the exposed surface of most metals. The rate at which the oxide layer is formed varies from metal to metal. The layer forms quickly on newly exposed metal, and over time, the layer slowly become quite thick.

This oxide layer on metals interferes with soldering. Hence, it must be removed before a soldered joint can be made.

The purpose of flux is to first dissolve the thin layer of oxide from the surface of the metals to be joined, and then form a protective blanket over them until the solder can flow over the joint surfaces to form the joint.

However, thick layers of oxide must be removed using an abrasive method as all types of flux are not capable of dissolving their oxide layers.

Types of flux

There are several types of fluxes used in different types of soldering. The type of flux used for soldering electronic components is called **rosin**. Rosin is made from a resin obtained from the sap of trees.

Rosin flux is ideal for soldering electronic components because, it become active at the soldering temperature, but revert to an inactive state when cooled again. An additional advantage is that it is non-conductive.

The rosin has activators or halides added to it. The activators used in rosins are mild acids that become very active at soldering temperatures. These acids dissolve the oxide layer on the metals to be soldered.

Organic and inorganic acid fluxes are available. These fluxes are not suitable for soldering electronic circuits.

For further details on the different types of rosin fluxes refer reference books listed at the end of this book.

Common forms of flux

Flux is available in a variety of forms to suit various types of application. Flux is available as a liquid, paste or a solid block. For most applications flux is often put in the solder itself during manufacture.

Not all flux types are available in all forms. For hand soldering work on electronic circuits, the best form for the flux is either as a liquid or a paste.

Rosin cored solder

Several manufacturers produce solder wire with the flux already included in one or more cores running along its length. This is known as **cored solder**.

The most popular type of cored solder for electronic hand soldering contains rosin type flux. Such solder is known as **rosin cored solder**.

When the solder is heated, the rosin flux melts before the solder. The rosin then flows out over the surface to be soldered ahead of the solder.

The amount of flux contained in the core is carefully controlled by the manufacturer and for most applications it will be sufficient. However, it is a common practice to apply additional liquid flux or flux paste to the joint, just prior to making the joint. This additional flux ensures that, sufficient flux available while the joint is being made. When the soldering has been completed, excess flux if any has to be removed.

Rosin-cored solder is available in different gauges as shown in Fig 5. It is important to choose a size suitable for the job at hand as given below;

- use 22 gauge for small joints
- use 18 gauge for medium joints
- use 16 gauge for large joints.

Tinning wires

When wires are to be connected to lugs or any other type of terminations, after skinning the wire, it is preferred to apply a thin coating of solder using a soldering iron. This process is known as **tinning** the wire.

When tinned, the solder penetrates the wire strands and holds them together. This holding of strands prevents the strands from becoming separate while soldering the wire onto terminations.

Tinning of the wire is advised to be done soon after stripping of the wire end, so that the wire strands do not tarnish.

Care must be taken when tinning a wire to ensure that capillary action does not draw the solder under the unstripped insulation. This action is called **wicking**. A special tool known as **anti-wicking tweezers** can be used to help prevent wicking. A wire that has wicked under the insulation must be cut off and the tinning process repeated.

Inspecting tinned wires

When a wire has been tinned, it is necessary to inspect the tinned wire to ensure that:

- the solder has not wicked under the insulation
- the insulation on the wire is not melted or burnt
- the wire strands are visible beneath the solder
- the tinned surface is smooth and shiny.

If the tinned wires does not meet these standards that portion of the wire must be cut. The wire must be reskinned and cut

If the tinned wire does not meet these standards, that portion of the wire must be cut. The wire must be reskinned and tinned.

Soldering technique

Soldering a joint

Selection and preparation of the soldering materials is the most time consuming phase of making a solder joint. Heating the joint and applying solder is the least time consuming but, it is the most important part of the soldering process.

Critical factors during soldering

- 1 Controlling the temperature of the workpiece
- 2 Limiting of time that a workpiece is held at soldering temperature.

These factors are specially critical while soldering electronic components like resistors, capacitors, transistors, ICs etc., Failure to correctly time and coordinate the heating of the joint and add solder, will result in a poor quality joint and may even damage the components.

Stages in soldering

The soldering process can be divided into several distinct stages or phases as given below:

- 1 Selection and preparation of materials.
- 2 Heating the joint and adding solder.
- 3 Cooling the joint.
- 4 Cleaning the joint.
- 5 Inspecting the joint.

1 Selection and preparation of materials

1.1 Selection of soldering iron wattage

Soldering irons are available in different wattage ratings starting from 10 watts to several 100 watts. The wattage of a soldering iron specifies the amount of heat it can produce. As a thumb rule, higher the physical dimension of the workpiece, higher should be the wattage rating of the soldering iron. Some of the suggested wattage choices are given below:

- i For soldering less temperature sensitive components such as, resistors on lug boards, tag boards, use 25 to 60W iron. For soldering on printed circuit boards, use 10 to 25 W iron.
- ii For soldering highly temperature sensitive components such as, diodes, transistors and integrated circuits, use 10 to 25 watts iron.

1.2 Selection of soldering iron tip

To ensure that the joint is heated to the required temperature ideally,

- the area of the tip face should be approximately equal to the area of the joint to be soldered
- the tip should be long enough to allow easy access to the joint.
- the tip should not be too long, as this may result in too low temperature at the tips working face.

In most soldering irons, the tip can be easily removed and replaced.

Selection of tip temperature

Good quality soldering iron tips have numbers punched on them. These numbers indicate the temperature to which the tip can be heated, as shown in table in the next page.

Selection of tip shape

Suggested soldering tip shapes selection table is given below;

Tip No.	Temperature °C	Temperature °F
5	260	500
6	316	600
7	371	700
8	427	800

1.3 Selection of solder and flux

There are several sizes of the cored solders whose choice depends on the size of the joints to be soldered. Also the tin and lead percentage of the solder should be checked before using the solder. Different tin and lead combinations of solder need different temperatures for it to melt and reach the liquid state.

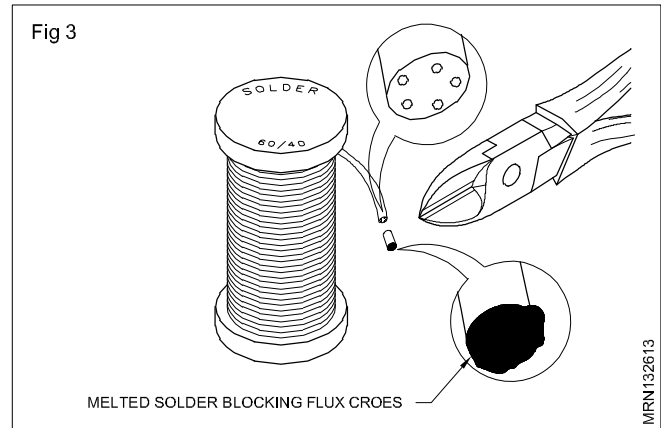
Type of soldering work	Soldering tip shape to choose
Wires, resistors and other passive components on to lug/tag boards	CHISEL TIP
All miniature electronic components except ICs on to lug boards and printed circuit boards (PCB)	BEVEL TIP
Integrated circuits (ICs) on to printed circuit boards (PCBs)	CONICAL TIP

For electronic soldering applications, solder of tin and lead of 60/40 proportion is used. This solder proportion has a melting point of 200°C which is the required temperature for general purpose soldering irons.

While soldering to make a strong solder joint the flux should melt first, and then the solder. Therefore, while using rosin cored solder, cut off the first 5 to 10mm of the solder using a side cutter, so that any earlier melted portion of the solder blocking the rosin core is removed.

For ease of application, the flux used in addition to the cored flux in solder should be of paste form.

Flux is a chemical substance which has acidic properties. Therefore, it is advised not to touch flux by hand. Use a stick or a thin stiff brush to apply flux on workpieces. Hands should be washed after soldering work.



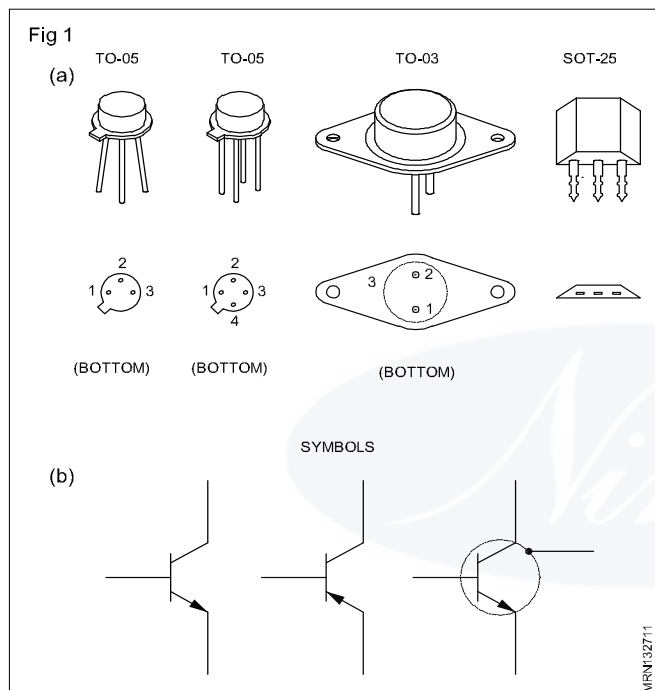
Transistors and classification, identification and checking transistor

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

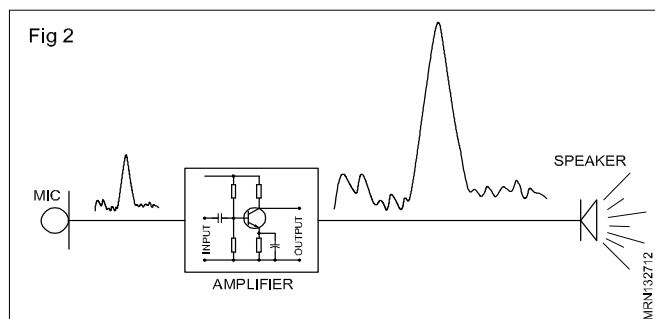
- state the two main uses of transistors
- list the advantages and classifications of transistors
- state the use of a transistor data book
- check the transistor with multimeter/ohmmeter.

Introduction to transistors

Transistors are the semiconductor devices having three or four leads/terminals. Fig 1a shows some typical transistors. Fig 1b shows the symbols used for different types of transistors.

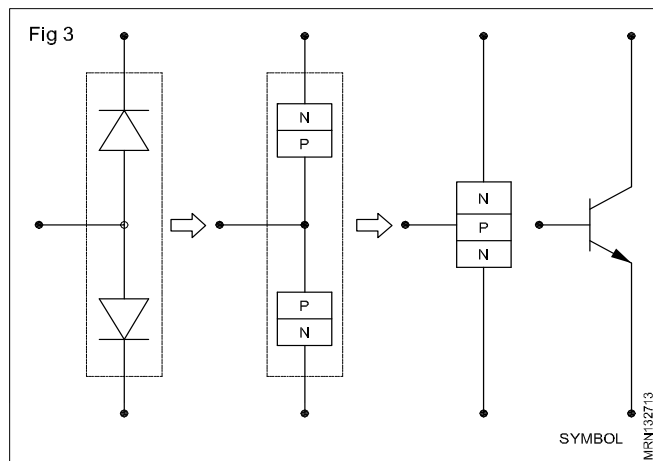


Transistors are mainly used for enlarging or amplifying small electric/electronic signals as shown in Fig 2. The circuit which uses transistors for amplifying is known as a transistor amplifier.



One other important application of transistors is its use as a solid state switch. A solid state switch is nothing but a switch which does not involve any physical ON/OFF contacts for switching.

Transistors can be thought of as two PN junction diodes connected back to back as shown in Fig 3.



Compared with the present day transistors the vacuum tubes were big in size, consumed more power, generated a lot of unwanted heat and were fragile. Hence vacuum tubes became obsolete as soon as transistors came to market.

Transistors were invented by Walter H. Brattain and John Bardeen of Bell Telephone Laboratories on 23rd Dec. 1947. Compared to vacuum tubes (also known as valves), transistors have several advantages. Some important advantages are listed below;

- Very small in size
- Light in weight
- Minimum or no power loss in the form of heat
- Low operating voltage
- Rugged in construction.

To satisfy the requirements of different applications, several types of transistors in different types of packaging are available. As in diodes, depending upon the characteristics, transistors are given a type number such as BC 107, 2N 6004 etc., The characteristics data corresponding to these type numbers are given in Transistor data books.

Classification of transistors

1 Based on the semiconductor used.

- Germanium transistors
- Silicon transistors

Like in diodes, transistors can be made, using any one of the above two important semiconductors. However, most of the transistors are made using silicon. This is because, silicon transistors work better over a wide temperature range (higher thermal stability) compared to germanium transistors.

Transistor data books give information about the semiconductor used in any particular transistor.

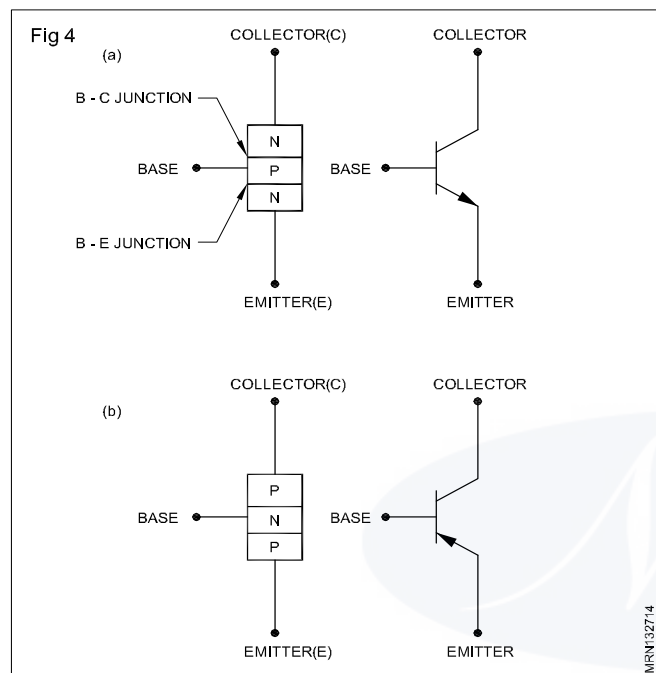
2 Based on the way the P and N junctions are organized as shown in Fig 4.

- NPN transistors
- PNP transistors

Both NPN and PNP transistors are equally useful in electronic circuits. However, NPN transistors are preferred for the reason that NPN has higher switching speed compared to PNP.

NOTE: Details of switching speed is discussed in further lessons.

Whether a transistor is PNP or NPN can be found with the help of transistor data book.



3 Based on the power handling capacity of transistors as shown in Table below (Fig 5).

Low power transistors (less than 2 watts)	Medium power transistors (2 to 10 watts)	High power transistors (more than 10 watts)
Fig 5 TO-92 	TO-05 	TO-03

Low power transistors, also known as small signal amplifiers, are generally used at the first stage of amplification in which the strength of the signal to be amplified is low. For example, to amplify signals from a microphone, tape head, transducers etc.,

Medium power and high power transistors, also known as large signal amplifiers are used for achieving medium to high power amplification. For example, signals to be given to loudspeakers etc. High power transistors are usually mounted on metal chassis or on a physically large piece

of metal known as heat sink. The function of heat sink is to, take away the heat from the transistor and pass it to air.

Transistor data books give information about the power handling capacity of different transistor.

4 Based on the frequency of application

- Low freq. transistors (Audio frequency or A/F transistors)
- High freq. transistor (Radio frequency or R/F transistors)

Amplification required for signals of low or audio range of frequencies in Tape recorders, PA systems etc., make use of A/F transistors. Amplifications required for signals of high and very high frequencies as, in radio receivers, television receivers etc., use R/F transistors.

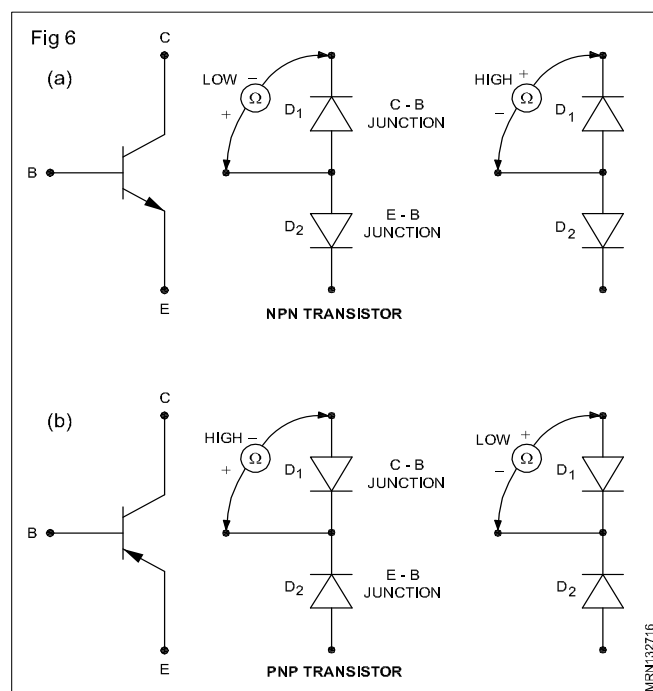
Testing transistors using ohmmeter

1 Junction test

Since a transistor can be regarded as two diodes connected back-to-back, a transistor's general working condition (quick-test) can be assessed by checking these two diodes as shown in Fig 6a and 6b.

Fig 6a shows a NPN transistor and Fig 6b shows a PNP transistor. The imaginary diodes 1 and 2 can be tested as testing any diode. When a diode is tested, if the ohmmeter shows high resistance in one direction and low resistance in another direction, then the diode corresponding to that diode junction can be regarded as GOOD. One important point to note in a transistor is that, both the diodes of the transistor should be GOOD to declare the transistor as GOOD.

While testing, a transistor using ohmmeter, it is suggested to use the middle ohmmeter range (Rx100) because, ohmmeters in low range can produce excessive current and ohmmeters in high range can produce excessive voltage which may be sufficient to damage small signal transistors.



Half wave and full wave rectifiers

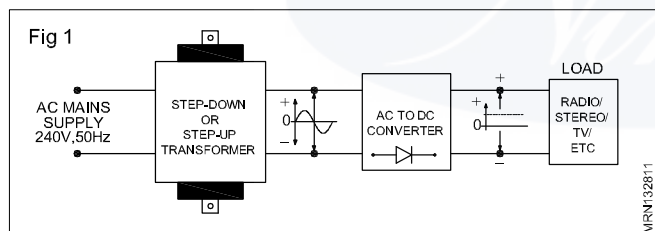
Objectives : At the end of this lesson you shall be able to

- state the meaning of the term rectification
- describe the working of a half-wave and two diode full-wave rectifier
- state the output of a half-wave rectifier in terms of rms value of input AC, peak value of input AC
- state the output DC level and the current rating of diode in a two-diode fullwave rectifier
- state the ripple frequency in a half-wave rectifier and a full-wave rectifiers
- state the value of PIV in half-wave and full-wave rectifiers
- list the limitations of half-wave and a two diode full-wave rectifiers.

Rectification

Almost all electronic circuits need DC voltage for their working. This DC voltage can be obtained by dry cells and batteries. Use of a dry cell is practicable only in portable electronic circuits such as transistor radio, tape recorders etc. But in circuits requiring large voltages and currents, like high power audio amplifiers, television sets etc. batteries will not only be very expensive but also be voluminous.

An alternative method of obtaining DC voltage is by converting the AC mains supply of 240V, 50Hz into DC voltage. This technique is not only convenient but also takes very small space compared to battery packs. This process of converting AC to DC is known as rectification. Fig 1 shows the principle of converting AC to DC of required voltage level.



The transformer will step-down or step-up the mains AC to the required level. The stepped-up or stepped-down AC from the output of the transformer is then converted to DC using diodes making use of their unique unidirectional property.

Half way rectifier

The simplest form of AC to DC converter is by using one diode. such an AC to DC converter is known as half-wave rectifier as shown in Fig 2.

At the secondary of the transformer, across terminals P & Q, when seen on a CRO, the electric signal is a sinusoidal wave with its peak value of V_p and a frequency determined by the rate at which the alternations (+ve to -ve) are taking place. In Fig 2, the frequency is 50Hz as this voltage is taken from 50Hz AC mains supply.

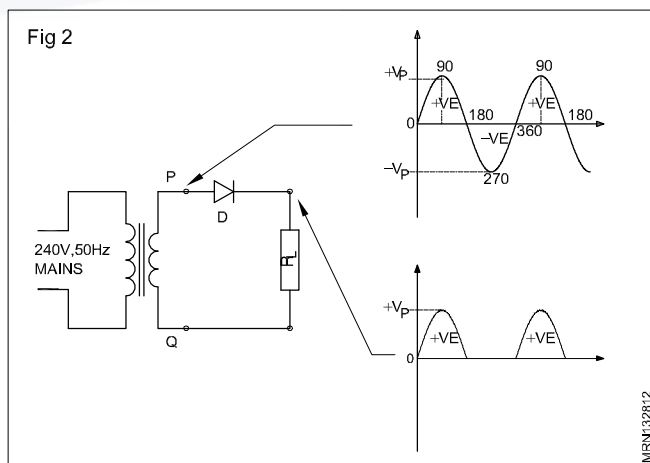
If the voltage across P and Q is measured using an AC voltmeter, the voltmeter shows the rms (root mean square) value, V_{rms} of the sinusoidal wave which will be less than the peak value. The relationship between V_{peak} and V_{rms} is given by,

$$V_{rms} = 0.707 V_{peak}$$

conversely,

$$V_{peak} = \frac{V_{rms}}{0.707} = \sqrt{2} V_{rms}$$

When this sinusoidal signal is applied across the diode D as shown in Fig 2, the diode conducts (behaves as a closed switch) only during the +ve half cycle of the input sinusoidal voltage and does not conduct (behaves as an open switch) during the -ve half of the input sinusoidal voltage. This process repeats again and again thus producing a pulsating +ve wave-form at the output across the load, R_L as shown in Fig 2.



Bridge rectifiers

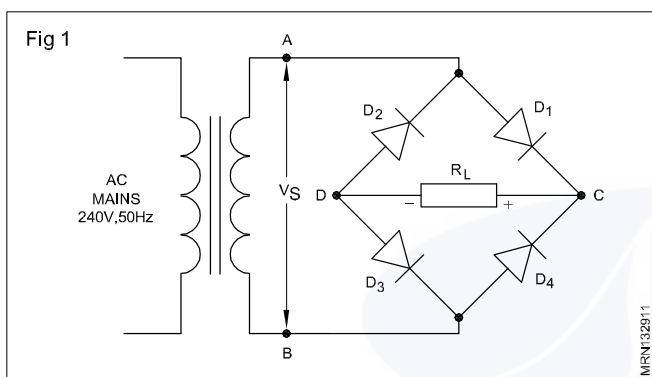
Objectives : At the end of this lesson you shall be able to

- describe the working of a bridge rectifier
- state the output DC level in a bridge rectifier
- state the ripple frequency in a bridge rectifier.

The bridge rectifier

The disadvantages of a full wave rectifier using two diodes and centre-tap transformer can be overcome by a modified fullwave rectifier as shown in Fig 1. In Fig 1, since the diodes are connected in the form of a bridge, this rectifier circuit is commonly known as a *Bridge rectifier*.

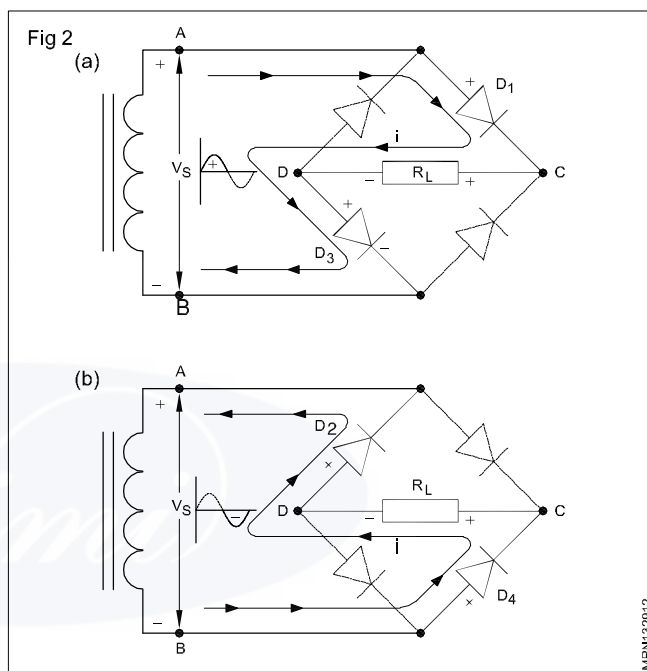
As can be seen in Fig 1, the bridge rectifier does not need a centre-tapped transformer. Also, all the secondary voltage is used for rectification at any given time.



The operation of a bridge rectifier can be summarized in the following steps;

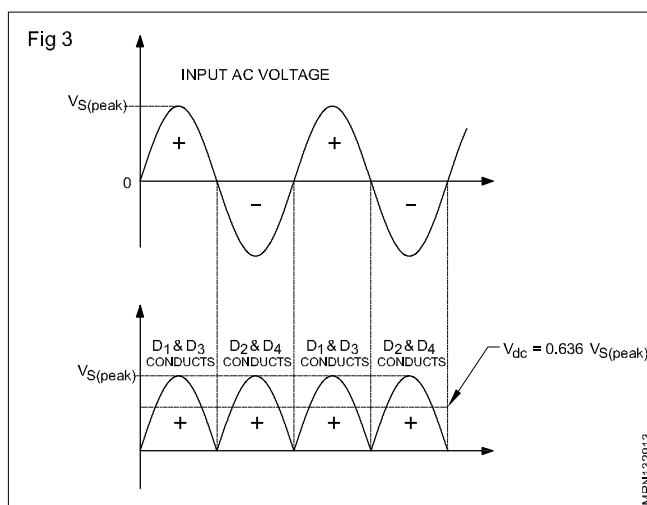
- When end A of the transformer secondary is +ve, as shown in Fig 2a, diodes D_1 and D_3 are forward biased whereas, D_2 and D_4 are reverse biased, and, hence, D_2 and D_4 do not come in the circuit.
- Current flows from the transformer (end A) D_1 R_L D_3 back to the transformer (end B). From the direction of the current flow point C is the positive terminal of the DC output across R_L .
- During the other half cycle of the input (–ve half cycle), end B of the transformer becomes +ve as shown in Fig 2b. Diodes D_4 and D_2 are forward biased, whereas D_1 and D_3 are reverse biased.
- Current flows from the transformer (end B) D_4 R_L D_2 back to the transformer (end A). From the direction of the current flow, point C is again the +ve terminal of the DC output across R_L .

Note that, current I is in the same direction through R_L during both +ve and –ve half cycles of the input AC. The result is, a +ve rectified DC voltage appears at the end of R_L connected to the cathodes of D_1 and D_4 .



Output DC level in a bridge rectifier

Fig 3 shows the input AC and the output pulsating DC waveform of a bridge rectifier.



Series voltage regulators

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

- state the disadvantages of a zener regulator
- state the working of a simple series regulator
- design a simple series regulator for a required dc output voltage
- write the blocks of a series regulator with voltage feedback and explain their functions
- design a series regulator for a given input-output specification
- state the modification necessary to make the output of a voltage regulator variable
- state the characteristics of a darlington pair connection
- state the method of increasing the load current capacity of series regulator.

Disadvantages of a zener regulator

- 1 When the load current requirement is higher, say of the order of a few amperes, the zener regulator requires a very high wattage zener diode capable of handling high current.
- 2 In a zener regulator, the load resistor sees an output impedance of approximately the zener impedance, R_Z which ranges from a few ohms to a few tens of ohms (typically 5Ω to 25Ω). This is a considerably high output impedance because the output impedance of an ideal power supply should be zero ohms.

These two disadvantages of zener regulators are overcome in a simple series regulator shown in Fig 1a.

The simple series regulator shown in Fig 1a, redrawn in Fig 1b is nothing but a zener regulator followed by an emitter follower. A circuit like this can hold the load voltage almost constant, thus working as a voltage regulator.

The advantages of this circuit are listed below;

1 Less load on the zener diode.

In this circuit Fig 1a or 1b the base current is very much smaller than the emitter current or the load current, a very small wattage zener diode itself is sufficient.

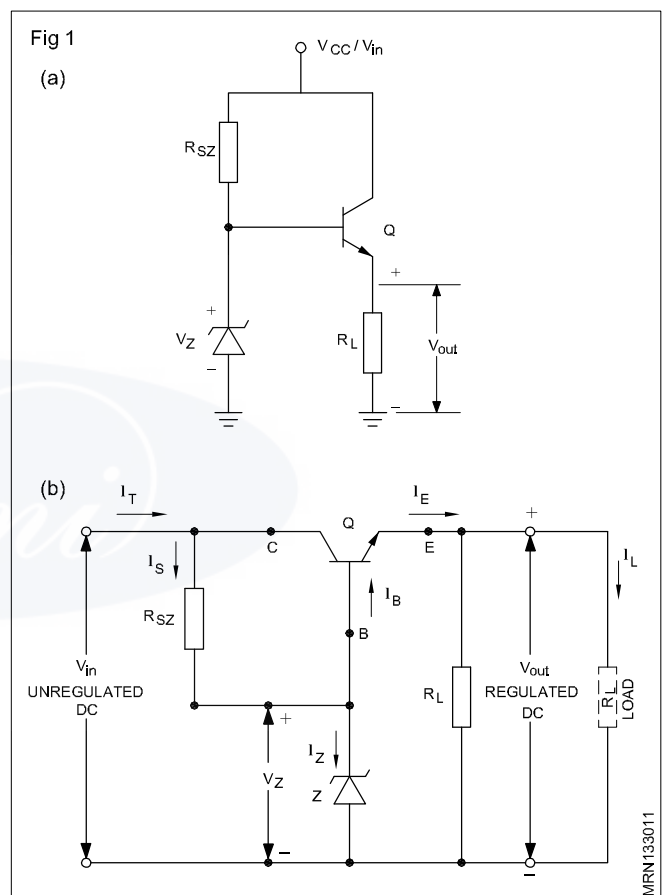
For instance for a load of say 1 amp, if the β_{dc} of the transistor is 100, then the zener diode need to handle only, 20mA for a typical $I_{Z(min)}$ of 5 to 10mA.

2 Lower output impedance

This circuit also offers a lower output impedance of $0.07W$ which is close to the ideal output impedance of zero required for a power supply. For further information, refer IMP of Electronic Mechanic 1st year.

Working of a simple series regulator

In Fig 1b, the current through R_{SZ} should be at least equal to zener breakdown current, plus, base current for the transistor Q.



The voltage across the zener, V_Z drives the base of the emitter follower. Therefore, the dc output voltage is bootstrapped to within one V_{BE} drop of the zener voltage. The regulated dc output voltage will be,

$$V_{out} = V_Z - V_{BE} \quad \dots\dots\dots[1]$$

The collector-emitter voltage across the transistor will be the difference in the voltage between the input and output.

$$V_{CE} = V_{in} - V_{out}$$

Using voltage regulator using zener diode

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

- state the need of regulators in power supplies
- state the formula to calculate the % load regulation factor
- list the main similarities and differences between rectifier diodes and zener diodes
- name the main application of zener diodes
- state the meaning of ICs
- explain the fixed voltage regulators.

Voltage regulators

Recall that, the DC output voltage level of power supplies such as, full-wave and bridge rectifiers, tend to decrease or increase,

- when the load current increases or decreases
- when the AC input voltage level decreases or increases.

Such variations in the output DC voltage level of power supply is not acceptable for most of the electronic circuits. Hence, it is required to regulate the DC output of power supplies so as to keep the DC output level constant, inspite of variations in the DC load current or the AC input voltage. Circuits or components used to keep the DC output voltage of a power supply constant are called voltage regulators.

Regulation factor

The ability of a power supply to maintain a constant DC output voltage for variations in the load current is referred to as load regulation. Load regulation of a power supply is generally given as a percentage.

$$\text{Load regulation factor \%} = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100$$

where,

$$V_{NL} = \text{DC output at no load or open circuit}$$

$$\text{and } V_{FL} = \text{DC output at rated full load.}$$

It should be noted that lower the percentage of load regulation factor, better is the voltage regulation.

Example: The DC output of a power supply is 12 volts at no-load and 11 volts at full load.

$$\% \text{ Load regulation} = \frac{12 - 11}{11} \times 100 = 9.09\%$$

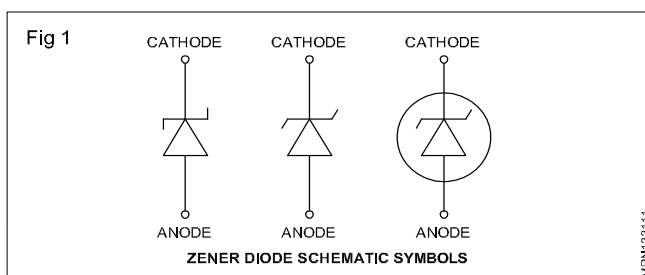
In practice the load regulation of a good power supply should be less than 0.1 %.

Regulating the DC output voltage for variations in the input AC level is termed as line regulation. This is discussed in further units.

The zener diode

In a power supply one of the simplest ways of regulating the DC output voltage (keeping the output voltage constant) is by using a zener diode. With zener in reverse breakdown condition, the voltage across the zener diode remains constant for a wide range of input and load variations.

Because of this property, zener diodes are also known as voltage regulators or voltage reference diodes. Fig 1 shows the symbol used for zener diodes.



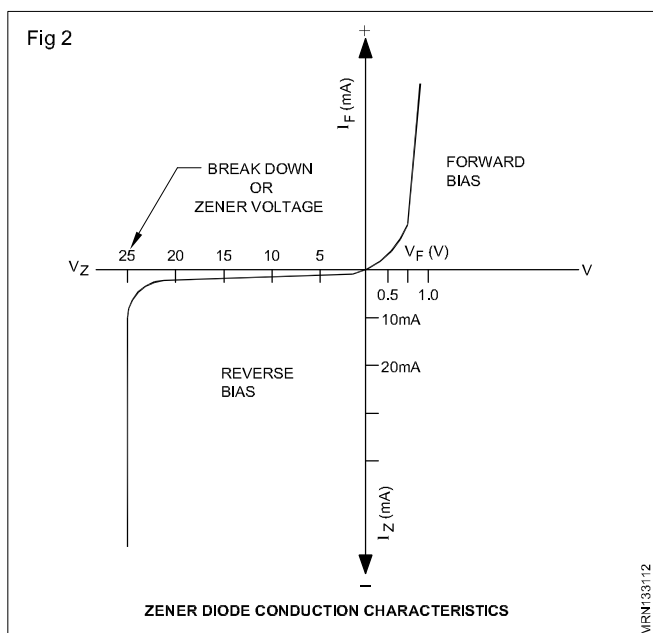
The difference between a rectifier diode and a zener diode are listed below;

- Compared to normal rectifier diodes, zener diodes are heavily doped.
- Unlike ordinary diodes which do not work in the breakdown region, zener diodes work only in the breakdown region.
- General rectifier diodes are used in forward-biased condition, whereas zeners are always used in reverse-biased condition.
- The reverse breakdown voltage of zener diodes is very much less (3 to 18V) compared to rectifier diodes (minimum 50V).

The similarities of a zener diode with those of general purpose rectifier diodes are listed below;

- Zener diodes are also PN junction diodes, which are also generally made of silicon.
- Zener diodes also have two terminals (anode and cathode).
- In physical appearance, the zener diodes and ordinary diodes look alike.
- Like rectifier diodes, zener diodes are also available with glass, plastic and metal casing.
- The anode and cathode marking technique on the body is same for both zener and rectifier diodes.
- The zener can be tested with an ohmmeter in the same way as in rectifier diodes.
- Zener requires approximately the same voltage for it to be forward-biased into conduction as that of an ordinary diode.

Fig 2 shows the conduction characteristics of a typical zener diode. Because of the nature and heavy doping in a zener, its characteristics are different compared to a rectifier diode.



Note that, the zener diode acts as a rectifier diode when forward biased. It also behaves as a rectifier diode when reverse-biased, till the voltage across it reaches the breakdown voltage. As can be seen from Fig 2, even the reverse or leakage current remains almost negligible and constant despite the increase in the reverse-biased voltage till the break down voltage, also called zener voltage is reached. But, Once the zener breakdown voltage is reached, the diode current begins to increase rapidly and the zener suddenly begins to conduct. In the case of a normal rectifier diode, once the break down voltage is reached the diode gets punctured and starts conducting heavily whereas, in a zener diode, the diode does not get punctured even though it conducts current in the reverse biased condition.

The cause for this reverse conduction is referred to as the avalanche effect. The avalanche effect cause, the electrons to be knocked loose from their bonds in the crystal structure. As more electrons are loosened, they in turn knock others and current builds quickly. This action causes the voltage drop across the zener to remain constant regardless of the zener current. As shown in Fig 2, once the zener voltage is reached, very small voltage changes create much greater current changes. It is this characteristic, which makes the zener useful as a constant voltage source or as a voltage regulator.

Unlike in a rectifier diode, the reverse current through the zener is not destructive. If the current is kept within the specified limits depending upon the wattage rating of the zener, using a suitable series resistance, no harm is done to the zener diode.

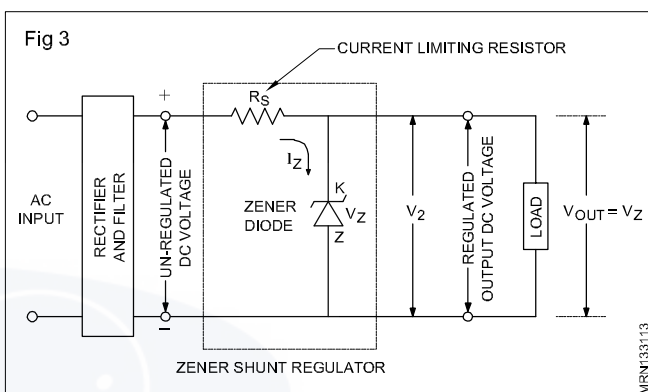
Because the zener diode is designed to operate as a breakdown device, the zener can be brought out of condition easily. A zener is brought out of its zener conduction by lowering the reverse-biased voltage below the zener voltage or by reversing the polarity of the applied voltage.

Application of zener diodes

The most popular use of zener diodes is as voltage regulators in DC power supplies. Fig 3 illustrates a simple zener regulated power supply.

In the circuit at Fig 3, the zener diode is in parallel with the output or load of the power supply. It is very important to note that the zener is connected in the reverse-biased condition. Such a parallel circuit connection is often called a shunt. When used in this way, the zener is said to be a shunt regulator.

In Fig 3, the zener begins to conduct in the reverse-biased condition as the voltage across it reaches the zener voltage V_Z . The voltage across the zener remains constant immaterial of the input DC voltage. Since the load is in parallel with the zener, the voltage across the load V_{OUT} will be same as the voltage across the zener V_Z ($V_{OUT} = V_Z$).



If the input DC voltage to the zener increases, as can be seen from its characteristics in Fig 2, the current I_Z through the zener increases but the voltage across the zener remains the same due to avalanche effect. Because the zener voltage, V_Z does not change, the output voltage V_{OUT} , does not change and so the voltage across the load is constant. Thus, the output is said to be regulated.

Introduction

Electronic circuits invariably consist of a number of discrete components connected to each other in a specific way. For instance, the series regulator circuit discussed in earlier lessons, consists of transistors, zener diodes, resistors and so on, connected in a defined way for it to function as a regulator. If all these components instead of building on a board, if they are built on a single wafer of a semiconductor crystal, then, the physical size of the circuit becomes very very small. Although small, this will do the same job as that of the circuit wired using discrete components. Such miniaturised electronic circuits produced within and upon a single crystal, usually silicon, are known as **integrated circuits** or **ICs**. Integrated circuits (ICs) can consists of thousands of active components like transistor, diodes and passive components like resistors and capacitors in some specific order such that they function in a defined way say as voltage regulators or amplifiers or oscillators and so on.

Classification of integrated circuits

Integrated circuits may be classified in several ways. However the most popular classifications is as follows:

1 Based on its type of circuitry

- a Analog ICs - Example: amplifier ICs, voltage regulator ICs etc.
- b Digital ICs - Example: Digital gates, flip-flops, adders etc.

2 Based on the number of transistors built into IC

- a Small scale integration (SSI) - consists of 1 to 10 transistors.
- b Medium scale integration (MSI) - consists of 10 to 100 transistors.
- c Large scale integration (LSI) - 100 to 1000 transistors.
- d Very large scale integration (VLSI) - 1000 and above.

3 Based on the type of transistors used

- a Bipolar - carries both electron and hole current.
- b Metal oxide semiconductor (MOS) - electron or hole current.
- c Complementary metal oxide semiconductor (CMOS) - electron or hole current.

NOTE: The terms MOS and CMOS are another type of transistors which will be discussed in further lessons. Further details on different classifications of ICs will be discussed at appropriate lessons.

Integrated circuit (IC) voltage regulators

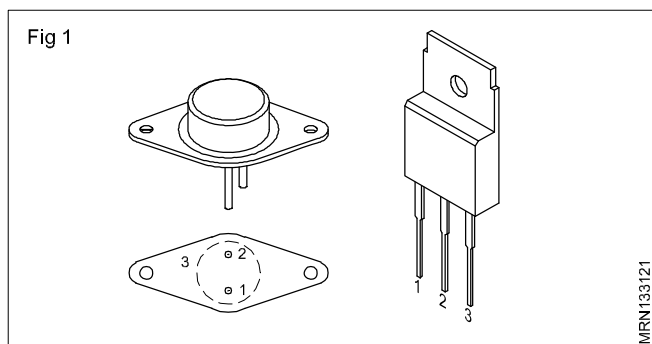
The series voltage regulators discussed in earlier lessons are available in the form of integrated circuits (ICs). They are known as voltage regulator ICs.

There are two types of voltage regulator ICs. They are,

- 1 Fixed output voltage regulator ICs
- 2 Adjustable output voltage regulator ICs.

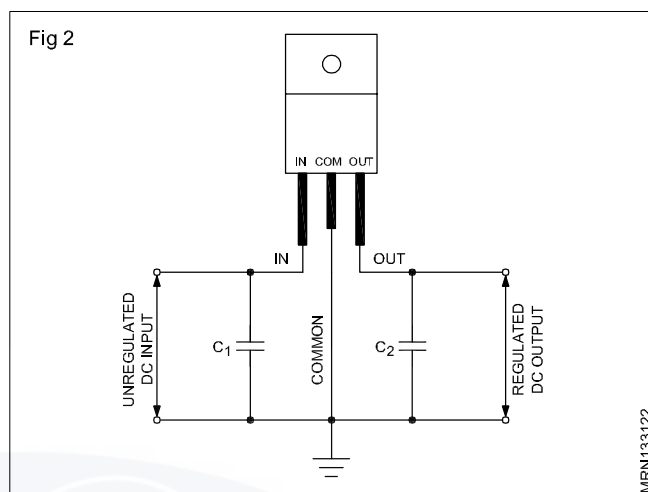
Fixed output voltage regulator ICs

The latest generation of fixed output voltage regulator ICs have only three pins as shown in Fig 1. They are designed to provide either positive or negative regulated DC output voltage.



These ICs consists of all those components and even more in the small packages shown in Fig 1. These ICs, when used as voltage regulators, do not need extra components other than two small value capacitors as shown in Fig 2.

The reason behind using capacitor C_1 is, when the voltage regulator IC is more than a few inches from the filter capacitors of the unregulated power supply, the lead inductance may produce oscillations within the IC. Capacitor C_1 prevents setting up of such oscillations. Typical value of bypass capacitor C_1 range from $0.220\mu\text{F}$ to $1\mu\text{F}$. It is important to note that C_1 should be connected as close to the IC as possible.



The capacitor C_2 is used to improve the transient response of the regulated output voltage. C_2 bypasses these transients produced during the ON/OFF time. Typical values of C_2 range from $0.1\mu\text{F}$ to $10\mu\text{F}$.

Fixed voltage three terminal regulators are available from different IC manufacturers for different output voltages (such as 5V, 9V, 12V, 24V) with maximum load current rating ranging from 100mA to more than three amps.

The most popular three terminal IC regulators are,

- 1 LMXXX-X series

Example: LM320-5, LM320-24 etc.

- 2 78XX and 79XX series

Example: 7805, 7809, 7812, 7905, 7909, 7912

Identify specifications and testing of SCR

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

- explain the role of SCR in the field of industrial electronics
- explain the construction and working principle of SCR
- explain the method of checking SCRs using JIG.

Introduction to Industrial electronics

Industrial electronics is concerned primarily with electronics as applied to industries such as industrial equipments, controls and processes. An important application of electronics in industries is in controlling of machinery.

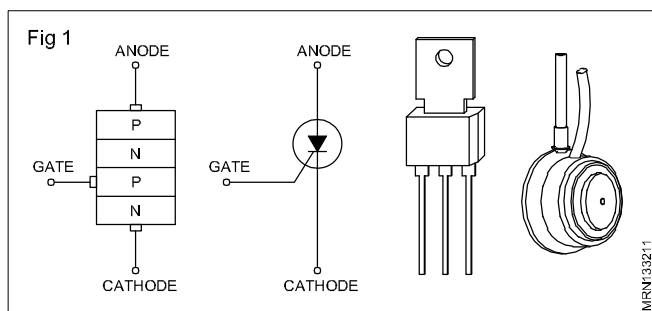
In communication electronics, domestic & entertainment electronics, generally, the electronic devices operate with currents in the order of microamperes to milliamperes. For industrial applications, most frequently, devices are required to handle currents in the range of amperes to several thousands of amperes. This, therefore calls for high power electronic devices. One such high power electronic device frequently used in industrial electronic application is the SCR. SCRs can be used to run, dc motors from an ac power source, control power tool speed, also to control motor speeds of small appliances like, mixers and food blenders, illumination control, temperature control and so on.

Silicon Controlled Rectifier(SCR)

Before Silicon controlled rectifiers were invented (1956), a glass tube device called Thyatron was used for high power applications. Silicon Controlled Rectifier (SCR) is the first device of the thyristor family. The term thyristor is coined from the expression Thyatron-transistor. SCR is a semiconductor device. SCR does the function of controlled rectification. Unlike a rectifier diode, SCR has an additional terminal called the gate which controls the rectification (gated silicon rectifier).

The basic principle application of SCRs is to control the amount of power delivered to a load (motor, lamp, etc.,).

A rectifier diode will have one PN junction. SCRs on the other hand will have two PN junctions (P-N-P-N layers). Fig 1 shows the electrical symbol, basic construction and a typical SCR packages.



Basic operation of SCR

When a gate current is applied to the gate terminal, forward current conduction commences in the SCR (latched into conduction). When the gate current is removed, the forward current through the SCR **does not cut-off**. This means, once the SCR is latched into conduction, the gate loses control over the conduction. The current through the SCR can be turned off only by reducing the current through it (load current) below a critical value called the **Holding current**.

QUICK Check of SCRs

Quick check on SCRs can be carried out using an ohmmeter/multimeter. Since SCRs are made of PNPN junction, resistance between junctions can be measured to conclude good working condition of the SCR. A good SCR shows following resistances between its terminal leads;

CHECK - 1

Between Anode - Cathode - Infinite resistance

[Irrespective of polarity]

Between Gate - Cathode

(i) Forward biased - Very low resistance
(30 to 500 ohms)

(ii) Reverse biased - High resistance

Between Gate - Anode - Infinite resistance

[Irrespective of polarity]

CHECK - 2

- Set multimeter to low resistance range.
- Connect positive lead of multimeter to the anode and the negative lead to the cathode. Meter should show infinite resistance.
- Now, for moment, short anode and gate of SCR by a piece of wire. The meter should show low resistance and will continue to show low resistance even after the short between anode and gate is removed.

It is difficult to check leaky SCRs using only an ohmmeter/multimeter.

Checking SCRs using a SCR checking JIG

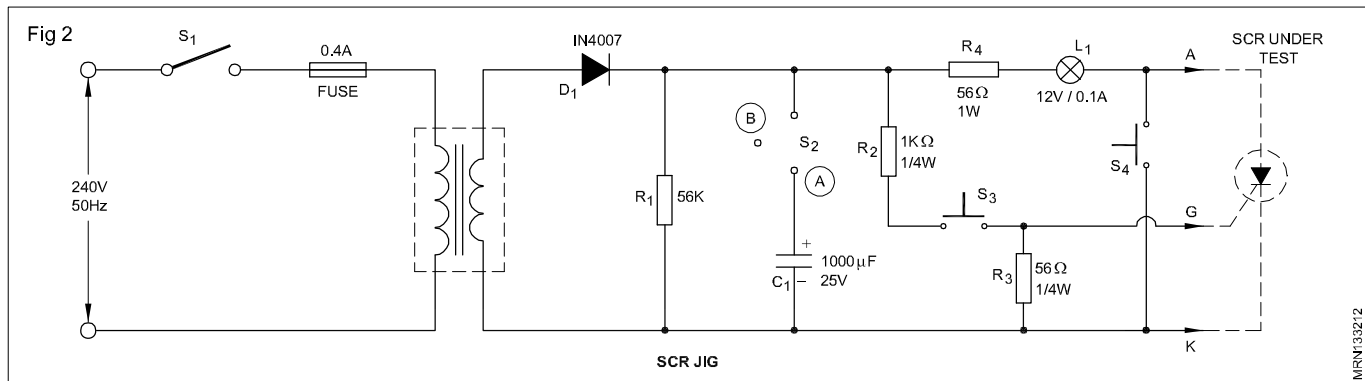
A simple "SCR checking jig" is shown in Fig 2. In Fig 2, the SCR shown in dotted lines is the SCR to be checked. This could be any SCR that you want to check.

In Fig 2, the stepped down to 12 AC is rectified by diode D_1 and filtered by capacitor C_1 when switch S_2 is at position A. The rectified and filtered DC is applied to the anode of SCR through lamp L_1 via a limiting resistor R_4 . Resistor R_2 , R_3 in series with a push button switch S_3 form a potential divider across dc. Voltage across R_3 is applied to the gate of SCR. This voltage is sufficient to turn on the SCR. Another push button Switch S_4 is connected directly across the Anode and Cathode of the SCR to be checked.

When a good SCR is placed in the test jig (in place of the SCR shown dotted) the circuit should function as given below;

- 1 When mains supply is on, and S_2 is at DC position, the lamp will start glowing as soon as the switch S_3 is pressed. Even on releasing S_3 , the lamp should keep on glowing. Under this condition, if switch S_4 is pressed once and released the SCR stops conducting and hence the lamp stops glowing.
- 2 If switch S_2 is put to AC position, lamp should glow only as long as switch S_3 is pressed.

The Instructor has to discuss the reasons for 1 & 2 above as an interactive discussion. Instructor also discuss the outcome of above steps, when a open or a shorted SCR is checked.



Application of UJT as time delay

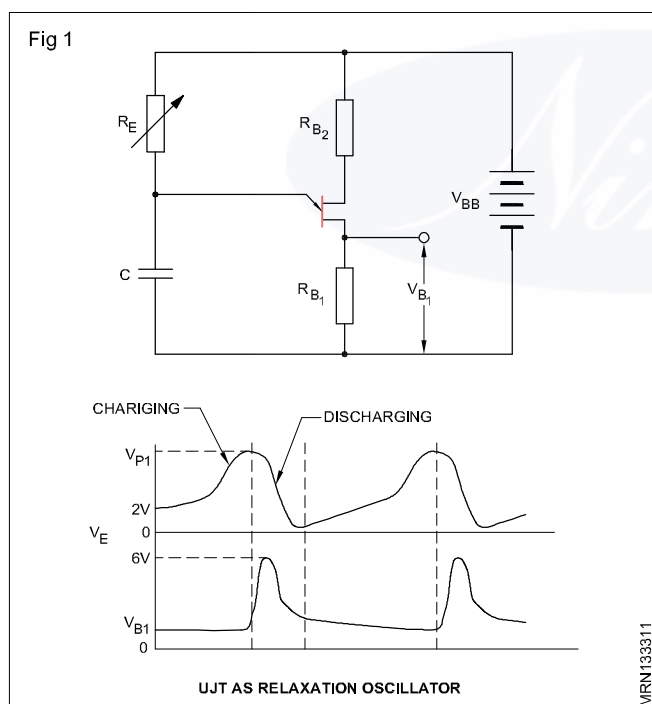
Objectives: At the end of this lesson you shall be able to

- list the use of UJT in electric circuit
- state the method of varying oscillator frequency
- explain the method of triggering SCR through UJT band relaxation oscillator.

Application of UJTs: UJTs are employed in a wide variety of circuits involving electronic switching and voltage or current sensing applications. These include

- triggers for thyristors
- as oscillators
- as pulse and sawtooth generators
- timing circuits
- regulated power supplies
- bistable circuits and so on.

Let us analyse the waveform generated across the capacitor and R_{B1} with respect to the relaxation oscillator shown in Fig 1.



The negative - resistance portion of the UJT characteristic is used in the circuit shown in Fig 1 to develop a relaxation oscillator.

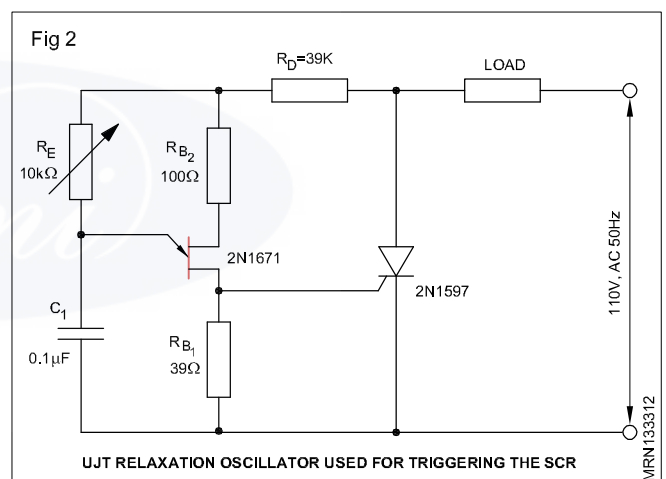
The wave form developed across the capacitor is shown in Fig 1 as V_E , whereas the waveform produced across the resistor R_{B1} is shown as a pulse V_{B1} .

The frequency of oscillation

$$f = \frac{1}{R_E C}$$

Where R_E is the value of variable resistor in ohms and C is the value of the capacitor in farad.

By varying the value of R_E , the frequency of the oscillator can be varied. Although such an oscillator using a DC supply voltage could be used to trigger a SCR, there would be trouble in synchronizing the pulses with the cycles of alternating current. Fig 2 shows a stable triggering circuit for an SCR in which the firing angle can be varied from 0° to 180° .



The low output impedance of the UJT (39ohms) is ideal for driving the SCR, which has a relatively low input impedance from gate to cathode.

Resistor R_D is used as a dropping resistor to restrict the peak voltage across the UJT to within its specifications.

By varying the variable resistor R_E the oscillator frequency can be varied thereby the frequency of trigger pulses which are used to trigger the SCR. Time used for delay in switching the SCR could be measured through a slip watch from the time of switching on.

Photodiodes and phototransistors

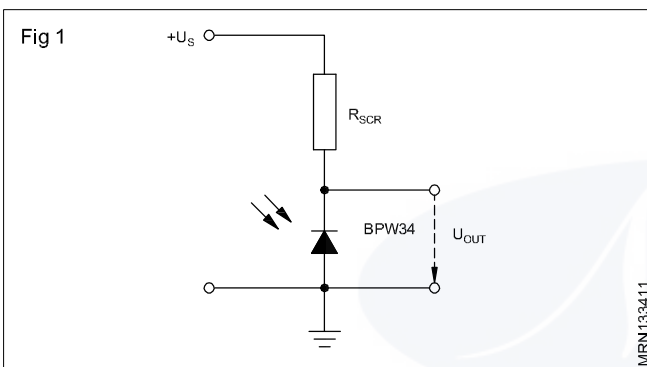
Objectives: At the end of this lesson you shall be able to

- explain working of photodiode
- explain the advantages of PIN photodiode
- list a few application of photodiodes
- explain working of photodiode
- explain the working of a light controlled switch using photo transistor
- state the working principles of operational amplifier.

Photo diodes

P-N Photo diodes

Photodiodes are produced by silicon techniques. Photodiodes are operated in the reverse direction. A supply voltage and a series resistor are therefore required to operate photodiodes. The basic circuit for the operation of photodiodes is shown in Fig.1



When no light is incident on the photodiode, a reverse current flows through the p-n junction, as it does in any normal semiconductor diode, but in photodiodes it is usually referred to as the “dark current” I_{Ro} .

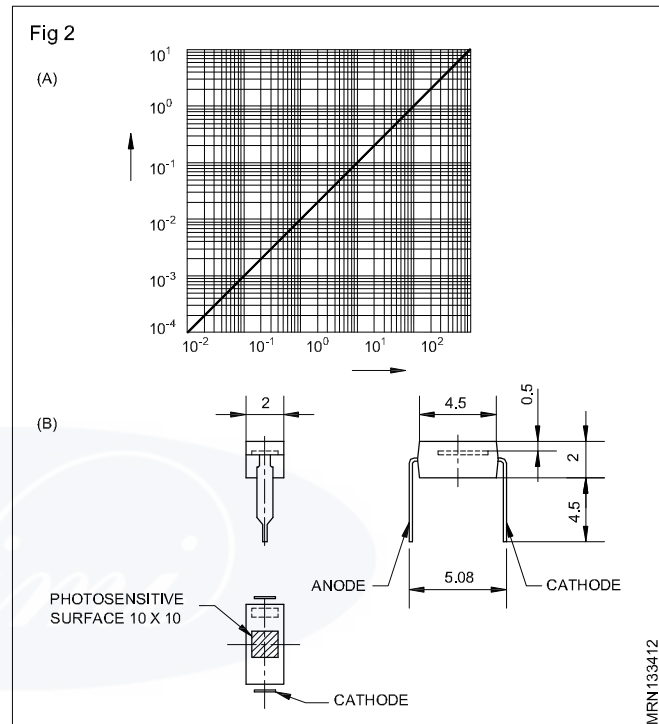
When light strikes the p-n junction, crystal bonds are broken as a result of the supply of energy. Mobile charge-carrier pairs are produced, which immediately migrate as a result of the electric field present. The holes travel towards the p-layer and the electrons towards the n-layer. As a result of illumination, an additional photocurrent I'_{photo} occurs, which increases linearly with the illuminance. This photocurrent is superimposed as a reverse current on the relatively small dark current, so that for the total photocurrent occurring with illumination, the following applies:

$$I_{photo} = I_{Ro} + I'_{photo}$$

Since I_{Ro} is far smaller than I'_{photo} then:

$$I_{photo} = I'_{photo}$$

The rise in I_{photo} is almost linear. Photodiodes are therefore particularly suitable for the accurate measurement of illuminance. Physical appearance and dimensions of a typical photodiode BPW 32 is shown in Fig 2.

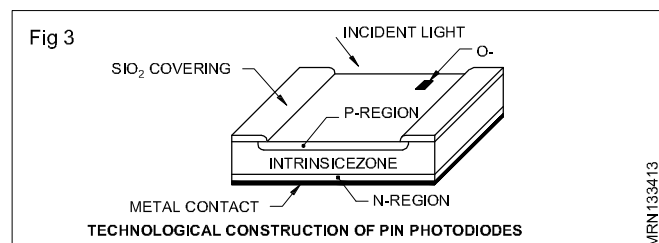


PIN Photo diodes

PIN photodiodes were developed to overcome the drawbacks of p-n photodiodes. The letters PIN indicate the zone sequence as given below;

P-layer/Intrinsic-layer/N-layer

A typical internal construction of a PIN photodiode is shown in Fig 3.



The advantages of PIN photodiodes are;

- high sensitivity in the infrared range
- short switching times,

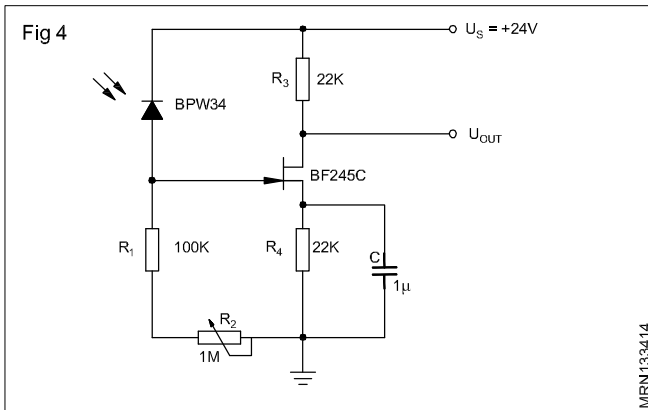
because of which, they are extensively used in remote control using modulated infrared light.

In operation they are similar to p-n photo diodes as shown in Fig 1.

Typical application of Photodiodes

Because of the very small photocurrent, photodiodes are generally used with an amplifier as shown in Fig 4. Amplifier stages with FET (Field Effect Transistor) are usually used with photodiodes because of the high input resistance of FET.

Note: Field Effect Transistors well known as FET is another type of transistor. Details of FET is discussed in lessons to follow.



Circuit diagram of a simple Light controlled amplifier is shown in Fig 5. This circuit uses a single FET for amplifying the output of the photodiode connected in series with a resistor.

The working point of the FET can be adjusted with trimmer R_2 . As the illumination on the photo diode increases, the negative gate is reduced and therefore V_{out} reduces. The same value of R_3 and R_4 are chosen to ensure linear relationship between I_{photo} and V_{out} over a wide range. Thus this photoamplifier works satisfactorily not only for very slow changes in illumination but also with alternating light.

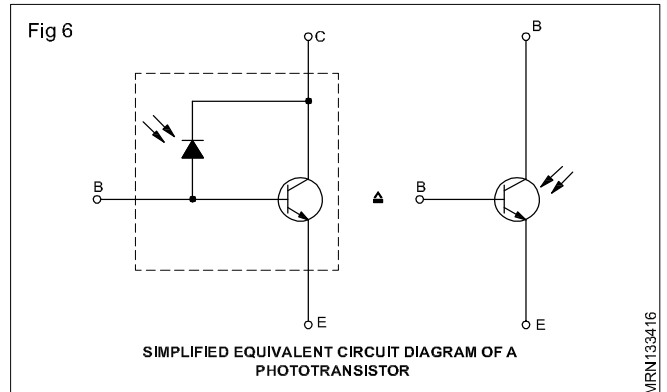
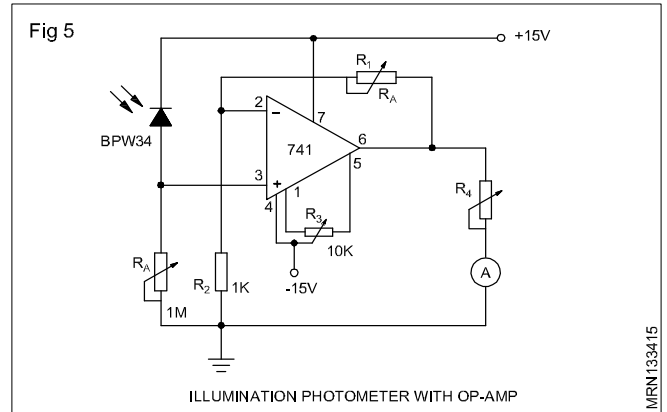
Illumination Photometer using photodiode and Opamp

An illumination Photometer with an op-amp as an amplifier is shown in Fig 5. The output of the photo sensor follows the illuminance linearly, which may be in the range between 0.05 lx and 5000 lx, with a sensitivity of 5μA/lx. The sensor has the type designation TFA 1001W and is intended for use in video cameras and optical instruments.

Photo Transistor

Both in the construction and in their mode of operation, phototransistor's can be thought of as a combination of a photodiode and a normal bipolar transistor. The simplified equivalent circuit diagram of a phototransistor is shown in Fig 6.

Without illumination, only a very small dark current I_{Ro} flows through the photodiode. This dark current, at the same time is the base current of the transistor. The following is then obtained for the dark current I_{Co} of the transistor,



$$I_{Co} = B \times (I_{CBo} + I_{Ro}),$$

Where,

I_{CBo} is the reverse current of the collector/base diode and B is the current gain of the transistor.

When the photodiode is illuminated, a photocurrent I_{photo} flows, which is amplified by the current gain B and is superimposed on the dark current.

Therefore, the collector current of the phototransistor is,

$$I_C = I_{Co} + B \times I_{photo}$$

Since the dark current I_{Co} is much less than $B \times I_{photo}$, I_{Co} can generally be neglected, so in practice,

$$I_C \text{ approximately } = B \times I_{photo}$$

Advantage of Phototransistors over Photodiodes

Advantages of phototransistors over photodiodes are,

- their considerably greater sensitivity and
- the illuminance-dependent collector current I_C , which is increased by a factor B.

Operational Amplifier

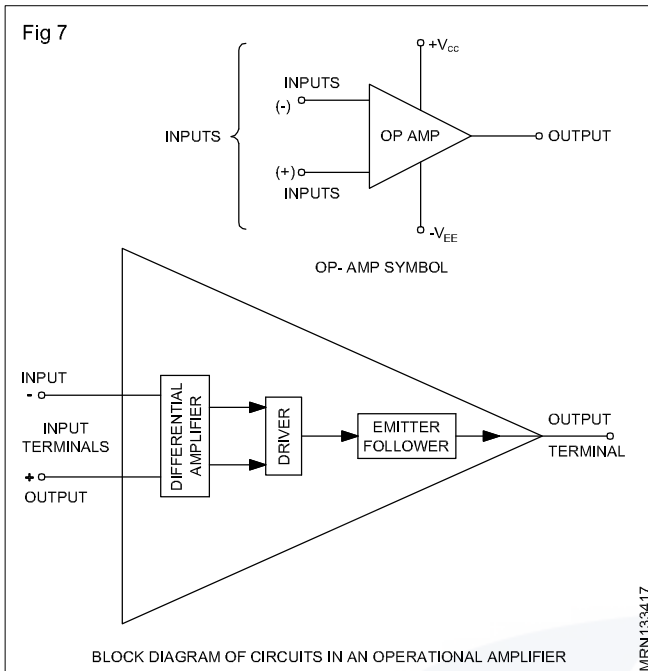
Basic linear integrated circuit-‘Operational Amplifiers’ (OP Amps)

An operational amplifier, often referred as op-Amp, is a high gain, direct coupled differential amplifier, designed to amplify both DC and AC signals.

The term operational is used with these amplifiers because, in early days these amplifiers were used in analog computers to perform mathematical operations such as addition, multiplication etc.,

Symbol used to represent an Op-Amp and the functional blocks inside it are shown in Fig 7.

As can be seen from Fig 7, operational amplifiers will have two inputs and one output. The reason for having two input points is that Op Amps have a special type of amplifier configuration known as Differential amplifier as its first stage.



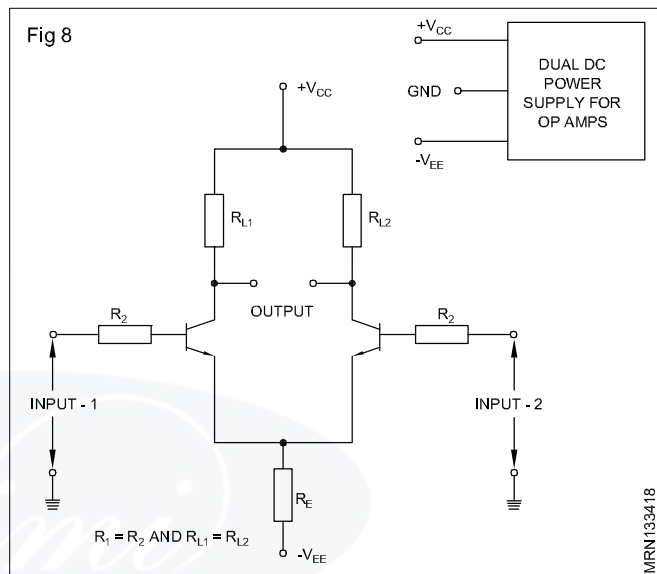
A typical differential amplifier stage is shown in Fig 8. A differential amplifier stage consists of two transistors with an input to each transistor. The output is taken between the collectors of the transistors as shown in Fig 8. The most important point to note is, both the transistors have

identical characteristics, load resistors, input resistors and a single emitter resistor. Dual power supply(+ve,-ve and Gnd) is required for differential amplifiers (single supply can also be used with a few extra components). If a dual supply is used and if the amplifier is properly balanced (symmetrical values), the output voltage across the collectors will be equal to the difference of the two input voltages. Hence, this amplifier is called differential amplifier.

Modes of operation of differential amplifiers

Any operational amplifier can be operated in two modes. They are,

- Common-mode operation
- Differential-mode operation.



Introduction and definition of welding

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

- **state the invention of welding**
- **describe the different ways to weld.**

The history of joining metals goes back several millennia. Called forge welding, the earliest come from the Bronze and Iron Ages in Europe and the Middle East. The middle Ages brought advances in forge welding, in which blacksmiths used to heat the metal repeatedly until bonding occurred.

In 1801, Sir Humphry Davy discovered the electrical arc. In 1802, Russian Scientist Vasily Petrov also discovered the electric arc and subsequently proposed possible practical applications such as welding. In 1881-82, a Russian Inventor Nikolai Benardos and Polish Stanislaw Olszewski created the first electric arc, welding method known as carbon arc welding; they used carbon electrodes.

The advances in arc welding continued with the invention of metal electrodes in the late 1800's by a Russian, Nikolai Slavyanov (1888), and an American, C.L. Coffin (1890). Around 1900, A.P. Strohmenger released a coated metal electrode in Britain, which gave a more stable arc.

In 1905, Russian scientist Vladimir Mitkevich proposed using a three-phase electric arc for welding. In 1919, alternating current welding was invented by C.J. Holtslag but did not become popular for another decade.

Welding is a fabrication process that joins materials normally metals. This is often done by melting the work pieces and adding a filler material to form pool of molten material that cools to become a strong joint, with pressure sometimes used in conjunction with the heat or by itself, to produce the weld. This is in contrast with soldering & brazing, which involve melting a lower-melting-point material to form a bond between them, without melting the work pieces.

There are many different ways to weld. Such as; Shielded Metal Arc Welding (SMAW). Gas Tungsten Arc Welding (GTAW), and Gas Metal Arc Welding (GMAW).

GMAW involves a wire fed "gun" that feeds wire at an adjustable speed and sprays a shielding gas (generally pure Argon or a mix of Argon and CO_2) over the weld puddle to protect it from the effect of atmosphere.

GTAW involves a much smaller hand-held gun that has a tungsten rod inside of it. With most, you use a pedal to adjust your amount of heat and hold a filler metal with your other hand and slowly feed it.

Stick welding or Shielded Metal Arc Welding has an electrode that has flux, the protecting for the puddle, around it. The electrode holder holds the electrode as it slowly melts away. Slag protects the weld puddle from the affection of atmosphere. Flux-core is almost identical to stick welding except once again you have a wire feeding gun; the wire has a thin flux coating around it that protects the weld puddle.

Many different sources of energy can be used for welding, including a gas flame, an electrical arc, a laser, an Electron Beam (EB), Friction, and ultrasound. While often an industrial process, welding may be performed in many different environments, including in open air, under water, and on outer space. Welding is a potentially hazardous undertaking and precautions are required to avoid burns, electric shock, vision damage, inhalation of poisonous gases and fumes, and exposure to intense ultraviolet radiation.

Safety is shielded metal arc welding

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

- **identify the safety apparels and accessories used in arc welding**
- **select the safety apparels and accessories to protect from burns and injuries**
- **learn how to protect yourself and others from the effect of harmful arc rays and toxic fumes**
- **select the shielding glass for eye and face protection.**

Non-fusion welding

This is a method welding in which similar or dissimilar metals are joined together without melting the edges of the base metal by using a low melting point filler rod but without the application of pressure.

Example: Soldering, Brazing and Bronze welding.

During arc welding the welder is exposed to hazards such injury due to harmful rays (Ultra violet and infra red rays) of the arc, burns due to excessive heat from the arc and contact with hot jobs, electric shock. Toxic fumes, flying hot spatters and slag particles and object falling on the feet.

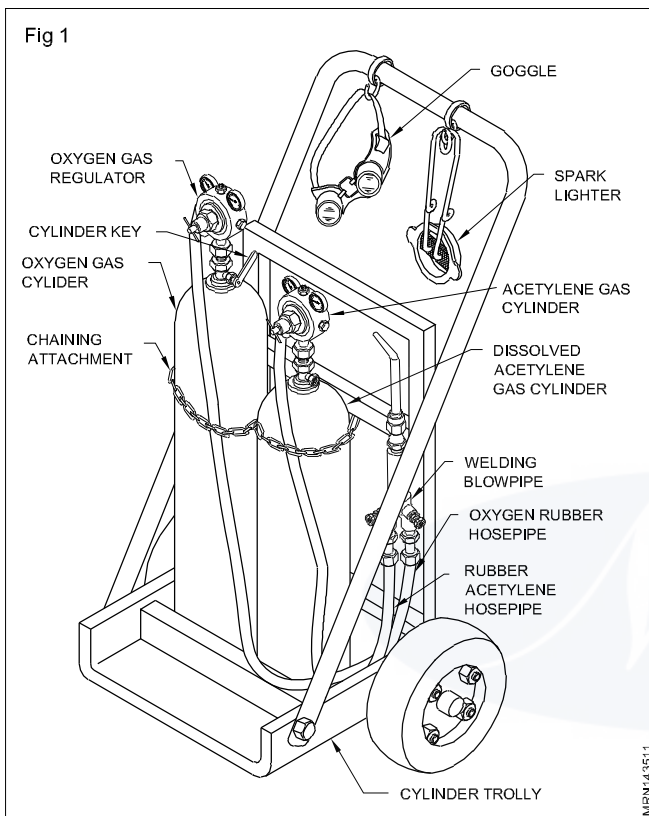
The following safety apparels and accessories are used to protect the welder and other persons working near the welding area from the above mentioned hazards.

High pressure oxy-acetylene welding equipment and accessories

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

- distinguish between the features of oxygen and acetylene gas cylinders
- compare the features of oxygen and acetylene gas regulators
- distinguish between the hose-connectors used in oxygen and acetylene regulators
- describe the function of hose-protectors
- state the functions of blowpipes and nozzles.

Oxy-acetylene welding is a method of joining metals by heating them to the melting point using a mixture of oxygen and acetylene gases. (Fig 1)



Oxygen gas cylinders: The oxygen required for gas welding is stored in bottle-shaped cylinders. These cylinders are painted in black colour. (Fig 2) Oxygen cylinders can store gas to a capacity of 7 m³ with the pressure ranging between 120 to 150 kg/cm². Oxygen gas cylinder valves are right hand threaded.

Dissolved acetylene cylinders: The acetylene gas used in gas welding is stored in steel bottles (cylinders) painted in maroon colour. The normal storing capacity of storing acetylene in dissolved state is 6m³ with the pressure ranging between 15-16 kg/cm².

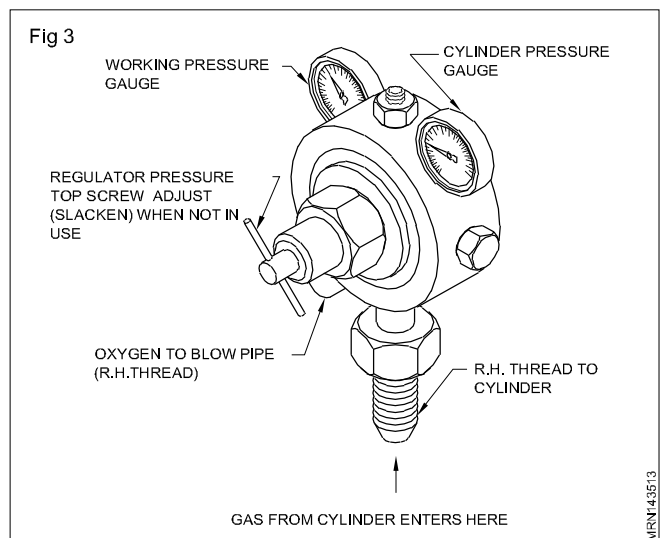
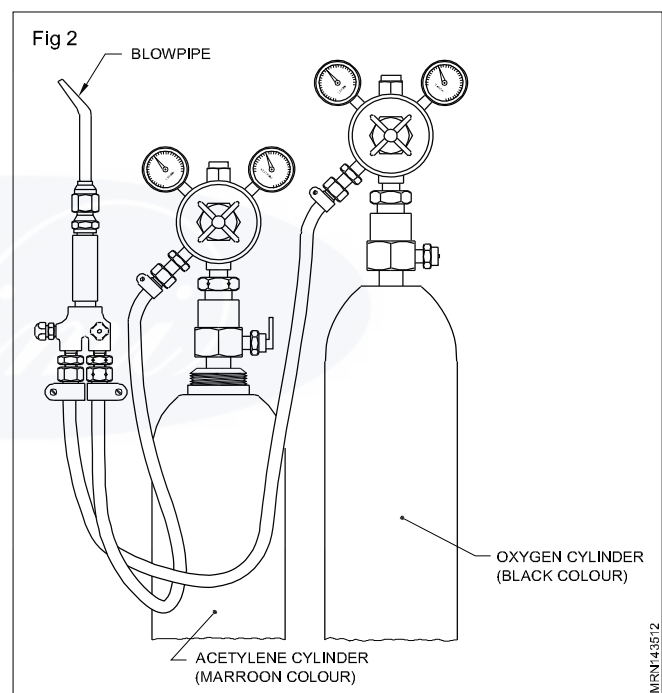
Oxygen pressure regulator: This is used to reduce the oxygen cylinder gas pressure according to the required working pressure and to control the flow of oxygen at a constant rate to the blowpipe. The threaded connections are right hand threaded. (Fig 3)

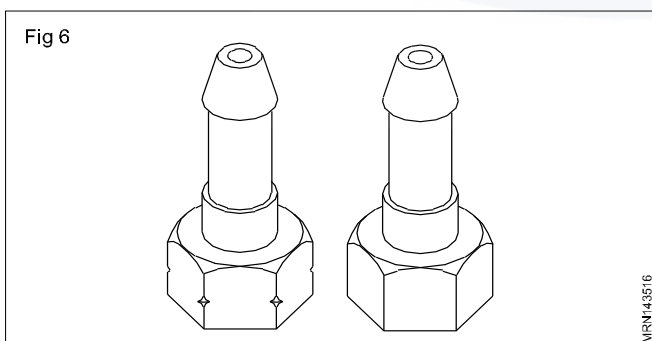
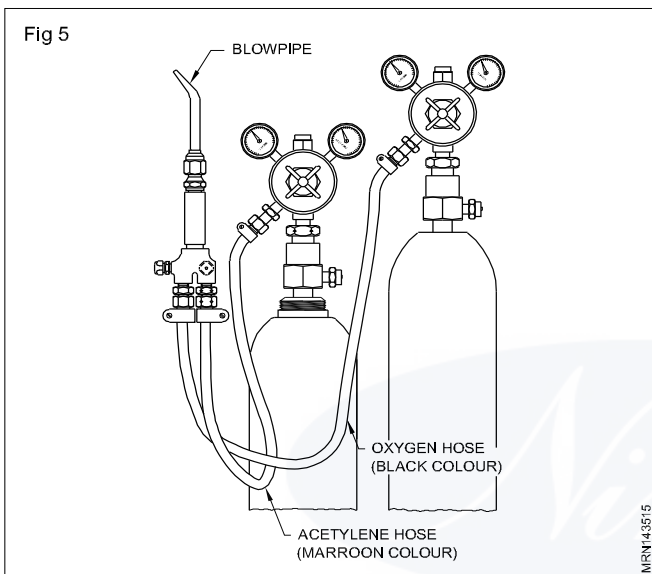
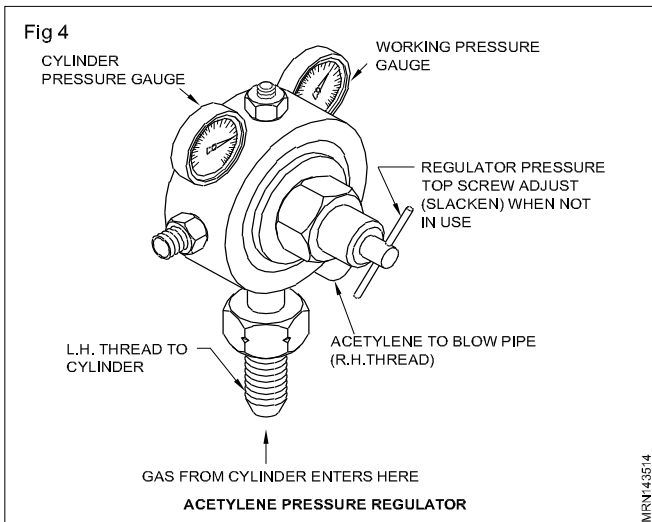
Acetylene regulator: As with the case of oxygen regulator this also is used to reduce the cylinder gas pressure to the required working pressure and to control the flow of acetylene gas at a constant rate to the blowpipe. The threaded connections are left handed, For quickly

identifying the acetylene regulator, a groove is cut at the corners of the but. (Fig 4)

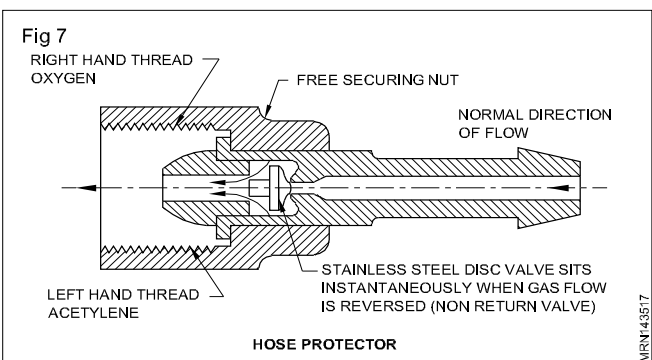
Rubber hose-pipes and connections: These are used to carry gas from the regulator to the blowpipe. These are made of strong canvas rubber having good flexibility. Hosepipes which carry oxygen are black in colour and the acetylene hoses are of maroon colour (Fig 5)

Rubber hoses are connected to regulators with the help of unions. These unions are right hand threaded for oxygen and left hand threaded for acetylene. Acetylene hose unions have a groove cut on the corners. (Fig 6)

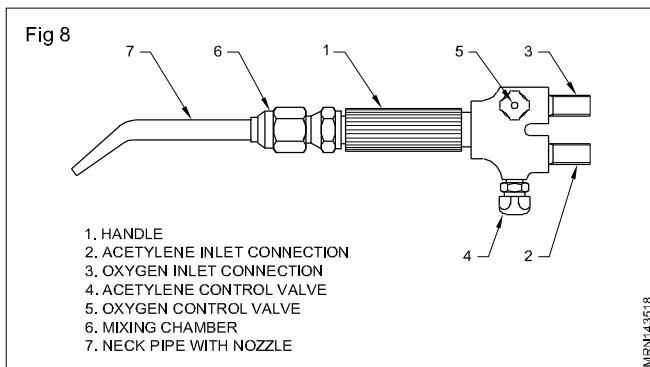




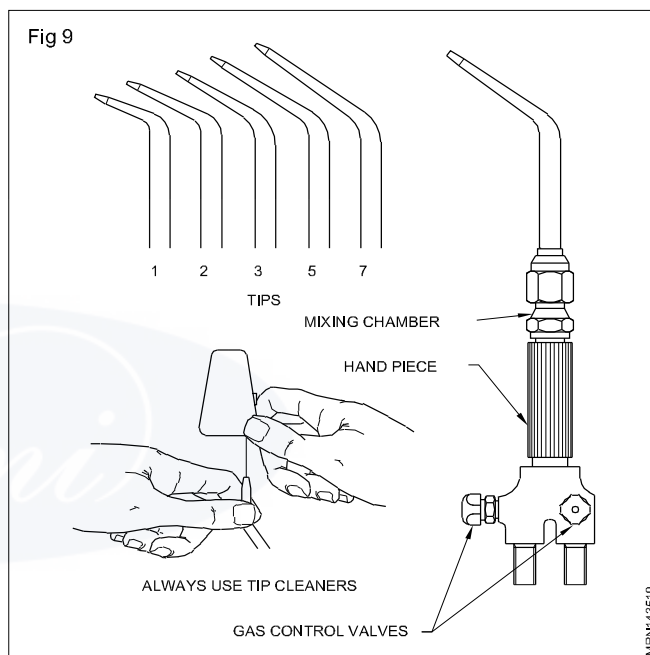
At the blowpipe end of the rubber hoses-protectors are fitted. The hose protectors are in the shape of a connecting union and have a non-return disc fitted inside to protect from flashback and backfire during welding. (Fig 7)



Blowpipe and nozzle: Blowpipes are used to control and mix the oxygen and acetylene gases to the required proportion. (Fig 8)



A set of interchangeable nozzles/tips of different sizes is available to produce smaller bigger flames. (Fig 9)



The size of the nozzle varies according to the thickness of the plates to be welded. (Table)

TABLE 1

plate thickness	Nozzle size
mm	Number
0.8	1
1.2	2
1.6	3
2.4	5
3.0	7
4.0	10
5.0	13
6.0	18
8.0	25
10.0	35
12.0	45
19.0	55
25.0	70
Over 25 .0	90

Gas welding hand tools

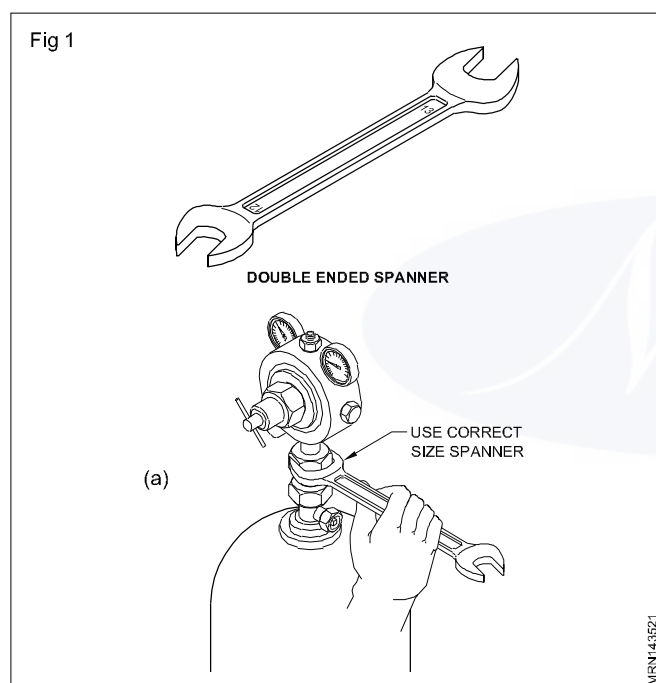
Objectives: At the end of this lesson you shall be able to

- identify and name the hand tools used by a welder
- state their uses
- state the care and maintenance to keep the hand tool in good working condition.

The following are the details of different hand tools used by a welder.

Double ended spanner: A double ended spanner is shown in Fig.1 and 1a. It is made of forged chrome vanadium steel. It is used to loosen or tighten nuts, bolts with hexagonal or square heads. The size of the spanner is marked on it as shown in Fig 1. In welding practice the spanners are used to fix the regulator onto the gas cylinder valves, hose connector and protector to the regulator and blow pipe, fix the cable lugs to the arc welding machine output terminals, etc.

Do not use any size of hammer, use the correct size of spanner to avoid damage to the nut/bolt head.



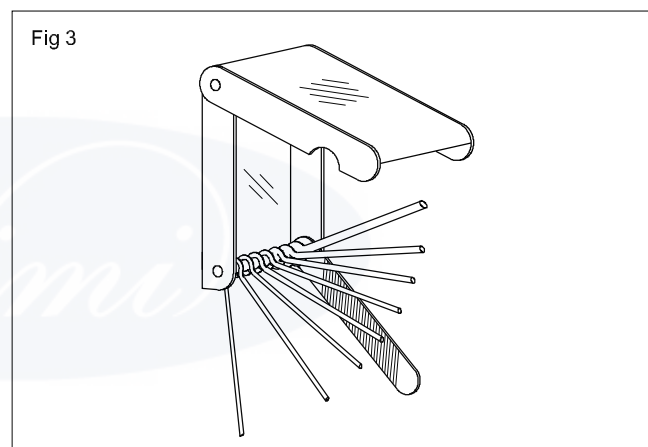
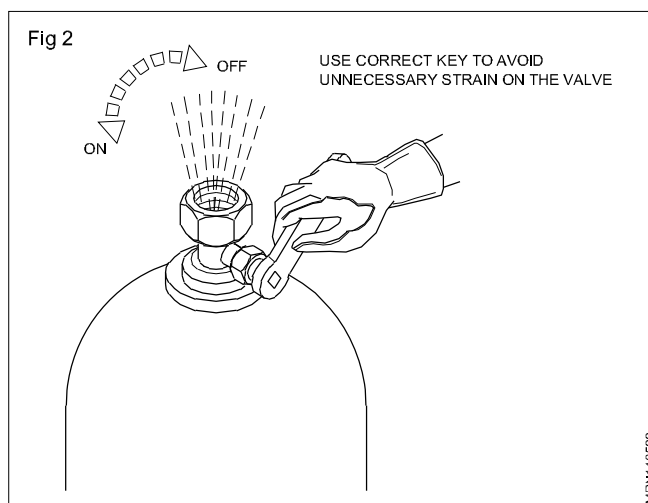
Cylinder Key: A cylinder key is shown in Fig.2. It is used to open or close the gas cylinder valve socket to permit or stop the gas flow from the cylinder to the regulator.

Always use correct size key to avoid damage to the square rod used to operate the valve. The key must always be left on the valve socket-itself so that the gas flow can be stopped immediately in case of flash back/back fire.

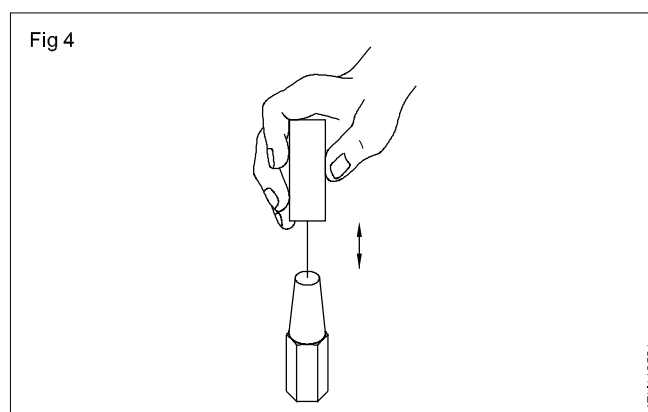
Nozzle or tip cleaner

Cleaning the tip: All welding torch tips are made of copper. They can be damaged by the slightest rough handling. Dropping, tapping or chopping with the tip on the work may damage the tip beyond repair.

Tip cleaner: A Special tip cleaner is supplied with the torch container. For each tip there is a kind of drill and a smooth file Fig.3.

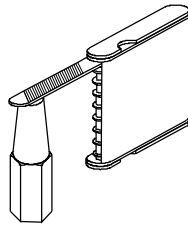


Before cleaning the tip, select the correct drill and move it, without turning, up and down through the tip Fig.4.



The smooth file is then used to clean the surface of the tip Fig.5. While cleaning, leave the oxygen valve partly open to blow out the dust.

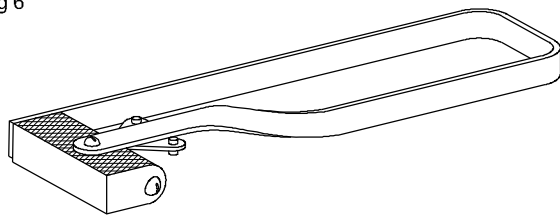
Fig 5



MRN143525

Spark lighter: The spark lighter, as illustrated in Fig.6 &7 is used for igniting the torch. While welding, form the habit of always employing a spark lighter to light a torch. Never use matches. The use of matches for this purpose is very dangerous because the puff of the flame produced by the ignition of the acetylene flowing from the tip is likely to burn your hand.

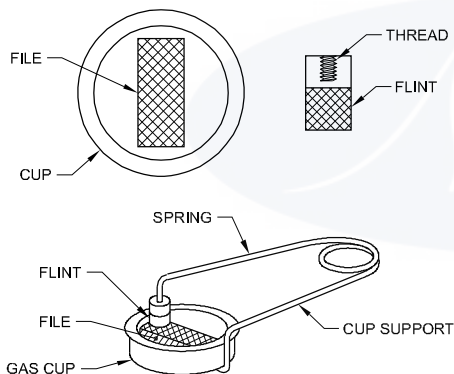
Fig 6



ALWAYS USE A SPARKLIGHTER TO LIGHT A TORCH

MRN143526

Fig 7

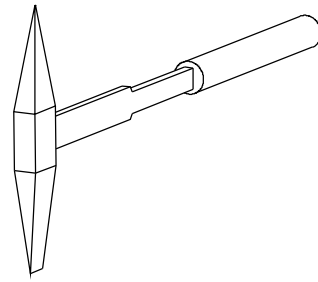


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Chipping hammer: The chipping hammer (Fig 8) is used to remove the slag which covers the deposited weld bead. It is made of medium carbon steel with a mild steel handle. It is provided with a chisel edge on one end and a point on the other end for chipping off slag in any position.

Care should be taken to maintain the sharp chisel edge and the point for effective chipping of slag.

Fig 8

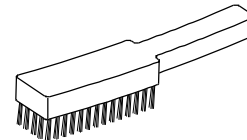


CHIPPING HAMMER

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Carbon steel wire brush: A carbon steel wire brush is shown in Fig.9. It is used for

Fig 9



WIRE BRUSH

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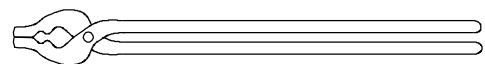
- Cleaning the work surface from rust, oxide and other dirt etc. prior to welding.
- Cleaning the interbead weld deposits after chipping off the slag
- General cleaning of the weldment.

A stainless steel wire brush is used for cleaning a non ferrous and stainless steel welded joint.

It is made of bunch of steel wires fitted in three to five rows on a wooden piece with handle. The wires are hardened and tempered for long life and to ensure good cleaning action.

Tongs: Fig.10 and Fig.11 show a pair of tongs used to hold hot work pieces and to hold the job in position.

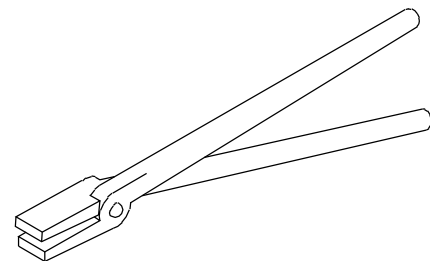
Fig 10



TONGS

MRN14352A

Fig 11



TONGS

MRN14352B

Various welding processes and their application

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

- **state and classify the electric welding processes**
 - **state and classify the gas welding processes**
 - **name and classify the other welding processes**
 - **state the applications of various welding processes.**
-

According to the sources of heat, welding processes can be broadly classified as:

- Electric welding processes (heat source is electricity)
- Gas welding processes (heat source is gas flame)
- Other welding processes (heat source is neither electricity nor gas flame)

Electric welding processes can be classified as:-

- Electric arc welding
- Electric resistance welding
- Laser welding
- Electron beam welding
- induction welding

Electric arc welding can be further classified as:

- Shielded Metal Arc Welding/Manual Metal Arc Welding
- Carbon arc welding
- Atomic hydrogen arc welding
- Gas Tungsten Arc Welding / TIG Welding
- Gas Metal Arc Welding / MIG/MAG Welding
- Flux cored arc welding
- Submerged arc welding
- Electro-slag welding
- Plasma arc welding

Electric resistance welding can be further classified as:

- Spot welding
- Seam welding
- Butt welding
- Blash butt welding
- Projection welding.

Gas welding processes can be classified as:

- Oxy-acetylene gas welding
- Oxy-hydrogen gas welding
- Oxy-coal gas welding
- Oxy-liquified petroleum gas welding
- Air acetylene gas welding.

The other welding processes are:

- Thermit welding
- Forge welding
- Friction welding
- Ultrasonic welding
- Explosive welding
- Cold pressure welding
- Plastic welding.

Code	Welding process
AAW	Air Acetylene
AHW	Atomic Hydrogen
BMAW	Bare Metal Arc
CAW	Carbon Arc
EBW	Electron Beam
EGW	Electro Gas
ESM	Electroslag
FCAW	Flux Cored Arc
FW	Flash
FLOW	Flow
GMAW	Gas Metal Arc
GTAW	Gas Tungsten Arc
IW	Induction
LBW	Laser Beam
OAW	Oxy-Acetylene
OHW	Oxy-Hydrogen
PAW	Plasma Arc
PGW	Pressure Gas
RPW	Resistance Projection
RSEW	Resistance Seam
RSW	Resistance Spot
SAW	Submerged Arc
SMAW	Shielded Metal Arc
SW	Stud Arc
TW	Thermit
UW	Ultrasonic

Applications of Various welding processes

Forge welding: It is used in olden days for joining metals as a lap and butt joint.

Shielded Metal arc welding is used for welding all ferrous and non-ferrous metals using consumable stick electrodes,

Carbon arc welding is used for welding all ferrous and non-ferrous metals using carbon electrodes and separate filler metal. But this is a slow welding process and so not used now-a-days.

Submerged arc welding is used for welding ferrous metals, thicker plates and for more production.

Co₂ Welding (Gas Metal Arc Welding) is used for welding ferrous metals using continuously fed filler wire and shielding the weld metal and the arc by carbon-dioxide gas.

TIG welding (Gas Tungsten Arc Welding) Is used for welding ferrous metals, stainless steel, aluminium and thin sheet metal welding.

Atomic hydrogen welding is used for welding all ferrous and non-ferrous metals and the arc has a higher temperature than other arc welding processes.

Electroslag welding is used for welding very thick steel plates in one pass using the resistance property of the flux material.

Plasma arc welding: The arc has a very deep penetrating ability into the metals welded and also the fusion is taking place in a very narrow zone of the joint.

Spot welding is used for welding thin sheet metal as a lap joint in small spots by using the resistance property of the metals being welded.

Seam welding is used for welding thin sheets similar to spot welding. But the adjacent weld spots will be overlapping each other to get a continuous weld seam.

Projection welding is used to weld two plates one over the other on their surfaces instead of the edges by making projection on one plate and pressing it over the other flat surface. Each projection acts as a spot weld during welding.

Butt welding is used to join the ends of two heavy section rods/blocks together to lengthen it using the resistance property of the rods under contact.

Flash butt welding is used to join heavy sections of rods/blocks similar to butt welding except that arc flashes are produced at the joining ends to melt them before applying heavy pressure to join them.

Oxy-acetylene welding is used to join different ferrous and non ferrous metals, generally of 3mm thickness and below.

Oxy-other fuel gases welding: Fuel gases like hydrogen, coal gas, liquified petroleum gas (LPG) are used along with oxygen to get a flame and melt the base metal and filler rod. Since the temperature of these flames are lower than the oxy-acetylene flame, these welding are used to weld metals where less heat input is required.

Air-acetylene gas welding is used for soldering, heating the job etc.

Induction welding is used to weld parts that are heated by electrical induction coils like brazing of tool tips to the shank, joining flat rings, etc.

Thermit welding is used for joining thick, heavy, irregularly shaped rods, like rails, etc using chemical heating process.

Friction welding is used to join the ends of large diameter shafts, etc by generating the required heat using the friction between their ends in contact with each other by rotating one rod against the other rod.

Welding terms & Its definition

- 1 **Butt Weld:** joining of two pieces placed in 180° (surface level) & the welding performed is called as Butt weld.
- 2 **Fillet weld:** joining of two pieces placed in 90° (surface level / one surface & another edge surface/both edge surface) & the welding performed is called as fillet weld.
- 3 **Weld reinforcement:** the material which is above the place surface/mitter surface is called as weld reinforcement.
- 4 **Miter line:** the straight line which is bisecting two toe points is known as miter line.
- 5 **Toe of weld:** the point at which the weld reinforcement is resting on base metal surface is known as toe point.
- 6 **Toe Line:** the line on which the weld reinforcement is resting on base metal surface.
- 7 **Concave bead:** the weld metal below the miter line is known as concave bead.
- 8 **Convex bead:** the weld metal above the miter line is known as convex bead.
- 9 **Miter bead:** If the weld bead is up to the level of miter line it is known as miter bead.
- 10 **Gas welding torch:** A device which is used for mixing, carrying, flow control and flame igniting of gases is known as gas welding torch.
- 11 **Gas cutting torch;** A device which is used for mixing, carrying, flow control and flame igniting of gases is known as gas cutting torch.
- 12 **Gas pressure regulator:** A device which monitors content of gas pressure in cylinder and regulates drawing/working gas pressure.
- 13 **Gas Rubber hose pipe:** A rubber hose which carries gases from gas pressure regulators and supplies to gas welding/cutting torches.

- 14 BACK fire:** If gas flame is snapped out due to wrong gas pressure setting is known as back fire.
- 15 Flash back:** When the gas flame is snapped out and starts reverse burning towards cylinder with hissing sound which is very hazardous is known as flash back,
- 16 Flash back arrestor:** Sometimes during backfire, the flame goes off and the burning acetylene gas travels backward in the blowpipe, towards the regulator or cylinder. At the time in between the device which has to be arrested the backfire.
- 17 Electrode holder:** A device by which electricity provided by cable will be carried to the electrode and which holds the electrode in desired angles. (This device is available with different capacities and type i.e. 300 Amps, 400 Amps and 600 Amps partly, semi and fully insulated).
- 18 Earth clamp:** A device by which electricity will carry provided by cable will be carried to the job table. (This device is available with different capacities and type i.e. 300 Amps, 400 Amps and 600 Ams. It is prepared by brass casting, G.I. Coated in spring or fixed form.
- 19 Arc welding cable:** This is made of copper/aluminium

strands to carry electricity from welding machine to electrode holder and earth cable.

- 20 Cable Lug:** This is available with different capacities and type i.e. 300Amps, 400Amps and 600Amps. This is preferably made of copper metal.
- 21 SMAW:** Shielded Metal Arc Welding. Also known as manual metal arc welding and stick welding. (In this process the electrode is consumable).
- 22 GMAW:** Gas Metal Arc welding covers CO2 welding (MAG), metal inter gas arc welding (MIG) & flux cored arc welding. (In these processes the electrode is consumable).
- 23 GTAW:** Gas Tungsten Arc welding. (In this process the electrode is consumable).
- 24 FCAW:** Flux cored Arc welding. Flux cored arc welding. (In the process the electrode is consumable).
- 25 Electrode (Flux coated)** A metal stick which is coated with flux and having parts indicated as stub end, tip, bare/core wire and flux coating. The size of this is determined by size of bare/core wire diameter. (This is used in shielded Metal Arc welding as consumable material).

Safety rules for gas cylinders

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

- state various improper practices, while working in gas cylinders
- state different precautions to be taken for the gas cylinders.

oxy - acetylene equipment is safe if it is properly handled. but it may become a great destructive power if handled carelessly. It is important that the operator be familiar with all the safety rules before handling gas cylinders.

Keep the cylinders free of oil, grease or any type of lubrication.

Check leakage before use.

Open cylinder valves slowly.

Never fall or trip over gas cylinders.

A valve broken in the oxygen cylinder will cause it to become a rocket with tremendous force.

keep the gas cylinders away from exposure to high temperature.

Remember the pressure in the gas cylinders increases with the temperature.

Store full and empty gas cylinders separately in a well ventilated place.

Mark the empty cylinders (MT/EMPTY) with chalk.

If a cylinder leaks due to defective valve or safety plug, do not try to repair it yourself, but move it to a safe area with

a tag to indicate the fault and then inform the supplier to pick it up.

When the cylinders are not in use or they are being moved, at on the valve protection caps.

Cylinders should always be kept in upright position and properly chained when in use.

Close the cylinder valves both when the gases are full or empty.

Never remove the valves protection cap while lifting cylinders.

Avoid exposing the cylinders to furnace heat, open fire or sparks from the torch.

Never move a cylinder by dragging, sliding or rolling it on its sides.

Never apply undue force to open or close a cylinder valve.

Avoid the use of hammer or wrench.

Always use a proper cylinder (or spindle) key to open or close the cylinder valves.

Do not remove the cylinder key from the cylinder valve when it is in use. It may be needed immediately to close the gas in case of emergency.

Smoking or naked lights should be strictly prohibited near gas cylinders.

Never strike an arc or direct gas flame on a gas cylinder.

Safety procedure for handling an internally fired dissolved acetylene (D A) cylinder.

In the case of severe backfire or flashback the DA cylinder may catch fire.

Close the blowpipe valve immediately (oxygen first).

No damage will occur to the cylinder if the backfire is arrested at the blowpipe.

The signs of severe backfire or flashback are:

- a squeezing or hissing noise in the blowpipe
- a heavy black smoke and sparks coming out of the nozzle
- over heating of the blowpipe handle.

To control this:

- Close the cylinder valves
- Disconnect the regulator from the cylinder valve
- Check the hoses and blowpipe before re-use.

If the cylinder catch fire externally due to the leakage of gas at the connection:

- Close the cylinder valve immediately (wearing asbestos gloves as a safety measure)
- Use carbon dioxide fire extinguisher to extinguish the fire
- rectify the leakage thoroughly before putting into further use.

If the cylinder becomes overheated due to internal or external fire:

- close the cylinder valve
- detach the regulator from the cylinder
- remove the cylinder to an open space, away from smoking or naked light
- cool the cylinder by spraying with water
- inform the gas cylinder supplier immediately.

Never keep such defective cylinders with the other cylinders.



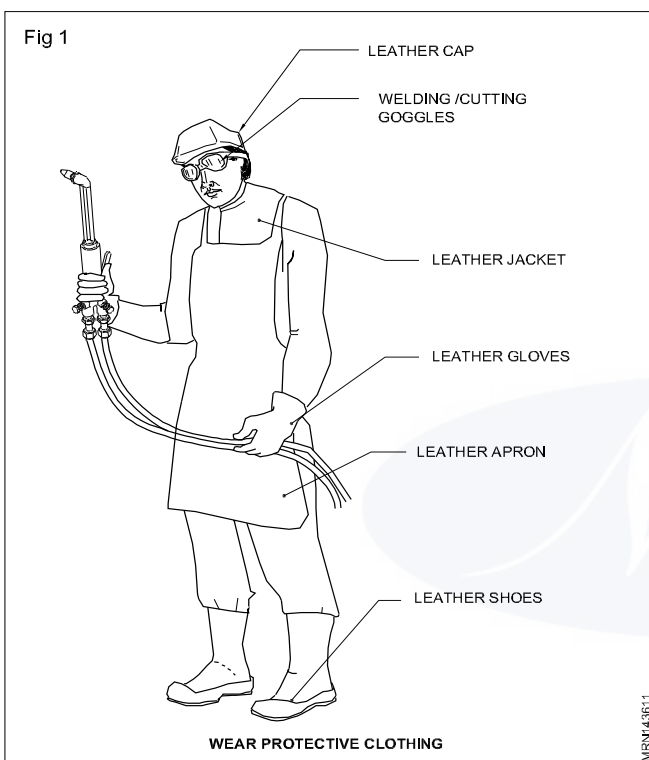
Safety in gas cutting process

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

- describe the safety precautions to be followed by handling gas cutting equipment
- explain the safety precautions to be followed by the operator
- state the safety required during gas cutting operation.

Equipment safety: Safety precautions for gas cutting equipment are the same as those adopted in the case of gas welding equipment.

safety for the operator (Fig 1)



Always use safety apparel

Goggles, gloves and other protective clothing must be worn.

Safety during operation: Keep the work area free from flammable materials.

Ensure that the combustible material is at least 3 meters away from the cutting operation area.

In case the flammable material is difficult to remove, suitable fire resisting guards/partitions must be provided.

- protection of your eyes
- protection from burns
- protection of clothing
- protection of inhaling burnt gases.

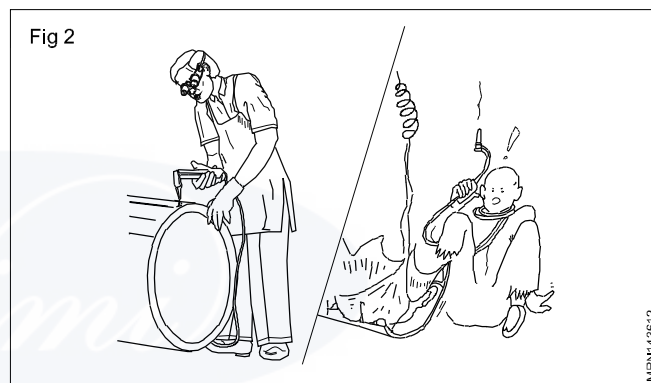
protect yourself and others from the flying sparks.

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

Keep the space clear underneath the cutting job so as to allow the slag to run freely, and the cutting parts to fall safely.

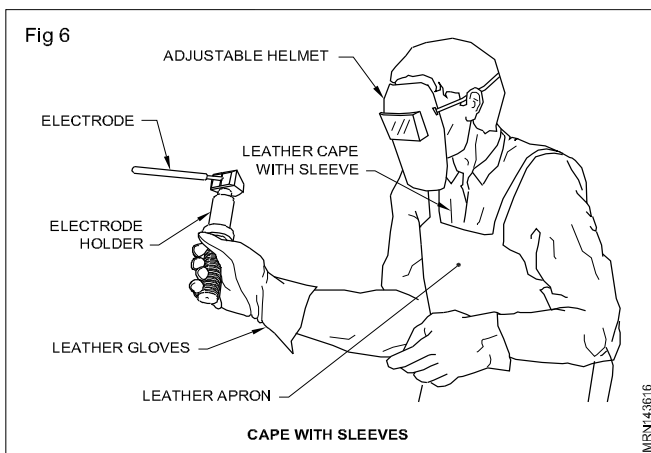
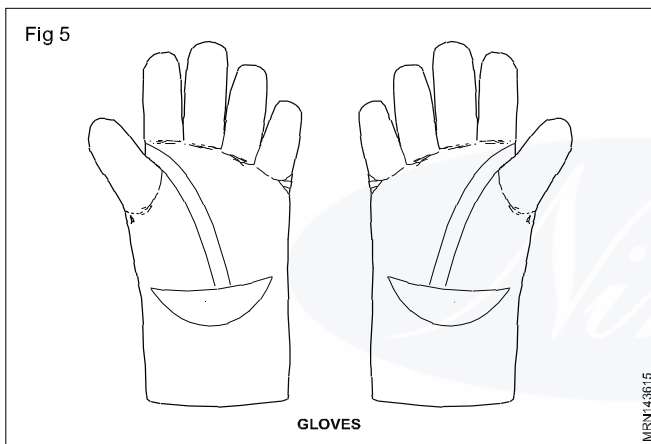
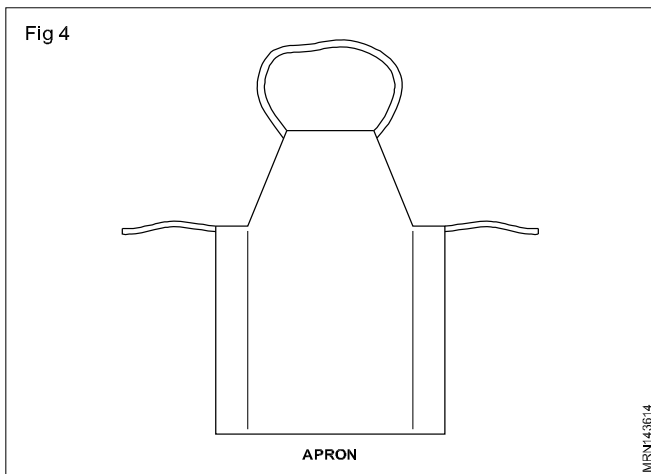
Be careful about flying hot metal and sparks while starting a cut. Containers which hold combustible substance should not be taken directly for cutting or welding. (Fig 2) Wash the containers with carbon tetrachloride and caustic soda before welding or cutting and fill them with water before repairing. (Fig 3)

Keep fire-fighting equipment handy and ready.



1 Safety apparels

- Leather apron (Fig 4)
- Leather gloves (Fig 5)
- Leather cape with sleeves (Fig 6)
- Industrial safety shoes

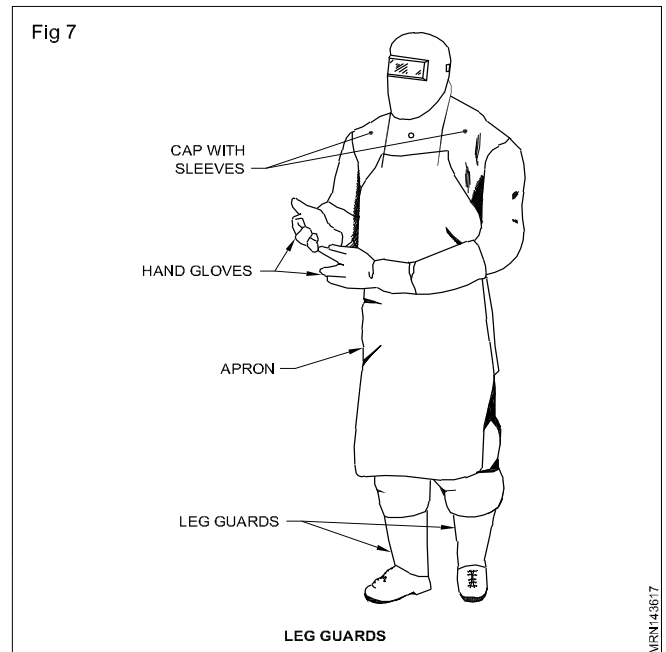


- Hand screen
 - Adjustable helmet
 - Portable fire proof canvas screens
- Chipping/grinding goggles
- Respirator and exhaust ducting

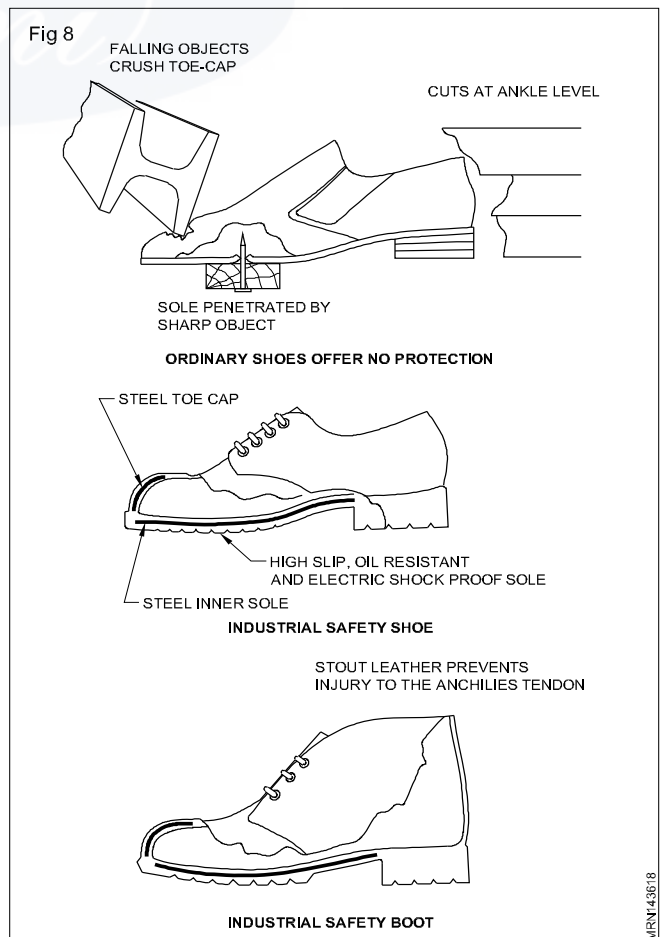
The leather apron, gloves, cape with sleeves and leg guard Fig 4,5,6 and 7 are used to protect the body, hands, arms,

neck & chest of the welder from the heat radiation and hot spatters from the arc & also from the hot slag particles flying from the weld joint during chipping off the solidified slag.

All the above safety apparels should not be loose while wearing them & suitable size has to be selected by the welder.

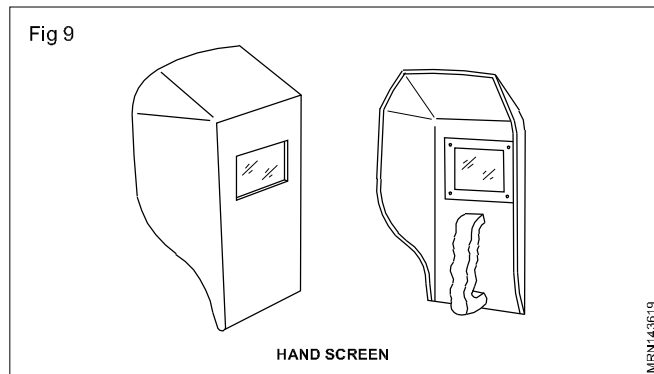


The industrial safety boot (Fig 8) is used to avoid slipping injury to the toes and ankle to the foot. It also protects the welder from the electric shock as the sole of the shoe is specially made of shock resistant material.

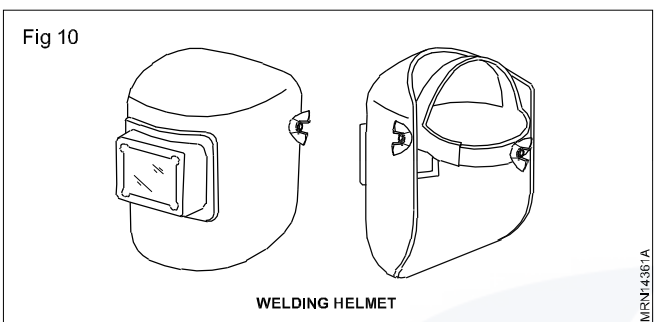


Welding hand screens and helmet: These are used to protect the eyes and face of a welder from arc radiation and sparks during arc welding.

A hand screen is designed to hold in hand. (Fig 9)

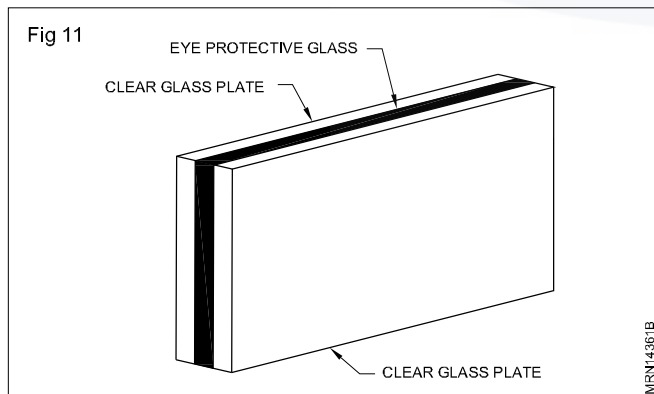


A helmet screen is designed to wear on the head. (Fig 10)



Clear glasses are fitted on each side of the coloured glass to protect it from weld spatters. (Fig 11)

The helmet screen provides better protection and allows the welder to use his both hands freely.



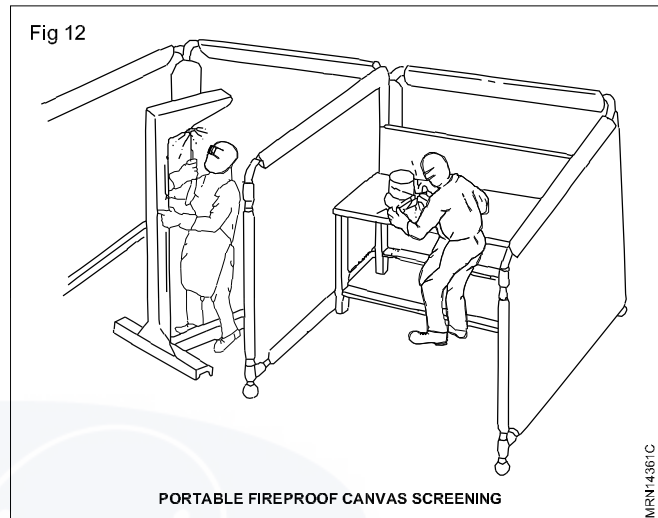
Coloured (filter) glasses are made in various shades depending on the welding current ranges. (Table1)

Table 1

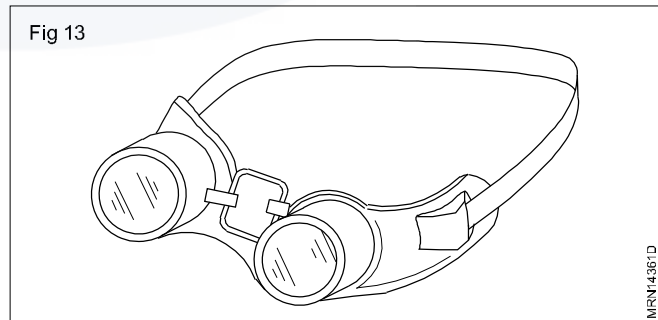
Recommendations of filter glasses for manual metal arc welding

Shade No. of coloured glass	Range of welding current in amperes
8-9	Up to 100
10-11	100 to 300
12-14	Above 300

Portable fire proof canvas screens Fig 12 are used to protect the persons who work near the welding area from arc flashes.



Plain goggles are used to protect the eyes while chipping the slag or grinding the job. Fig. 13



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

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

Gases used for welding and gas flame combinations

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

- name the different types of gases used for welding
- compare the different types of gas flame combinations
- state the temperatures and uses of the different gas flame combinations.

In the gas welding process, the welding heat is obtained from the combustion of fuel gases in the presence of a supporter of combustion (oxygen).

(Oxy-acetylene gas flame combination is used in most gas welding processes because of the high temperature and heat intensity.)

Comparison of different gas flame combinations and their uses

Sl. No	Fuel gas	Supporter of combustion	Name of the gas flame	Temperature	Application/uses
1	Acetylene	Oxygen	Oxy-acetylene flame	3100 to 3300°C (Highest temperature)	To weld all ferrous and non-ferrous metals and their alloys; gas cutting & gouging of steel; brazing bronze welding; metal spraying and hard facing.
2	Hydrogen	Oxygen	Oxy-hydrogen flame	2400 to 2700°C (Medium temperature)	Only used for brazing, silver soldering and underwater gas cutting of steel.
3	Coal gas	Oxygen	Oxy-coal gas flame	1800 to 2200°C (Low temperature)	Used for silver soldering underwater gas cutting of steel.
4	Liquid petroleum gas (LPG)	Oxygen	Oxy-liquid petroleum gas flame	2700 to 2800°C (Medium temperature)	Used for gas cutting steel heating purposes. (Has moisture and carbon effect in the flame.)
5	Acetylene	Air	Air-acetylene flame	1825 to 1875°C (Low temperature)	Used only for soldering, brazing, heating Purposes and lead burning.

Chemistry of oxy-acetylene flame

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

- identify the features and illustrate the different zones of an oxy-acetylene flame with their corresponding temperatures
- explain the chemical reaction between oxygen and acetylene during primary and secondary combustion in the flame.

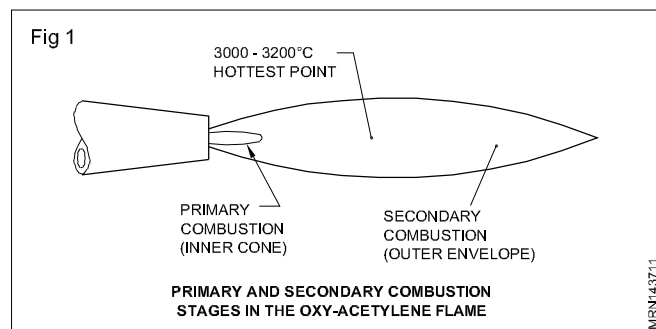
Oxy-acetylene flame is produced by the combustion of a mixture of oxygen and acetylene in various proportions. The temperature and characteristics of the flame depend on the ratio of the two gases in the mixture.

To know the characteristics and effects of oxy-acetylene flame a welder must know the chemistry of the flame.

Features of neutral flame: Oxy-acetylene flame consists of the following features by appearance.

- Inner cone
- inner reducing zone
- Outer zone or envelope (Fig 1)

Different zones and temperature: To know and make the best use of oxy-acetylene flame, the temperature in different zones is shown in Fig 1.



The greatest amount of heat is produced at just ahead of the inner cone called the hottest point or region of maximum temperature.

Combustion ratio of oxygen and acetylene in flame

For complete combustion/burning one volume of acetylene requires two and a half volumes of oxygen.

Acetylene	:	Oxygen + O
1 litre	:	2.5 litres

Equal volumes of acetylene and oxygen are supplied from the blowpipe to produce a neutral flame. (Fig 1)

Acetylene	:	Oxygen
1 litre	:	1 litre

(primary combustion)

So another 1.5 litres of oxygen is required for complete burning of acetylene.

The flame takes an additional 1.5 litres of oxygen from the surrounding atmosphere. (Secondary combustion) (Fig 1)

Chemical reaction: 1 volume of acetylene combines with 2 1/2 volumes of oxygen and burns to form 2 volumes of carbon dioxide and 1 volume of water vapour plus heat.

Types of oxy - acetylene flames

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

- name the different types of oxy-acetylene flames
- state the characteristics of each type of flame
- explain the uses of each type of flame.

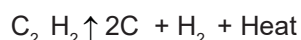
The oxy-acetylene gas flame is used for gas welding because

- it has a well controlled flame with high temperature
- the flame can be easily manipulated for proper melting of the base metal
- it does not change the chemical composition of the base metal /weld.

Three different types of oxy-acetylene flames as given below can be set.

Primary combustion: It takes place in the inner cone right in the tip of the nozzle. (Fig 1)

In the bright nucleus:



In the inner cone - first burning stage:

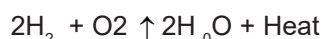
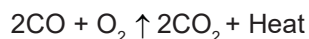


CO and H₂ have reducing effect (no oxides are forming) Maximum heat (Hottest point) is just in front of the inner cone.

One volume of oxygen combines with one volume of acetylene (delivered through the torch) and burns to form. Two volume of carbon monoxide and one volume of hydrogen plus heat.

Secondary combustion: It takes place in the outer envelope of the flame.

In the outer envelope - secondary burning



Combustion in air (Fig 1): Two volumes of carbon monoxide and 1 volume of hydrogen (Product of primary combustion) combine with 1.5 volume of oxygen from the surrounding air and burn to form. two volumes of carbon dioxide and 1 volume of water vapour.

The product of primary combustion is further burnt in the reducing zone.

The region surrounding the inner cone and its tip is called reducing zone

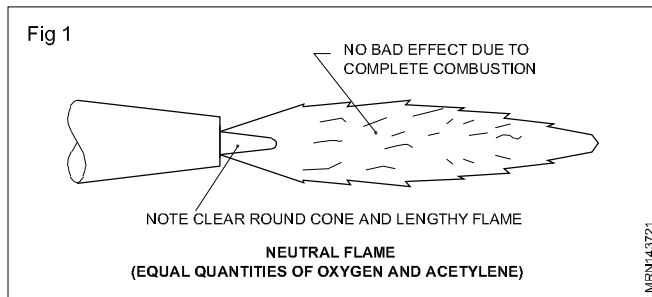
The reducing zone protects the molten metal from atmospheric effects as it uses the atmospheric oxygen for secondary combustion.

- Neutral flame
- Oxidising flame
- Carburising flame.

Characteristics and uses

Neutral flame (Fig 1): Oxygen and acetylene are mixed in equal proportion in the blowpipe.

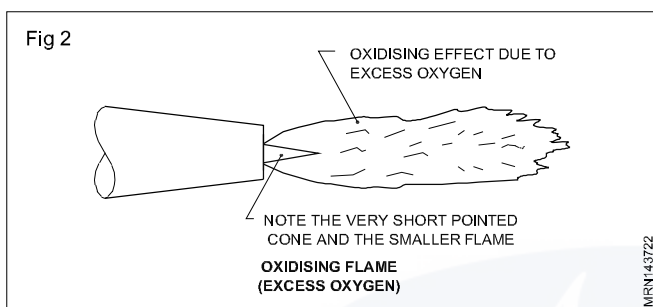
Complete combustion takes place in this flame.



This flame does not have a bad effect on the base metal/ weld i.e. the metal is not oxidised and no carbon is available for reacting with the metal.

Uses: It is used to weld most of the common metals, i.e. mild steel, cast iron, stainless steel, copper and aluminium.

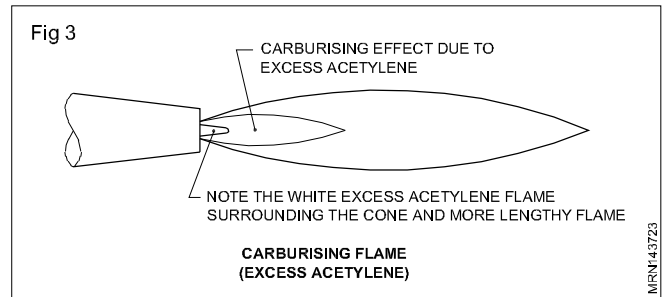
Oxidising flame (Fig 2): It contains excess of oxygen over acetylene as the gases come out of the nozzle.



The flame has an oxidising effect on metals which prevents evaporation of zinc/tin in brass welding/brazing.

Uses: Useful for welding of brass and for brazing of ferrous metals.

Carburising flame (Fig 3): It receives an excess of acetylene over oxygen from the blowpipe.



Uses : Useful for stellite (hard facing), 'Linde' welding of steel pipes, and flame cleaning.

The selection of the flame is based on the metal to be welded

The neutral flame is the most commonly used flame. (See the chart given below.)

Metal	Flame
1 Mild steel	Neutral
2 Copper (de-oxidised)	Neutral
3 Brass	Oxidising
4 Cast iron	Neutral
5 Stainless steel	Neutral
6 Aluminium (Pure)	Neutral
7 Stellite	Carburising

Oxy-acetylene cutting equipment

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

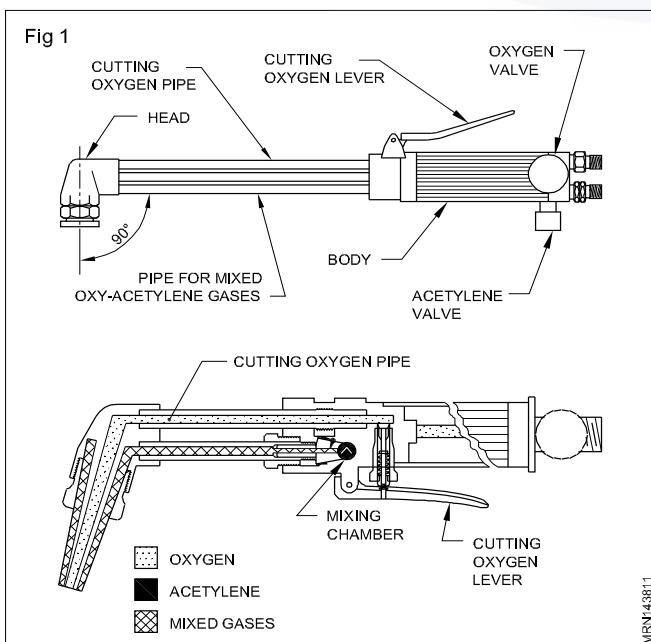
- explain the features of the oxy-acetylene cutting equipment, its parts and cutting torch
- describe the oxy-acetylene cutting procedure
- differentiate between cutting and welding blowpipes.

Cutting equipment: The oxy-acetylene cutting equipment is similar to the welding equipment, except that instead of using a welding blowpipe, a cutting blowpipe is used. The cutting equipment consists of the following.

- Acetylene gas cylinder
- Oxygen gas cylinder
- Acetylene gas regulator
- Oxygen gas regulator (Heavy cutting requires higher pressure oxygen regulator.)
- Rubber hose-pipes for acetylene and oxygen
- Cutting blowpipe

(Cutting accessories i.e. cylinder key, spark lighter, cylinder trolley and other safety appliances are the same as are used for gas welding.)

The cutting torch (Fig 1): The cutting torch differs from the regular welding blowpipe in most cases: it has an additional lever for the control of the cutting oxygen used to cut the metal. The torch has the oxygen and acetylene control valves to control the oxygen and acetylene gases while preheating the metal.

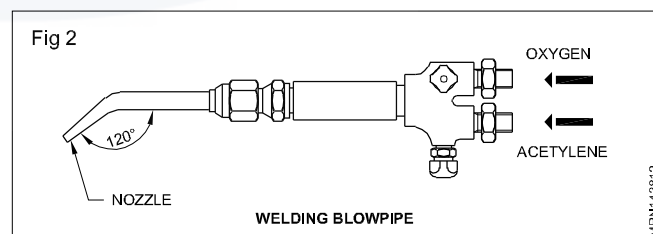


The cutting tip is made with an orifice in the centre surrounded by five smaller holes. The centre opening permits the flow of the cutting oxygen and the smaller holes are for the preheating flame. Usually different tip sizes are provided for cutting metals of different thicknesses.

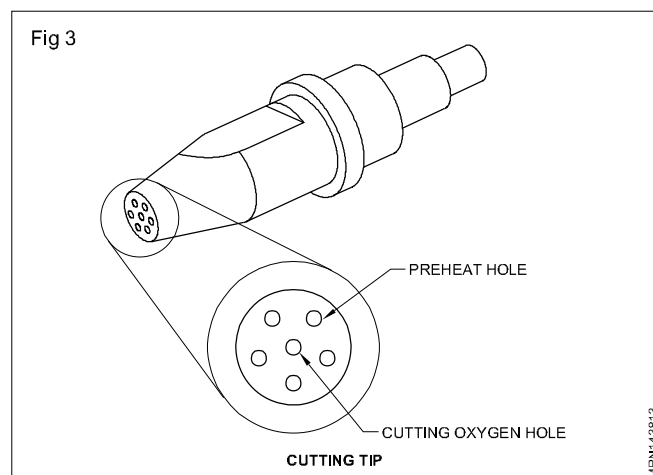
Oxy-acetylene cutting procedure: Fix a suitable size cutting nozzle in the cutting blowpipe. Ignite the cutting torch the same way as was done in the case of the welding blowpipe. Set the neutral flame for preheating. To start the cut, hold the cutting nozzle at angle 90° with the plate surface, and the inner cone of the heating flame 3 mm above the metal. Preheat the metal to bright red before pressing the cutting oxygen lever. If the cut is proceeding correctly, a shower of sparks will be seen to fall from the punched line. If the edge of the cut appears to be too ragged, the torch is being moved too slowly. For a bevel cut, hold the cutting torch at the desired angle and proceed as is done in making a straight line cut. At the end of the cut, release the cutting oxygen lever and close the control valves of the oxygen and acetylene. Clean the cut and inspect.

Difference between cutting blowpipe and welding blowpipe: A cutting blowpipe has two control valves (oxygen and acetylene) to control the preheating flame and one lever type control valve to control the high pressure for oxygen for making the cut.

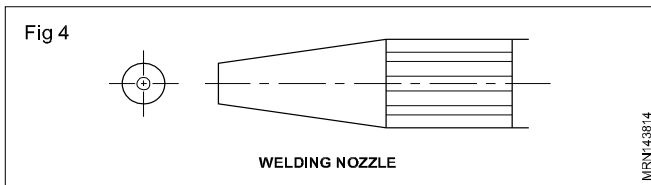
A welding blowpipe has only two control valves to control the heating flame (Fig 2).



The nozzle of the cutting blowpipe has one hole in the center for cutting oxygen and a number of holes around the circle for the preheating flame. (Fig 3)



The nozzle of the welding blowpipe has only one hole in the center for the heating flame. (Fig 4)



The angle of the cutting nozzle with the body is 90°

The angle of the welding nozzle with the neck is 120°

The cutting nozzle size is given by the diameter of the cutting oxygen orifice in mm.

The welding nozzle size is given by the volume of oxy-acetylene mixed gas coming out of the nozzle in cubic meter per hour.

Operating data for cutting mild steel

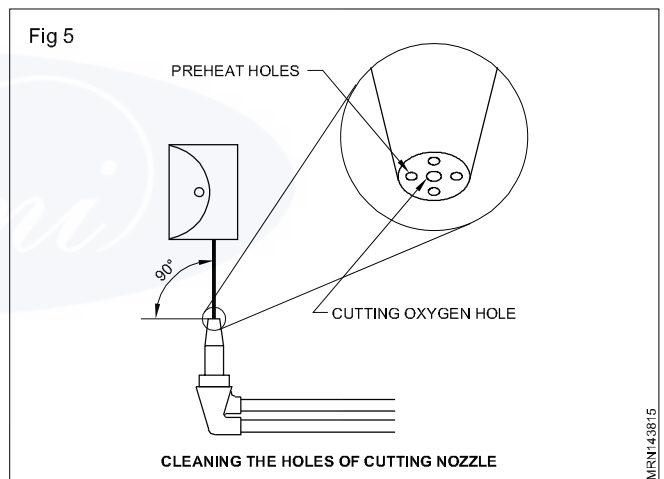
Cutting nozzle size-mm	Thickness of plate (mm)	Cutting oxygen Pressure kgf/cm ²
0.8	3-6	1.0 - 1.4
1.2	6-9	1.4 - 2.1
1.6	19-100	2.1 - 4.2
2.0	100-150	4.2 - 4.6
2.4	150-200	4.6 - 4.9
2.8	200-250	4.9 - 5.5
3.2	250-300	5.5 - 5.6

However, the oxidation of metals has also certain useful effects, i.e a stream of pure oxygen if applied (used) on a red hot mild steel plate through a nozzle, the plate will get cut into 2 pieces. Hence the principle of oxidation is effectively used in gas cutting and gouging of mild steel.

Care and maintenance: The high pressure cutting oxygen lever should be operated only for gas cutting purposes.

Care should be taken while fitting the nozzle with the torch to avoid wrong thread. Dip the torch after each cutting operation in water to cool the nozzle.

To remove any slag particles of dirt from the nozzle orifice use the correct size nozzle cleaner Fig.5. Use an emery paper if the nozzle tip is damaged to make it sharp and to be at 90° with the nozzle axis.



Acetylene gas - Properties

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

- **explain the composition and properties of acetylene and oxygen gas**
- **describe the method of producing oxygen by air liquefaction process and by electrolysis of water.**

Acetylene is a fuel gas, which produces a very high temperature flame with the help of oxygen, because it has more amount of carbon (92.3%) than any other fuel gas. The temperature of oxy-acetylene flame is 3100°C - 3300°C.

Composition of acetylene gas: Acetylene is composed of:

- carbon 92.3% (24 parts)
- hydrogen 7.7% (2 parts)

Its chemical symbol is C_2H_2 which shows that two atoms of carbon are combined with two atoms of hydrogen.

Properties of acetylene gas: It is a colourless gas, lighter than air. It has a specific gravity of 0.9056 as compared with air. It is highly inflammable and burns with a brilliant flame. It is slightly soluble in water and alcohol. Impure acetylene has pungent (garlic like) odour. It can be easily detected by its peculiar smell. Acetylene dissolves in acetone liquid.

Impure acetylene reacts with copper and forms an explosive compound called copper acetylene. therefore, copper should not be used for acetylene pipeline. Acetylene gas can cause suffocation if mixed 40% or more in air. Acetylene mixed with air becomes explosive on ignition. It is unstable and unsafe when compressed to high pressure i.e. its safe storage pressure in free state is fixed as 1 kg/cm². The normal temperature pressure (N.T.P) is 1.091 kg/cm². The normal temperature is 20°C and the normal pressure 760mm of mercury or 1 kg/cm². It can be dissolved in liquid acetone. at high pressure. One volume of liquid acetone can dissolve 25 volumes of acetylene under N.T.P. It can dissolve 25X15=375 volume of acetylene cylinder if it is dissolved with a pressure of 15kg/cm² pressure. In an acetylene cylinder it is dissolved acetylene. For complete combustion one volume unit of acetylene requires two and a half volume units of oxygen.

Flash back arrestor

Introduction: It is a safety device and fitted with carbide to water acetylene generator. It is made out of mild steel cylindrical body.

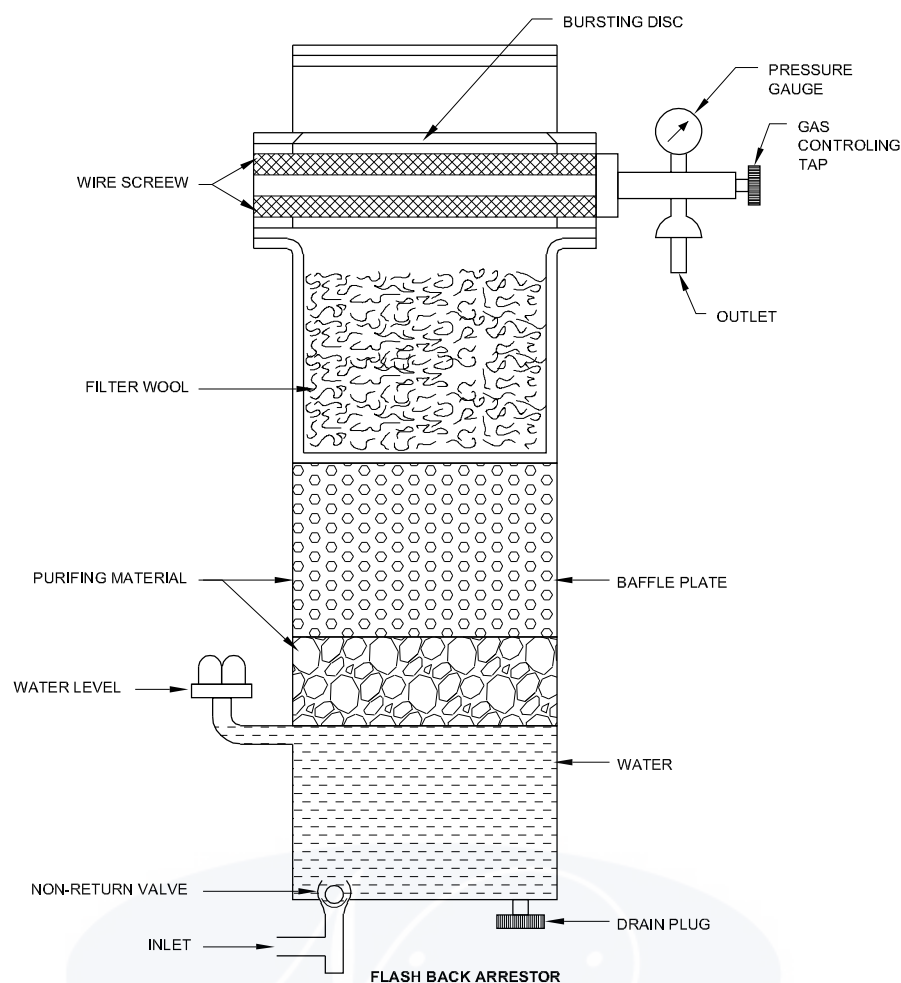
Parts: Flash back arrestor has the following parts

- 1 Inlet
- 2 Drain plug
- 3 Non-return valve
- 4 Water level
- 5 Water
- 6 Baffle plate
- 7 Purifying materials
- 8 Filter wool
- 9 Wire screen
- 10 Bursting disc
- 11 Pressure gauge
- 12 Gas controlling tap

Working principle in normal stage: The acetylene gas from the carbide to water acetylene generator enters through the inlet connection of the flash back arrestor and goes to water compartment through non, return space valve and baffle plate, filter wool. Baffle plate reduces the velocity of acetylene gas whereas the purifying materials purify the generated acetylene gas that goes to outlet through the regulator and gas controlling tap.

Accidental condition: Flash back from the blow pipe enters through the outlet connection in flashback arrestor and goes to the non-return valve through the filter wool, baffle plate and water. Flash back creates the pressure and pushes the water downwards when the ball of non-return valve comes down and closes the inlet acetylene gas with the help of the disc. With the result, no more gas enters inside the flash back arrestor. The acetylene gas which is already in the flash back arrestor burns due to this pressure, the bursting disc bursts remaining gas in the flash back arrestor. So the damages of flash back arrestor outside the water acetylene generator is prevented from the accident. Thereafter water and the carbon particle are taken out through the drain plug and fresh water is filled in the flash back arrestor for further use. (Fig 1)

Fig 1



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Oxygen gas - properties and production

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

- explain the composition and properties of oxygen gas
- describe the method of producing oxygen by air liquefaction process and by electrolysis of water.

Oxygen gas: Oxygen is a supporter of combustion. Its chemical symbol is O_2

Properties of oxygen gas

- Oxygen is colourless, odourless and tasteless gas,
- It has atomic weight of 16.
- Its specific gravity at $32^\circ F$ and at normal atmosphere pressure is 1.1053, as compared with air.
- It is slightly soluble in water.
- It does not burn itself. but readily supports combustion of fuels.

When compressed oxygen comes in contact with finely divided particles of combustible material (i.e., coal dust, mineral oil, grease) it will self-ignite them, leading to fire or explosion. Self-ignition in such cases may be initiated by the heat given up suddenly by compressed oxygen,

Oxygen becomes liquefied at a temperature of $-182.962^\circ C$ at normal atmospheric pressure.

Liquid oxygen has a pale blue colour.

Liquid oxygen becomes solid at $-218.4^\circ C$ at normal atmospheric pressure. It combines rapidly with most of the metals and forms oxide. i.e.,

Iron + oxygen = Iron oxide

Copper + oxygen = Cuprous oxide

Aluminium + oxygen = Aluminium oxide

The process of making oxide is called oxidation. Oxygen is found everywhere in nature, either in free state or in a combination with other elements. It is one of the chief constituents of atmosphere i.e., 21% oxygen 78% Nitrogen. Water is chemical compound of oxygen and hydrogen, in which approximately 89% is oxygen by weight and 1/3 by volume. One volume of liquid oxygen produces 860 volumes of oxygen gas. One kg of liquid oxygen produces 750 liters of gas. The weight of the container used to store liquid oxygen is several times less than the weight of cylinders required to store an equivalent quantity of gaseous oxygen.

Production of oxygen gas

Air liquefaction process: This method is based upon the idea of separating the various gases that constitute the air by liquefaction process.

This process is done in three stages.

- purification
- liquefaction
- Distillation

The composition of air and the boiling points of its components are given in Table 1.

Table 1
Composition of air

Name of component	Quantity by volume %	Boiling point °C
Nitrogen	78.0300	-195.80
Oxygen	20.9300	-182.96
Argon	00.9325	-185.70
Neon	00.0018	
Helium	00.0005	
Krypton	00.0001	
Xenon	00.000009	
Hydrogen	00.00005	
Carbon dioxide	00.030000	

Air is a mixture of roughly 78% nitrogen, 21% oxygen and 1% argon and other inert gases.

The basis of the separation of the elements in air by this method depends on the difference in the boiling point of the major elements.

Between nitrogen and oxygen - 13°C

Between nitrogen and argon - 10°C

Between oxygen and argon - 3°C

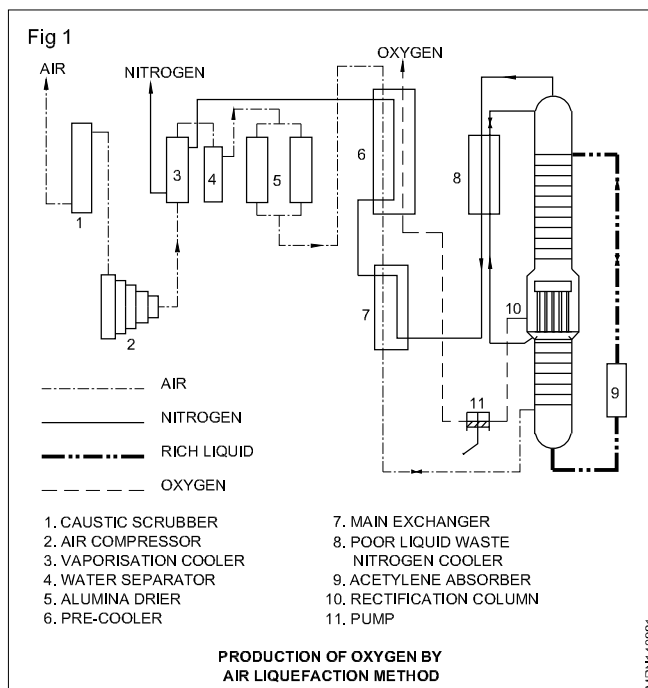
Steps for separating oxygen (Fig 1)

Purification: Air is drawn from the atmosphere into large containers called washing towers, where it is washed and purified of carbon dioxide dust particles by means of caustic soda solution. The washed air from the washing towers is compressed by a compressor to 150 atmospheric pressure and passed through oil purging cylinders and then through aluminium driers, which remove the remaining carbon dioxide and water vapours.

Liquefaction: The dry, clean, compressed air then goes into liquefaction columns, where it is cooled and then expanded to change into liquid form.

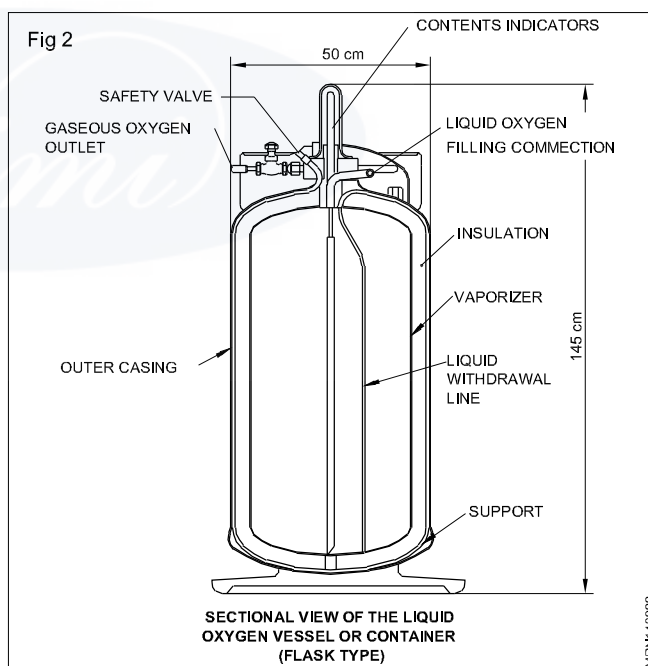
Distillation: The liquid air is then rectified in the CONDENSER column by increasing the temperature on the basis of difference in the boiling points of its elements.

Nitrogen having a lower boiling point (-195.8°C) evaporates first.



Argon having a boiling point (-185.70°C) evaporates second leaving liquid oxygen in the bottom of the condenser.

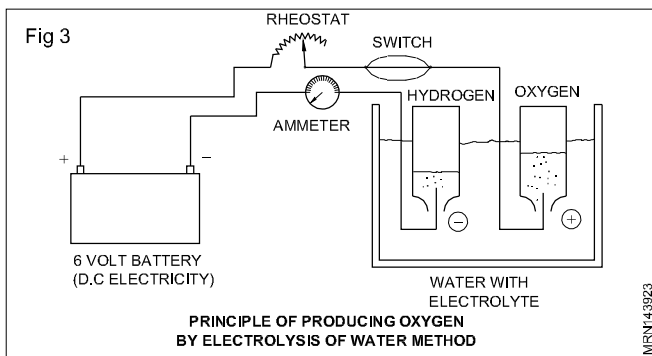
Liquid oxygen can be stored in liquid form as shown in the liquid oxygen container. (Fig 2)



The liquid oxygen next passes through a heated coil which changes the liquid into a gaseous form.

The gaseous oxygen goes into a storage tank from where it is drawn and compressed into oxygen gas cylinders.

Electrolysis of water (Fig 3): In this method, DC electricity is passed through water causing the water to separate into its elements which are oxygen and hydrogen oxygen will collect at the positive terminal and hydrogen at the negative.



Caustic soda is added to the water to make it a good electrolyte since pure water will not allow the current to pass.

This method produces two volumes of hydrogen and one volume of oxygen.

The cost of producing oxygen by this method is more the oxygen contains more moisture and it is difficult to obtain 99% purity and the process requires enormous quantity of water and electricity. So the air liquefaction method is more commonly used to produce commercial oxygen with a purity of 99.99%.



Oxygen gas cylinders

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

- identify different gas cylinders
- explain the constructional features of oxygen gas cylinder and the method of charging.

Definition of a gas cylinder: It is a steel container, used to store different gases at high pressure safely and in large quantity for welding or other industrial uses.

Types and identifications of gas cylinders: Gas cylinders are called by names of the gas they are holding. (Table 1)

Gas cylinders are identified by their body colour marks and valve threads. (Table 1)

Table 1
Identification of gas cylinders

Name of gas Cylinder	Colour coding	Valve threads
Oxygen	Black	Right hand
Acetylene	Maroon	Left hand
Coal	Red (With name coal gas)	Left hand
Hydrogen	Red	Left hand
Nitrogen	Grey (With black neck)	Right hand
Air	Grey	Right hand
Propane	RED (with larger diameter and name propane)	Left hand
Argon	Blue	Right hand
Carbon-di-Oxide	Black (With white neck)	Right hand

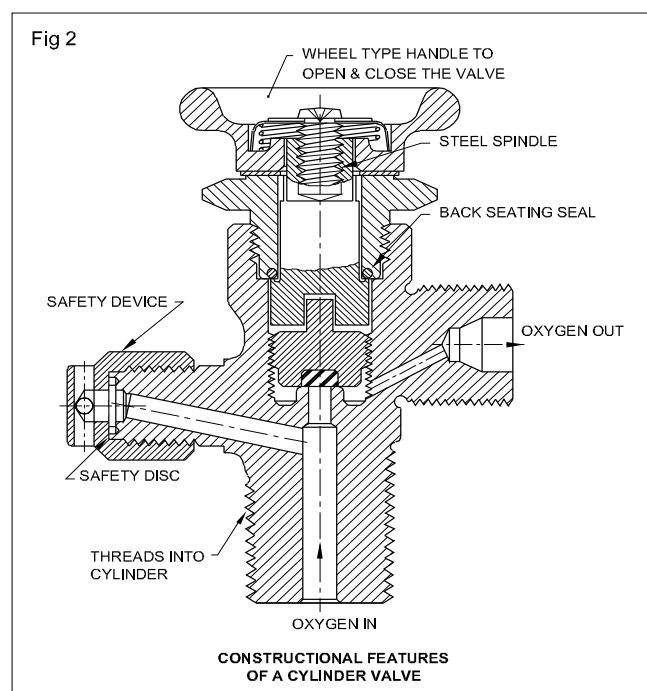
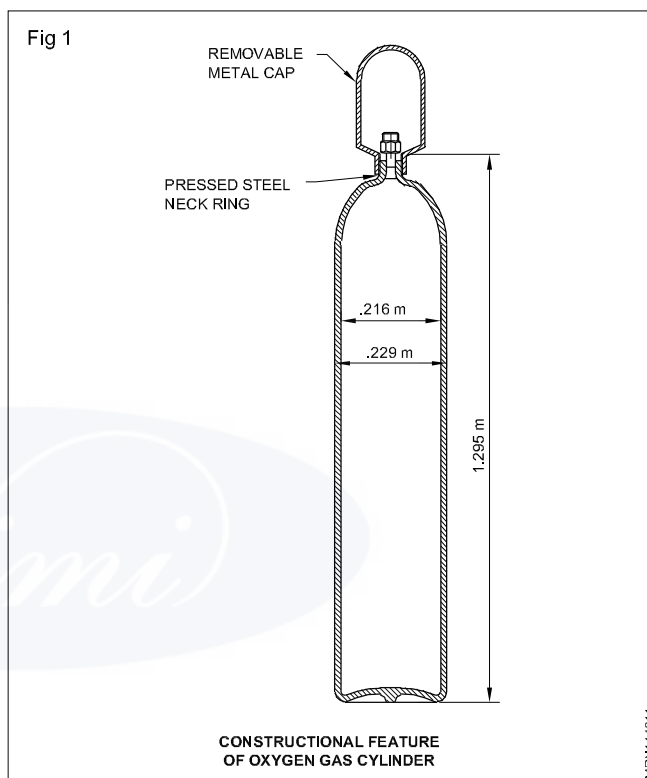
Oxygen gas cylinder: It is a seamless steel container used to store oxygen gas safely and in large quantity under a maximum pressure of 150 kg /cm², for use in gas welding and cutting.

Constructional features of oxygen gas cylinder (Fig1)

It is made from seamless solid drawn steel and tested with a water pressure of 225kg/cm². The cylinder top is fitted with a high pressure valve made from high quality forged bronze. (Fig 2)

The cylinder valve has a pressure safety device, which consists of a pressure disc, which will burst before the inside cylinder pressure becomes high enough to break the cylinder body. The cylinder valve outlet socket fitting has standard right hand threads, to which all pressure

regulators may be attached. The cylinder valve is also fitted with a steel spindle to operate the valve for opening and closing. A steel cap is screwed over the valve to protect it from damage during transportation. (Fig 1)



The cylinder body is painted black.

The capacity of the cylinder may be 3.5m^3 - 8.5m^3 .

Oxygen cylinders of 7m^3 capacity are commonly used.

Dissolved acetylene gas cylinder

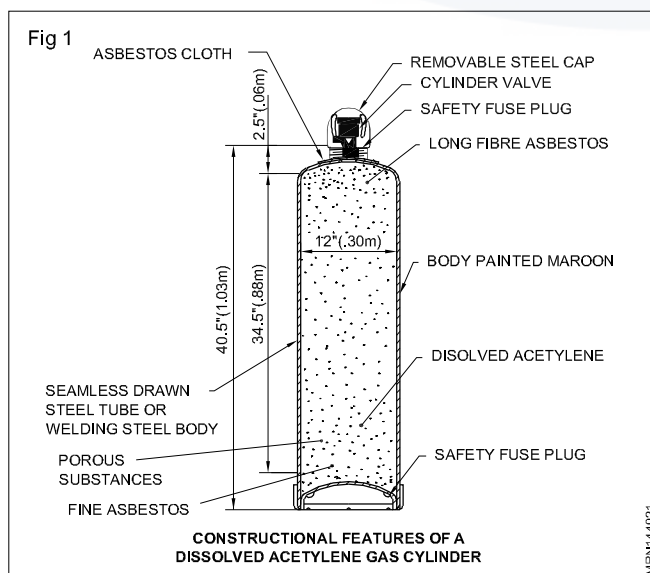
Objectives: At the end of this lesson you shall be able to

- describe the constructional features of the DA gas cylinder and the method of charging
- state the safety rules for handling gas cylinders
- explain the safe procedure to be followed in handling an internally fired DA cylinder.

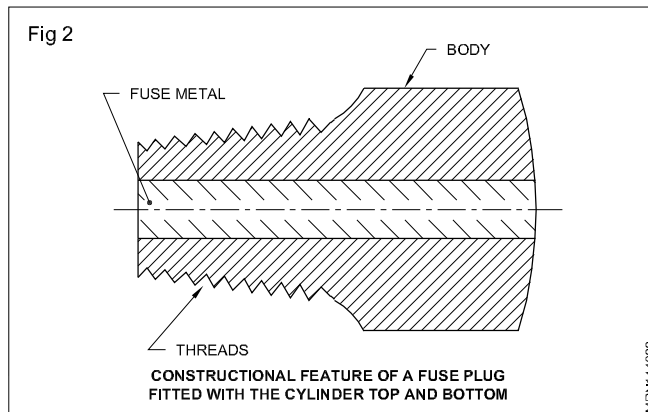
Charging of gas in oxygen cylinder: The oxygen cylinders are filled with oxygen gas under a pressure of $120\text{--}150\text{ kg/cm}^2$. The cylinders are tested regularly and periodically. They are annealed to relieve stresses caused during 'on the job' handling. They are periodically cleaned using caustic solution.

Definition: It is a steel container used to store high pressure acetylene gas safely in dissolved state for gas welding or cutting purpose.

Constructional features (Fig 1): The acetylene gas cylinder is made from seamless drawn steel tube or welded steel container and tested with a water pressure of 100kg/cm^2 . The cylinder top is fitted with a pressure valve made from high quality forged bronze. The cylinder valve outlet socket has standard left hand threads to which acetylene regulators of all makes may be attached. The cylinder valve is also fitted with a steel spindle to operate the valve for opening and closing. A steel cap is screwed over the valve to protect it from damage during transportation. The body of the cylinder is painted maroon. The capacity of the DA cylinder may be 3.5m^3 – 8.5m^3 .



The base of the DA cylinder (Curved inside) is fitted with fuse plugs which will melt at a temperature of app. 100°C . (Fig 2) In case the cylinder is subjected to high temperature, the fuse plugs will melt and allow the gas to escape, before the pressure increases enough to harm or rupture the cylinder. Fuse plugs are also fitted on the top of the cylinder.



Method of charging DA gas cylinder: The storage of acetylene gas in its gaseous form under pressure above 1kg/cm^2 is not safe. A special method is used to store acetylene safely in cylinders as given below.

The cylinders are filled with porous substances such as:

- pith from corm stalk
- fullers earth
- lime silica
- specially prepared charcoal
- Fiber asbestos.

The hydrocarbon liquid named acetone is then charged in the cylinder, which fills the porous substances ($1/3\text{rd}$ of total volume of the cylinder).

Acetylene gas is then charged in the cylinder, under a pressure of app. 15 kg/cm^2 .

The liquid acetone dissolves the acetylene gas in large quantity as safe storage medium: hence, it is called dissolved acetylene. One volume of liquid acetone can dissolve 25 volumes of acetylene gas under normal atmospheric pressure and temperature. During the gas charging operation one volume of liquid acetone dissolves $25 \times 15 = 375$ volumes of acetylene gas under 15kg/cm^2 pressure at normal temperature. While charging cold water will be sprayed over the cylinder so that the temperature inside the cylinder does not cross certain limit.

Welding gas regulator

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

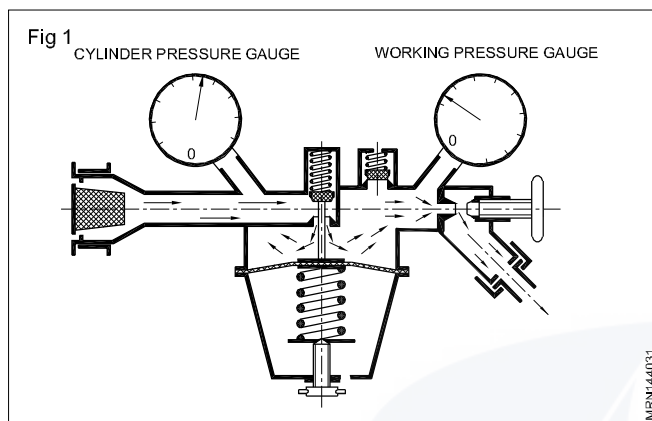
- state the different types of regulators
- describe the working principle of a single and double stage regulator
- explain the parts of each type of regulator
- explain the care and maintenance of the regulators.

Types of regulators

- single stage regulator
- Double stage regulator

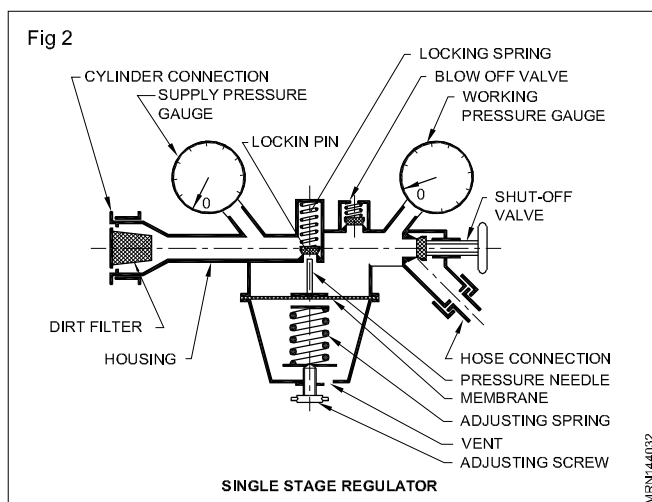
Welding regulator (Single stage)

Working principle: When the spindle of the cylinder is opened slowly, the high pressure gas from the cylinder enters into the regulator through the inlet valve. (Fig 1)



The gas then enters the body of the regulator which is controlled by the needle valve. The pressure inside the regulator rises which pushes the diaphragm and the valve to which it is attached, closes the valve and prevents any more gas from entering the regulator.

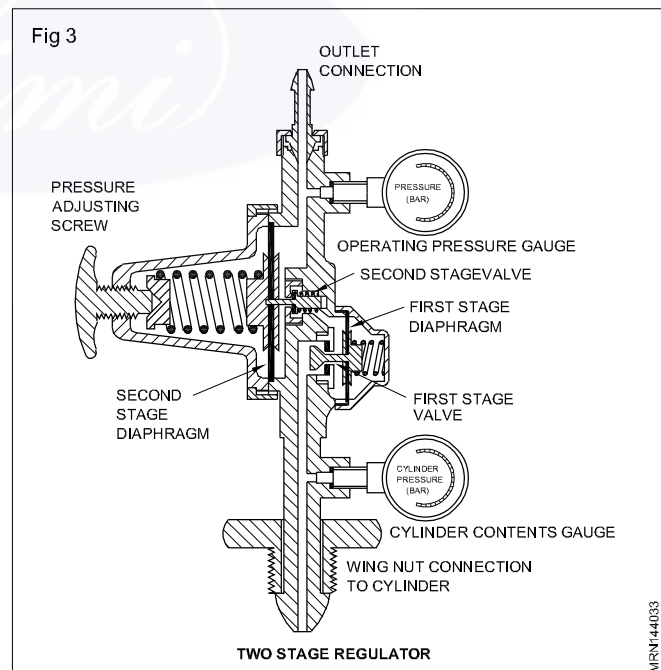
The outlet side is fitted with a pressure gauge which indicates the working pressure on the blowpipe. Upon the gas being drawn 'off from the outlet side, the pressure inside the regulator body falls, the diaphragm is pushed back by the spring and the valve opens, letting more gas 'in' from the cylinder. The pressure in the body, therefore, depends on the pressure of the springs and this can be adjusted by means of a regulator knob. (Fig 2)



Welding regulator (double stage)

Working principle: The two-stage regulator (Fig 3) is nothing but two regulators in one which operates to reduce the pressure progressively in two stages instead of one. The first stage, which is pre-set, reduces the pressure of the cylinder to an intermediate stage (i.e) 5 kg/mm² and gas at that pressure passes into the second stage, the gas now emerges at a pressure (Working pressure) set by the pressure adjusting control knob attached to the diaphragm. Two-stage regulators have two safety valves, so that if there is any excess pressure there will be no explosion. A major objection to the single stage regulator is the need for frequent torch adjustment, for as the cylinder pressure falls the regulator pressure likewise falls necessitating torch adjustment. In the two stage regulator, there is automatic compensation for any drop in the cylinder pressure.

Single stage regulators may be used with pipelines and cylinders. Two stage regulators are used with cylinders and manifolds.



Systems of oxy- acetylene welding

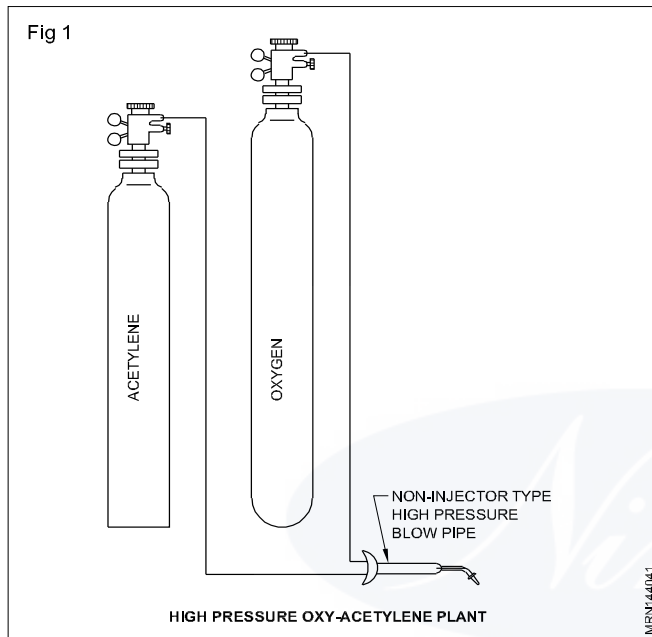
Objectives : At the end of this lesson you shall be able to

- explain the low pressure and the high pressure systems of oxy-acetylene plants and systems
- distinguish between low pressure and high pressure blowpipes
- state the advantages and disadvantages of both systems.

Oxy-acetylene plants: An oxy-acetylene plant can be classified into:

- high pressure plant
- low pressure plant.

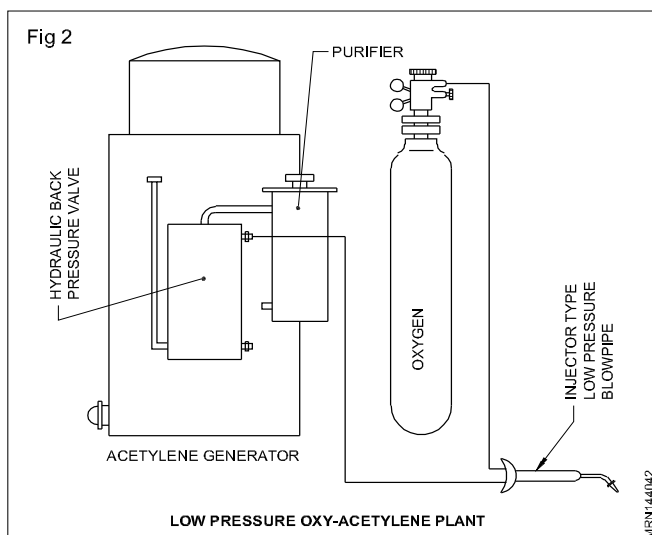
A high pressure plant utilises acetylene under high pressure (15 kg/cm^2). (Fig 1)



Dissolved acetylene (acetylene in cylinder) is the commonly used source.

Acetylene generated from a high pressure generator is not commonly used.

A low pressure plant utilizes acetylene under low pressure (0.017 kg/cm^2) produced by the acetylene generator only. (Fig 2)



High pressure and low pressure plants utilize oxygen gas kept in compressed high pressure cylinders only at 120 to 150 kg/cm^2 pressure.

Oxy acetylene systems: A high pressure oxy-acetylene plant is also called a high pressure system.

A low pressure acetylene plant with a low pressure acetylene generator and a high pressure oxygen cylinder is called a low pressure system.

The terms low pressure and high pressure systems used in oxy-acetylene welding refer only to acetylene pressure, high or low.

Types of blowpipes: For the low pressure system, a specially designed injector types blowpipe is required, which may be used for high pressure system also.

In the high pressure system, a mixer type high pressure blowpipe is used which is not suitable for the low pressure system.

To avoid the danger of high pressure oxygen entering into the acetylene pipeline an injector is used in a low pressure blowpipe. In addition a non-return valve is also used in the blowpipe connection on the acetylene hose. As a further precaution to prevent the acetylene generator from exploding, a hydraulic back pressure valve is used between the acetylene generator and the blowpipe.

Advantages of high pressure system: Safe working and less chances of accidents. The pressure adjustment of gases in this system is easy and accurate, hence working efficiency is more. The gases being in cylinder are perfectly under control. The D.A cylinder is portable and can be taken easily from one place to another place.

The D.A cylinder can be fitted with a regulator quickly and easily, thus saving time. Both injector and non-injector type blowpipes can be used. No license is required for keeping the D.A cylinder.

Sequence of steps

Slowly open the cylinder valve.

Open the shut-off valve or pressure reducing valve

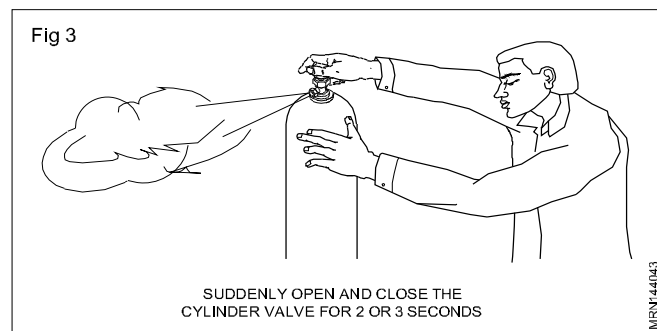
Slowly screw in the adjusting screw. (The locking bolt opens.)

Watch the working pressure gauge.

Turn the adjusting screw until the desired pressure is reached. There is an equilibrium between the bottom adjusting spring and the pressure of the gas on the membrane, which is amplified by the spring of the locking pin.

Care and maintenance of regulators

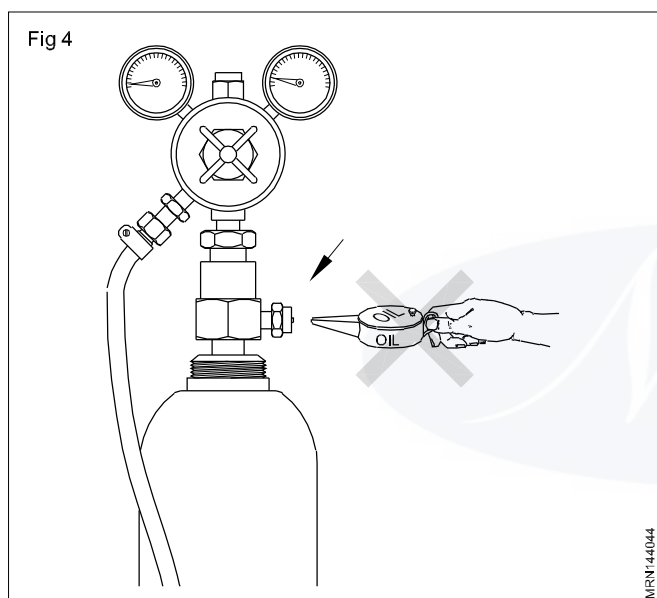
Check the cylinder connection and crack the cylinder before fixing the regulator. (Fig 3)



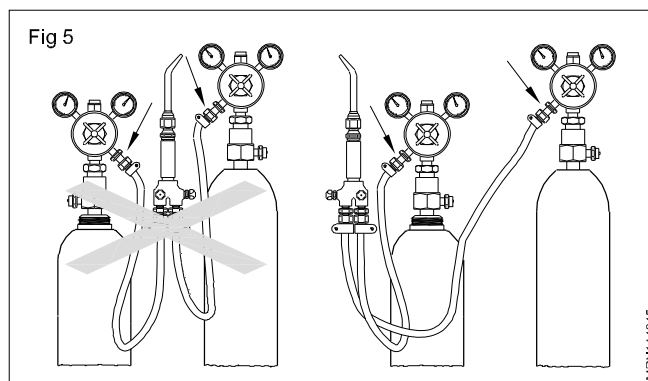
Open the cylinder valve slowly and allow the gas to pass to the regulator (cylinder) content gauge.

Loosen the pressure screw.

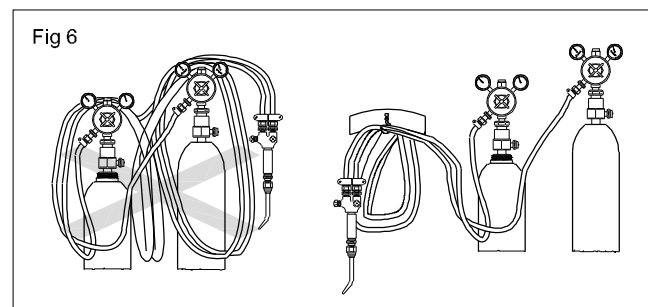
Do not use oil in regulator connections. (Fig 4)



Do not fix the oxygen and acetylene regulators close together. (Fig 5)

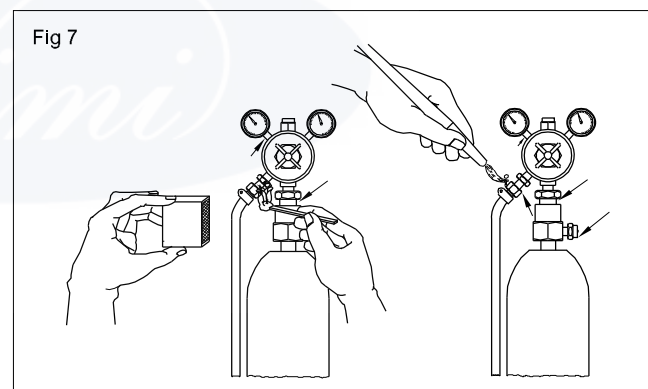


Do not wind the hose on the regulators. (Fig 6)



Use hose-clips before connecting to the regulator.

Use soap water to check the leakage in the acetylene regulator connections and plain water on the oxygen regulator connections Fig 7.



Filler rods for gas welding

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

- state the necessity of filler rods and name the different types of filler rods and their sizes
- select filler rods for the jobs to be welded by gas.

Filler rod and its necessity: Pieces of wires or rods of standard diameter and length used as filler metal in the joint during gas welding process are called filler rods or welding rods.

To obtain best results, high quality filler rods should be used.

The actual cost of welding rods, is very small compared with cost of job, labour, gases and flux.

Good quality filler rods are necessary to:

- reduce oxidation (effect of oxygen)
- Control the mechanical properties of the deposited metal
- Metal caused by fusion.

While welding, a cavity or depression will be formed at the joints of thin section metals. For heavy/thick plates a groove is prepared at the joint. This groove is necessary to get better fusion of the full thickness of the metal, so as to get a uniform strength at the joint.

This groove formed has to be filled with metal. For this purpose a filler rod is necessary. Each metal requires a suitable filler rod.

Sizes as per IS: 1278 - 1972)

The size of the filler rod is determined from the diameter as: 1.00, 1.20, 1.60, 2.00, 2.50, 3.15, 4.00, 5.00 and 6.30mm. For leftward technique filler rods up to 4mm dia. are used. For rightward technique upto 6.3 mm dia. is used. For C.I welding filler rods of 6mm dia. and above are used. Length of filler rod:-500mm or 1000mm.

Filler rods above 4mm diameter are not used often for welding of mild steel.

The usual size of mild steel filler rods used are 1.6mm and 3.15mm diameter. All mild steel filler rods are given a thin layer of copper coating to protect them from oxidation (rusting) during storage. So these filler rods are called copper coated mild steel (C.C.M.S) filler rods.

All types of filler rods are to be stored in sealed plastic covers until they are used.

Different types of filler rods used in gas welding

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

- define a filler rod
- specify and state the different types of ferrous, non-ferrous and alloy filler rods
- explain the method of selection of filler rod in respect to the metal to be welded.

Definition of filler rod: A filler rod is a metallic wire made out of ferrous or non-ferrous metal to deposit the required metal in a joint or on the base metal.

Types of filler rods: The following types of filler rods are classified in gas welding.

- Ferrous filler rod
- Non-Ferrous filler rod
- Alloy type filler rod for ferrous metals
- Alloy type filler rod for non-ferrous metals

A ferrous type filler rod has a major % of iron.

The ferrous type filler rod contains iron, carbon, silicon, sulphur and phosphorous.

The alloy type filler contains iron, carbon, silicon and any one or many of the following elements such as manganese, nickel, chromium, molybdenum, etc.

The non-ferrous type filler rod which contains elements of non-ferrous metals. The composition of non-ferrous

type filler rods is similar to any non-ferrous metal such as copper, aluminium. A non-ferrous alloy type filler rod contains metals like copper, aluminium, tin, etc. along with zinc, lead, nickel, manganese, silicon, etc.

Selection of the correct filler rod for a particular job is a very important step for successful welding. Cutting out a strip from the material to be welded is not always possible and even when it is possible, such a strip cannot replace a recommended welding filler materials. Composition of a filler metal is chosen with special consideration to the metallurgical requirement of a weldment. A wrong choice due to either ignorance or a false consideration of economy may lead to costly failures. IS: 1278-1972* specifies requirements that should be met by filler rods for gas welding. There is another specification IS: 2927-1975* which covers brazing alloys. It is strongly recommended that filler material conforming to these specifications is used. In certain rare cases, it may be necessary to use filler rods of composition not covered by these specifications; in such cases filler rods with well established performances should be used.

To select a filler rod in respect to the metal to be welded, the filler rod must have the same composition with respect to the base metal to be welded.

Factors to be considered for selection of filler rod are:

- the type and composition of base metal
- the base metal thickness
- the type of edge preparation
- the weld is deposited as root run, intermediate runs or final covering run
- welding position
- whether there is any corrosion effect or loss of material from the base metal due to welding.

Care and maintenance

Filler rods should be stored in clean, dry condition to prevent deterioration.

Do not mix different types of filler rods.

Ensure that packages and their labels are in order for easy and correct selection.

Where it is not practicable to store filler rods under heated conditions, an absorbent for moisture such as silica-gel may be used in the storage area.

Ensure the rod is free from contamination such as rust, scale, oil, grease and moisture.

Ensure the rod is reasonably straight to assist manipulation during welding.

Each metal requires a suitable filler rod. Refer to IS : 1278 - 1972 and IS : 2927 - 1975 attached. (Table 1: Filler metals and fluxes for gas welding.)

Table 1
Filler metals and fluxes for gas welding

Filler metal type	Application	Flux
Mild steel - Type S-FS1	A general purpose rod for welding mild steel where a minimum butt-weld tensile strength of 35.0 kg/mm ² is required. (Full fusion technique with neutral flame.)	Not required.
Mild steel - Type S-FS2	Intended for application in which minimum butt-weld tensile strength of 44.0 kg/mm ² is required. (Full fusion technique with neutral flame.)	Not required.
Wear-resisting alloy steel	Building up worn out crossings and other application where the steel surfaces are subject to extreme wear by shock and abrasion. (Surface fusion technique with excess acetylene flame.)	Not required.
3 percent nickel steel Type S-FS4	These rods are intended to be used in repair and reconditioning parts which have to be subsequently hardened and tempered. (Full fusion technique with neutral flame.)	Special flux (if necessary).
Stainless steel decay-resistant (niobium bearing)	These rods are intended for use in the welding of corrosion-resisting steels such as those containing 18 percent chromium and 8 percent nickel. (Full fusion technique with neutral flame.)	Necessary
High silicon cast iron-Type S-C11	Intended for use in the welding of cast iron where an easily machinable deposit is required. (Full fusion technique with neutral flame.)	Flux necessary.
Copper filler rod - Type S-C1	For welding of de-oxidized copper. (Full fusion technique with neutral flame.)	Flux necessary.
Brass filler rod - Type S-C6	For use in the braze welding of copper and mild steel and for the fusion welding of material of the same or closely similar composition. (Oxidising flame.)	Flux necessary.
Manganese bronze (high tensile brass) - Type S-C8	For use in braze welding of copper, cast iron and malleable iron and for the fusion welding of materials of the same or closely similar composition. (Oxidising flame.)	Flux necessary.

Filler metal type	Application	Flux
Medium nickel bronze - Type S-C9	For use in the braze welding of mild steel, cast iron and malleable iron. (Oxidising flame.)	Flux required.
Aluminium (Pure) - Type S-C13	For use in the welding of aluminium grade 1B. (Full fusion technique with neutral flame.)	Flux necessary.
Aluminium alloy-5 percent silicon - Type S-NG21	For welding of aluminium casting alloys, except those containing magnesium, or zinc as the main addition. They may also be used to weld wrought aluminium-magnesium-silicon alloys. (Full fusion technique with neutral flame.)	Flux necessary.
Aluminium alloy-10-13 percent silicon - Type 5-NG2	For welding high silicon aluminium alloys. Also recommended for brazing aluminium. (Neutral flame.)	Flux necessary.
Aluminium alloy-5 percent copper	For welding aluminium casting particularly those containing about 5 percent copper. (Full fusion technique with neutral flame.)	Flux necessary.
Stellite: Grade 1 iron	Hard facing of components subjected mainly to abrasion. (Surface fusion technique with excess acetylene flame.)	None is usually required. A cast flux may be used, if necessary
Stellite: Grade 6	Hard facing of components subjected to shock and abrasion, (Surface fusion technique with excess acetylene flame.)	-do-
Stellite: Grade 12	Hard facing of components subjected to abrasion and moderate shock. (Surface fusion technique with excess acetylene flame.)	-do-
Copper-phosphorus brazing alloy - Type BA-CuP2	Brazing copper, brass and bronze components. Brazing with slightly oxidising flame on copper; neutral flame on copper alloys.	Necessary
Copper-phosphorus brazing alloy - Type BA-CuP5	For making ductile joint in copper without flux. Also widely used on copper based alloys of the brass and bronze type in conjunction with a suitable silver brazing flux. (Flame slightly oxidising on copper; neutral on copper alloys.)	None for copper. A flux is necessary for brazing copper alloys.
Silver-copper-zinc (61 percent silver) type brazing alloys - Type BA-CuP3	Similar to type BA-CuP5 but with a slightly lower tensile strength and electrical conductivity (flame slightly oxidising on copper; neutral on copper alloys). NOTE: Phosphorus bearing silver brazing alloys should not be used with ferrous metal or alloys of high nickel content.	None for copper. A flux is necessary for brazing copper alloys.
Silver-copper-zinc (61 percent silver) - Type BA-Cu-AG6	This brazing alloy is particularly suitable for joining electrical components requiring high electrical conductivity. (Flame neutral)	Flux necessary.
Silver-copper-zinc (43 percent silver) - Type BA-Cu-Ag 16	This is a general purpose brazing alloy and is particularly suitable for joining electrical components requiring high electrical conductivity. (Flame neutral)	Flux necessary.
Silver-copper-zinc cadmium (43 percent silver) - Type BA-Cu-Ag 16A	An ideal composition for economy in brazing operation requiring a low temperature, quick and complete penetration. Suitable on steel, copper, brass, bronze, copper-nickel alloys and nickel-silver. (Flame neutral)	Flux necessary.
Silver-copper-zinc-cadmium (50 percent silver) - Type BA-Cu-Ag 11	This alloy is also suitable for steel, copper-nickel alloys and nickel-silvers. (Flame neutral)	Flux necessary.
Silver-copper-zinc-cadmium nickel (50 percent silver) -Type BA-Cu-Ag 12	Specially suitable for brazing tungsten carbide tips to rock drills, milling cutters, cutting and shaping tools; also suitable for brazing steels which are difficult to 'wet' such as stainless steels. (Flame neutral)	Flux necessary.

Gas welding fluxes and function

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

- explain flux and its function in gas welding
- describe the types of welding fluxes and their storage.

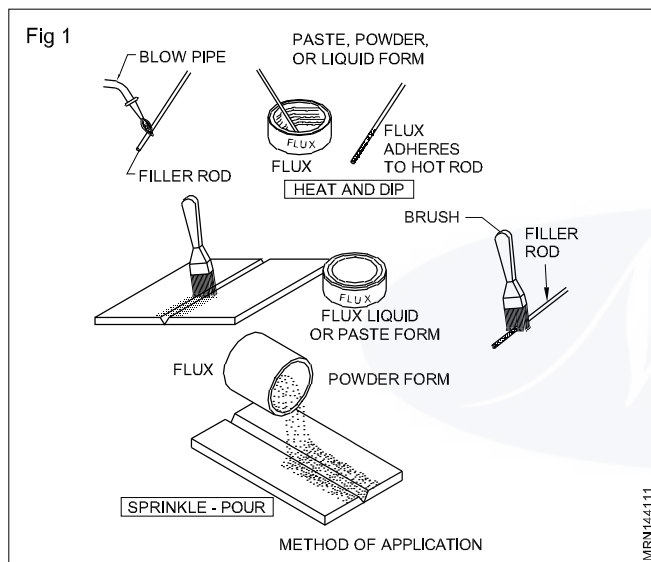
Flux is a fusible (easily melted) chemical compound to be applied before and during welding to prevent unwanted chemical action during welding and thus making the welding operation easier.

The function of flux in gas welding: To dissolve oxides and to prevent impurities and other inclusion that could affect the weld quality.

Fluxes help the flow of their metal into very small gap between the metals being joined.

Fluxes act as cleaning agents to dissolve and remove oxides and clean the metal for welding from dirt and other impurities.

Fluxes are available in the form of paste, powder and liquid. The method of application of flux is shown in Fig 1.



Storing of fluxes: Where the flux is in the form of a coating on the filler rod, protect carefully at all times against damage and dampness. (Fig 2)

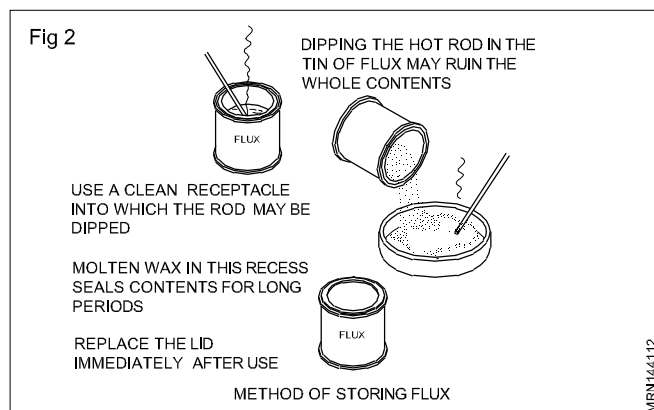
Seal flux tin lids when storing especially for long periods. (Fig 2)

Though the inner envelope of an oxy-acetylene flame offers protection to the weld metal, it is necessary to use a flux in most cases. Flux used during welding not only protects the weldment from oxidation but also from a slag which floats up and allows clean weld metal, to be deposited. After the completion of welding, flux residues should be cleaned.

Removal of flux residues: After welding or brazing is over, it is essential to remove the flux residues. Fluxes in general are chemically active. Therefore, flux residues, if not properly removed, may lead to corrosion of parent metal and weld deposit.

Some hints for removal of flux residues are given below:

- Aluminium and aluminium alloys - As soon as possible after welding, wash the joints in warm water and brush vigorously. When conditions allow, follow up by a rapid



dip in a 5 percent solution of nitric acid; wash again, using hot water to assist drying.

When containers, such as fuel tanks, have been welded and parts are inaccessible for the hot water scrubbing method, use a solution of nitric and hydrofluoric acids. To each 5.0 liters of water add 400 ml of nitric acid (specific gravity 1.42) followed by 33 ml of hydrofluoric acid (40 percent strength). The solution used at room temperature will generally completely remove the flux residue in 10 minutes, producing a clean uniformly etched surface, free from stains. Following this treatment the parts should be rinsed with cold water and finished with a hot water rinse. The time of immersion in hot water should not exceed three minutes, otherwise staining may result; after this washing with hot water the parts should be dried. It is essential when using this treatment that rubber gloves be worn by the operator and the acid solution should preferably be contained in an aluminium vessel.

- Magnesium alloys - Wash in water followed quickly by standard chromium. Acid chromate bath is recommended.
- Copper and brass - Wash in boiling water followed by brushing. Where possible, a 2 percent solution of nitric or sulphuric acid is preferred to help in removing the glassy slag, followed by a hot water wash.
- Stainless steel - Treat in boiling 5 percent caustic soda solution, followed by washing in hot water. Alternatively, use a de-scaling solution of equal volume of hydrochloric acid and water to which is added 5 percent of the total volume of nitric acid with 0.2 percent of total volume of a suitable restrainer.
- Cast iron - Residues may be removed easily by a chipping hammer or wire brush.
- Silver brazing - The flux residue can be easily removed by soaking brazed components in hot water, followed by wire brushing. In difficult cases the work piece should be immersed in 5 to 10 percent sulphuric acid solution for a period of 2 to 5 minutes, followed by hot water rinsing and wire brushing.

Soldering

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

- define 'soldering'
- state the different types of soldering processes.

Soldering method: There are different methods of joining metallic sheets. Soldering is one of them.

soldering is the process by which metals are joined with the help of another alloy called solder without heating the base metal to be joined. The melting point of the solder is lower than that of the materials being joined.

The molten solder wets the base material which helps in binding the base metal to form a joint.

Soldering should not be done on joints subjected to heat and vibration and where more strength is required.

Soldering can be classified as soft soldering and hard soldering. Hard soldering is further divided as (a) brazing (b) silver brazing.

The process of joining metals using tin and lead as a soldering alloy which melts below 420°C is known as soft soldering.

The process of joining metals using copper, zinc and tin alloy as filler material in which the base metal is heated above 420°C below 850°C is called brazing.

Silver brazing is similar to brazing except that the filler material used is a silver-copper alloy and the flux used is also different.

Soldering iron (soldering bit)

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

- state the purpose of soldering iron
- describe constrictional features of soldering iron
- state different types of copper bits and there uses.

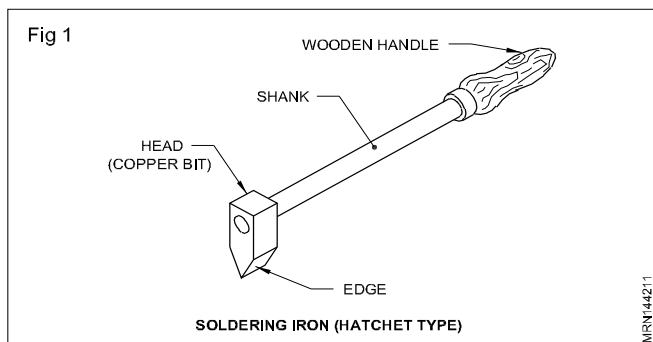
Soldering iron: The soldering iron is used to melt the solder and heat metal that are joined together.

Soldering irons are normally made of copper of copper alloys. So they are also called as copper bits.

Copper is the preferred material for soldering bit because

- it is a very good conductor of heat
- it has affinity for tin lead alloy
- it is easy to maintain in serviceable condition
- it can be easily forged to the required shape.

A soldering iron has the following parts. (Fig)



- Head (copper bit)
- Shank
- Wooden handle
- Edge

SOLDERING COPPER BIT

Type of soldering copper bits: There are 7 types of soldering copper bits in general use,

They are

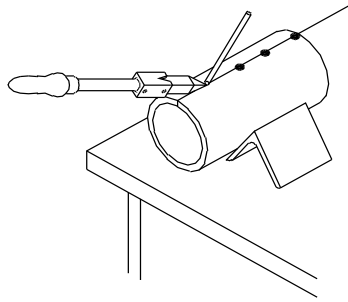
- The pointed soldering copper bit.
- The electric soldering copper bit.
- The gas heated soldering copper bit .
- Straight soldering copper bit.
- Hatchet soldering copper bit.
- Adjustable copper bit
- Handy soldering copper bit.

The bits of soldering irons are made in various shapes and sizes to suit the particular job. They should be large enough to carry adequate heat to avoid too frequent reheating and not too heavy to be awkward to manipulate.

Soldering bits are specified by the weight of the copper head. For general soldering process, the shape of the head is a square pyramid but for repetition, or awkward placed, other shapes are designated.

Point soldering copper bit: This is also called a square pointed soldering iron, The edge is shaped to an angle on four sides to form a pyramid. This is used for tacking and soldering. (Fig 2)

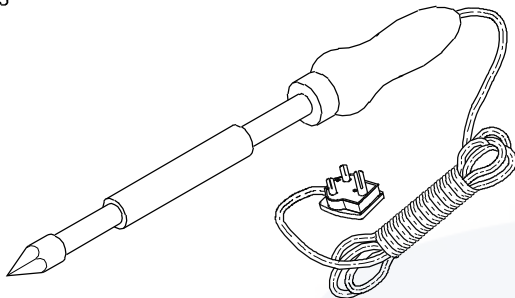
Fig 2



MRN144212

Electric soldering copper bit: The bit of the electric soldering iron is heated by an element. This type is preferred, if current is available because it maintains uniform heat. Electric soldering irons are available for different voltages and are usually supplied with a number of interchangeable tips. They can be made quite small and are generally used on electrical or radio assembly work (Fig 3)

Fig 3

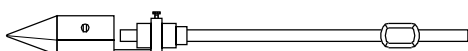


ELECTRIC COPPER SOLDERING

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Gas heated soldering copper bit: A gas heated soldering copper bit is heated by a gas flame which impinges on the back of the head. High pressure gas is used and the bit is large enough to have a good heat storage capacity. Liquified petroleum gas (L.P.G) flame is used extensively for this purpose. Soldering kit normally includes many sizes and shapes of bits which can be used to make most kinds of soldering connections. (Fig 4)

Fig 4

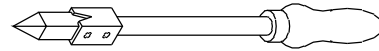


GAS HEATED SOLDERING COPPER BIT

MRN144214

Straight soldering copper bit: This type of soldering iron is suitable for soldering the inside bottom of a round job. (Fig 5)

Fig 5

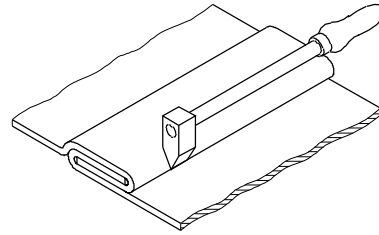


STRAIGHT SOLDERING COPPER WITH HANDLE

MRN144215

Hatchet soldering copper bit: This type of soldering iron is very much suitable for soldering on flat position or grooved joint outside round or square bottom. (Fig 6)

Fig 6



MRN144216

Adjustable soldering copper bit: This type of soldering iron is used for soldering where straight or hatchet bit cannot be used for soldering. Adjustable soldering bit can be adjusted in any position for soldering. (Fig 7)

Fig 7

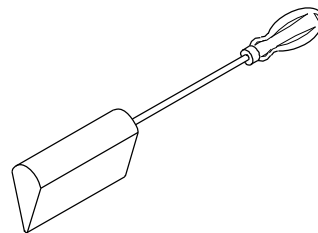


ADJUSTABLE SOLDERING BIT

MRN144217

Handy soldering copper bit: It is like a hatchet type but bigger in size than the hatchet. It is used for soldering heavy gauges of metal because additional heat will cause the metal to buckle. (Fig 8)

Fig 8



HANDY SOLDERING COPPER BIT

MRN144218

Solder

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

- define a solder
- state the types of solders
- state the constituents of soft and hard solders.

Solder is a bonding filler metal used in soldering process.

Pure metals or alloys are used as solders. Solders are applied in the form of wires, sticks, ingots, rods, threads, tapes, formed sections, powder, pastes etc.

TYPES OF SOLDERS

There are two types of solders.

- Soft solder
- Hard solder

Soft solders: Soft solders are alloys of tin lead in varying proportions. They are called soft solders because of their comparatively low melting point. One distinguishes between soft solder whose melting points are 450°C and hard solders whose melting points lie above 450°C. These are alloys of the materials tin, lead, antimony, copper, cadmium and Zinc and are used for soldering heavy (thick) and, etc. Table shows different compositions of solder and their application.

In the composition of soft solder, tin is always stated first.

WARNING

For cooking utensils, do not use solder containing lead. This could cause poisoning. Use pure tin only.

Hard solder: These are alloys of copper, tin, silver, zinc, cadmium and phosphorus and are used for soldering heavy metals.

Sl.NO.	Types of solder	Tin	Lead	Application
1	Common solder	50	50	General sheet metal applications
2	Fine solder	60	40	Because of quick setting properties and higher strength, they are used for copper water electrical work.
3	Fine Solder	70	30	
4	Coarse solder	40	60	Used on galvanised iron sheets
5	Extra fine solder	66	34	Soldering brass, copper and jewellery
6	Eutectic alloy	63	37	Similar to fine solder

Soldering Flux

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

- state the functions of soldering fluxes
- state the criteria for the selection of fluxes
- distinguish between corrosive and non-corrosive fluxes
- state the different types of fluxes and their applications.

All metal rust to some extent, when exposed to the atmosphere because of oxidation. The layer of the rust must be removed before soldering. For this, a chemical compound applied to the joint is called flux.

Function of the fluxes:

- 1 Fluxes remove oxides from the soldering surface. It prevents corrosion.
- 2 It forms a liquid cover over the workpiece and prevents further oxidation.
- 3 It helps molten solder to flow easily in the required place by lowering the surface tension of the molten solder.

Selection of flux: The following criteria are important for selecting a flux.

- Working temperature of the solder
- Soldering process
- Material to be joined

Different types of fluxes: Flux can be classified as (1) Inorganic or corrosive (Active) & (2) Organic or noncorrosive (Passive.)

Inorganic fluxes are acidic and chemically active and remove oxides by chemically dissolving them. They are applied by brush directly on to the surface to be soldered

and should be washed immediately after the soldering operation is completed.

Organic fluxes are chemically inactive. These fluxes coat the surface of the metals to be joined and exclude the air from the surface, to avoid further oxidation. They are applied only to the metal surfaces which have been previously cleaned, by mechanical abrasion. They are in the form of lump, powder, paste or liquid.

DIFFERENT TYPES OF FLUXES

A Inorganic fluxes

1 Hydrochloric acid: Concentrated hydrochloric acid is a liquid which fumes when it comes into contact with air. After mixing with water 2 or 3 times the quantity of the acid, it is used as dilute hydrochloric acid. Hydrochloric acid combines with zinc forming zinc chloride and acts as a flux. So it cannot be used as a flux for sheet metals other than zinc iron or galvanised sheet this is also known as muriatic acid.

2 Zinc chloride: Zinc chloride is produced by adding small pieces of clean zinc to hydrochloric acid. It gives off hydrogen gas and heat after a vigorous bubbling action, thus producing zinc chloride. The zinc chloride is prepared in heat resisting glass beakers in small quantities. (Fig1)

3 Ammonium choride or sal-Ammoniac: It is a solid white crystalline substance used when soldering copper, brass, iron and steel. it is used in the form of powder of mixed with water. It is also used as a clening agent in dipping solution.

4 Phosphoric acid: It is aminly used a flux for stinless stelel. It is extreme;y reactive. It is stored in plasic containers because it attacks glass.

B Organic fluxes

1 Resin: it is an amber coloured substance extracted from pine tree sap. It is available in paster or powder form.

Resin used for soldering copper, brass, bronze, tin plate, cadmium, nickel, silver and some alloys of these metals. This used extensively for eleitrical soldering work.

2 Tallow: It is a form of animal fat. It is used when soldering lead, brass and copper.

The following Table shows the nature nd type of flux used in soldering.

Metal to besoldered	Inorganic flux	Organic flux	Remarks
Aluminium Aluminium-bronze			Commercially prepared flux and solder required
Brass	Killed spirits Sal ammoniac	Resin Tallow	Commercial flux available
Cadmium	Killed spriits	Resin	commercial flux available
Copper	Killed spirits sal-ammoniac	Resin	Commercial flux available
Gold		Resin	
Lead	Killed Spirits	Tallow Resin	
Monel			Commercial flux required
Nickel	Killed spriits	Resin	commercial flux available
Silver		Resin	commercial flux available
Stainless steel	Phosphoric acid		commercial flux available
Steel	Killed spriits		
Tin	Killed spriits		commercial flux available
Tin -bronze	Killed spriits	Resin	
Tin-lead			
Tin-zinc	Killed spriits	Resin	
zinc	Muriatic acid		

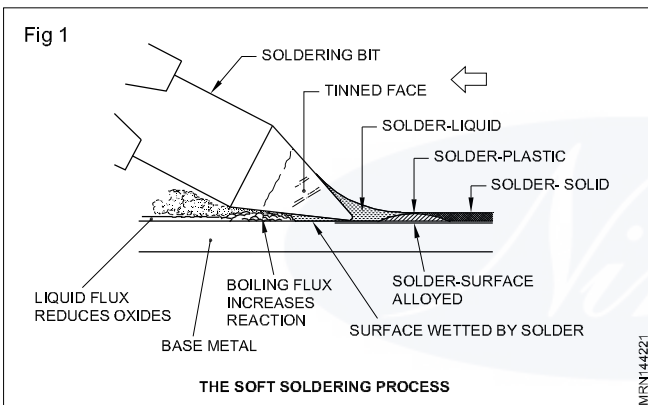
Soft soldering

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

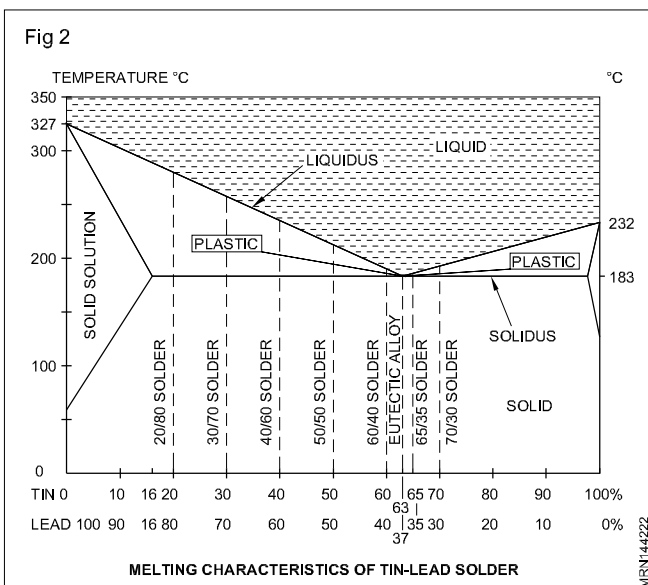
- explain soft soldering process
- state the melting characteristics of soft solders
- state the essential features of the soldering technique
- explain the importance of the attitude of the bit
- state the importance of movement of the bit in soldering
- state the characteristics of the soldered seams to be observed while inspection.

Soft soldering involves the process.

- Preparing the workpiece.
- Select the correct soft solder.
- Preparing the soldering iron.
- Select and apply suitable flux.
- heat the soldering iron bit and the workpiece to the correct temperature.
- manipulating the soldering iron on the workpiece skillfully as shown in Fig 1.
- Complete the job to a satisfactory standard.



Melting characteristics of soft solders: The eutectic alloy of tin lead solder is a mixture of 63% tin and 37% lead. 63/37 solder melts at 183°C and is the lowest melting point of all alloy series as shown in fig 2.

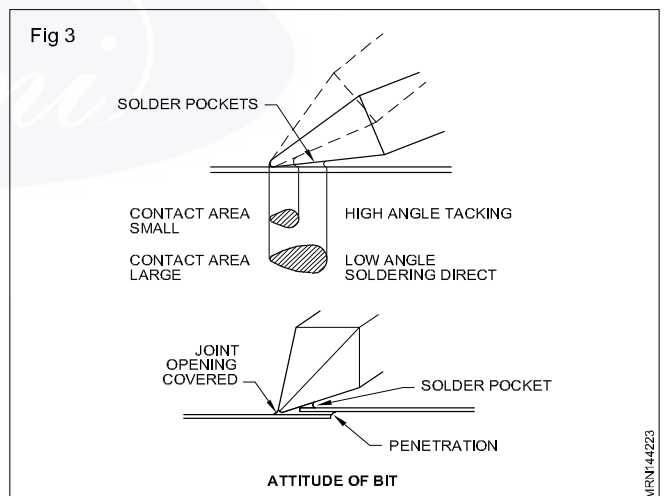


Soldering Techniques: The following features are essential to do soldering.

- Correct joint design
- Preparation of the joint
- Selection of the solder
- Selection and preparation of the soldering iron.
- Copper bit heating
- Soldering bit manipulation
- Cleaning after soldering
- Inspection of the seam.

Attitude of the bit: The soldering iron bit should be placed in a position that enables sufficient heat and solder to flow into the joint.

The angle between a working face of the bit and the joint surface should be filled with a pocket of solder. (Fig 3)

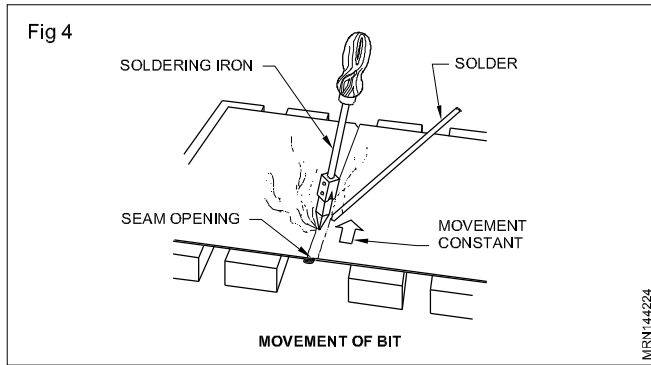


Any variation of this angle will control the amount of heat and solder which is transferred onto the lapped surfaces.

Contact between the molten solder and the joint opening is essential for the penetration of the solder into the joint as shown in figure.

Successful use of the soldering iron is influenced by the attitude of the bit and the movement of the bit on the workpiece.

Movement of the bit: The bit movement along the line of the seam, must be constant and consistent with a smooth flow of solder. When sweating wide overlaps, in addition to the progressive movement along the seam, it is required to move the bit back and forth across the seam. (Fig 4)



The pattern of the bit movement ensures successful heating of the solder deposited, when the point of the bit covering the joint opening penetrate through the lap as shown in figure.

Soldered joint

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

- state the types of the soldered joints
- state the points to be considered for correct joint design.

Types of soldered joints: Sheet metal components are joined together by soldered joints. In the many cases, the edges are joined by sheet metal mechanical joints and then soldered to make the joint stronger and leak proof.

Fig 1 shows soldered lap joints.

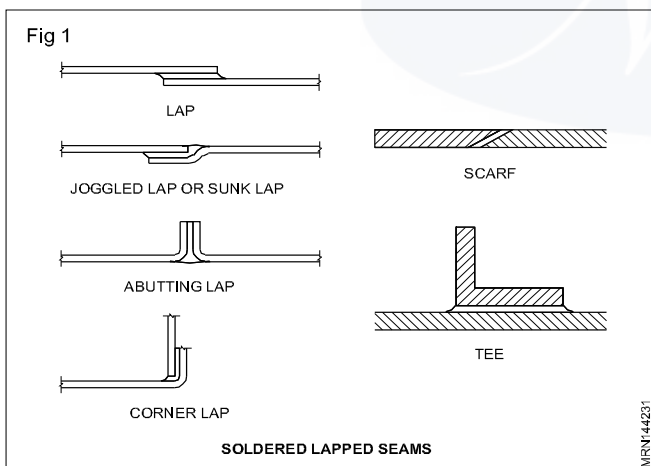
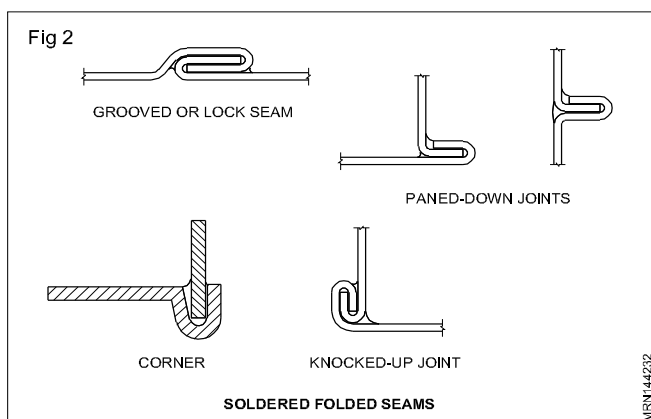


Fig 2 shows soldered seams.



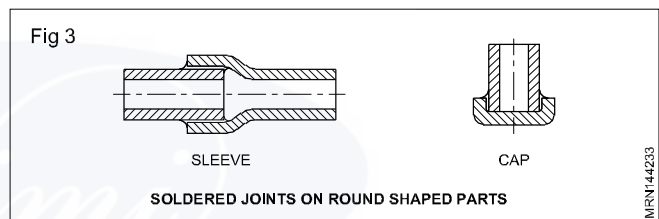
Flux residues and stains should be removed from the seam, to keep clean dry surfaces for paint finishes.

Inspection of the seam: A soldered seam should have the following characteristics.

- The solder has penetrated the lapped surface.
- The joint gap is sealed with a neat smooth fillet of the solder.
- The upper surfaces of the seam must be smooth, thin coating of solder, with tidy solder margins with uniform width.

Visual inspection is good to rectify the faults of the solder. However, physical testing for air or water tight seam is specified often. Leaks, detected by the tests are corrected by re-cleaning, re-fluxing and re-soldering of the faulty are in the soldered seam.

Fig 3 shows soldered joint on round shaped parts.



Correct joint design: Sheet metal joints with overlapping surfaces are ideal for joining or sealing with solder. Close fitting of lapped surfaces are essential for the flow of molten solder in into the joint by capillary action.

Joint design suitable for silver brazing or soldering mainly depends on the type of assembly and its intended use following conditions.

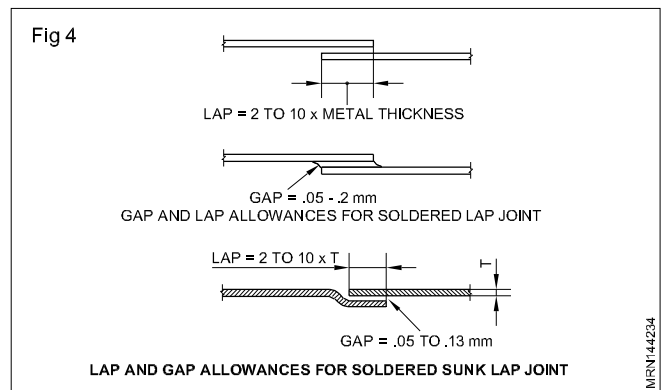
Maximum strength can be achieved by observing the following conditions.

- A suitable filler alloy must be used. Component metal is of major consideration.
- Joint clearances should be minimum. Close fitting surfaces helps capillary flow and gaps between 0.05 and 0.13 mm should be used.
- The solder must contact lapped surface sufficiently. Lap width is commonly made 2 to 10 times the component metal thickness. In case of unequal thickness, the lap size is based on the thinner materials.
- Workpieces must be firmly supported. It is essential to prevent the movement for the control of the solder application, alignment and accuracy of the component assembly.

Sheet metal joints both lapped and folded, are suitable for

silver soldering application as shown in fig 4.

Silver solder effects the union of lapped joints and seals the seam openings of the interlocking folded joints.

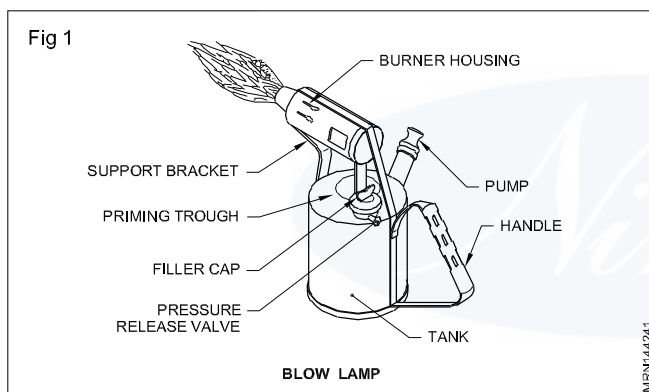


Blow lamp

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

- state the constructional feature of blow lamp
- identify the parts of blow lamp
- describe the operation of blow lamp.

In blow lamp (Fig 1) the kerosene is pressurized to pass through pre-heated tubes, thus becoming vaporised. The kerosene vapour continues through a jet to mix with air and when ignited directed through a nozzle, producing a forceful flame.



The flame within the housing provides the heat to maintain vaporisation of the kerosene. The free flame at the nozzle outlet is used to heat the soldering bit.

Blow lamp is a portable heating appliance used as a direct source of heat for soldering irons or other parts to be soldered. Fig 1 shows parts of blow lamp.

It has a tank made of brass, filler cap is fitted at its top to fill kerosene. A pressure relief valve is connected to the nozzle to switch ON/OFF and control the flame.

Priming trough is provided for filling methylated spirit for lighting the blow lamp. Set of nozzle is provided to direct the kerosene vapour to produce forceful flame. Burner housing is mounted on support brackets on which soldering iron is placed for heating as shown in figure.

Pump is provided to pressurise the kerosene in the tank.

Factors considered while soldering

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

- state the constructional feature of blow lamp
- identify the parts of blow lamp
- describe the operation of blow lamp.

Soldering is joining two metal parts with a solder, i.e., a third metal that has a lower melting point.

Before soldering the following conditions must be met.

- 1 The metal must be clean.
- 2 The correct soldering device must be used and it must be in good condition.
- 3 The correct solder and flux or soldering agent must be chosen.
- 4 Proper amount of heat must be applied. If you follow these conditions, you could get a good solder joint.

Cleanliness: Solder will never stick to a dirty, oil or oxide coated surface. Beginners often ignore this simple point. If the metal is dirty, clean it with a liquid cleaner. If it is black annealed sheet, remove the oxide with an abrasive cloth, and clean it until the surface is bright.

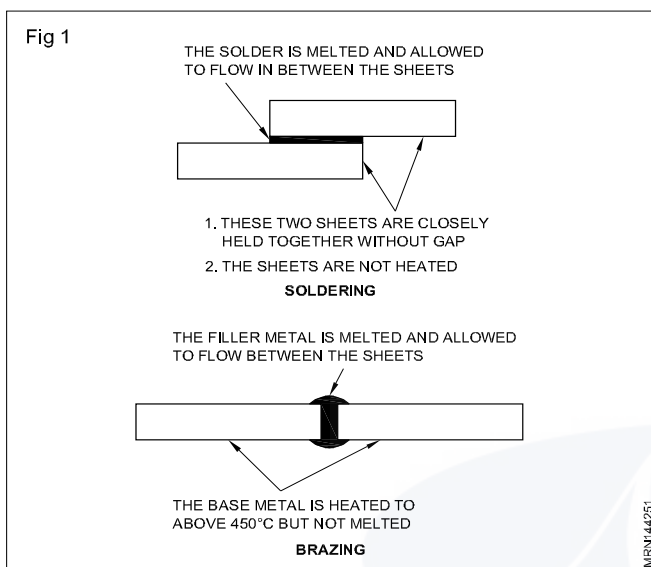
A bright metal, such as copper, can be coated with oxide even though you cannot see it. This oxide can be removed with any fine abrasive.

Soft soldering, brzing and silver brazing

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

- explain soft soldering and hard soldering
- describe the method of soft soldering, brazing and sliver brazing
- describe the difference between brazing and soldering
- explain the various methods of brazing
- explain the problems in brazing and the remedies.

Soldering amd brazing: The soldering and brazing processes differ from welding in the sense that there is no direct melting of the base metal(s) being welded. In brazing or soldering, the filler alloy flows between two closely adjacent surfaces by capillary action.fig.1



Soft soldering: The filler metals used in soldering have a melting point below **427°C**

The alloys used for soft soldering are:

- tin-lead (fog general purpose soldering)
- tin-lead-antimony
- tin-lead-cadmium,

The process is referred to as 'soft soldering'. The heat required for 'soft soldering' is supplied by a soldering iron, whose copper tip is heatd either by a forge of electrically.

Composition of soft solder

Usually soft solder is an lloy of lead and Tin in different ratios depending on the base metals soldered and the purpose of soldering.

Soft solders are available in different shapes and forms such as stick, bar, paste, tape or wire etc.

TYPES OF FLUXES

Corrosive: in this type the solution contains inorganic substances like zinc chloride. ammonium chloride, hydrochloric. This type of flux leaves a corrosive deposit on the base metal surface which must be thoroughly washed off after soldering. This type of flux is not used on electrical works or where the joints cannot be effectively washed.

Non-corrosive: These are fluxes based on resin. These

leave a non-corrosive residue. They are used on electrical wprks, instruments like pressure gauges, and parts where washing is difficult.

Suitable fluxes for various materials

Steel - zinc chloride

Zinc and galvanized iron - hydrochloric acid

Tin - Zin chloride

Lead - tallow resin

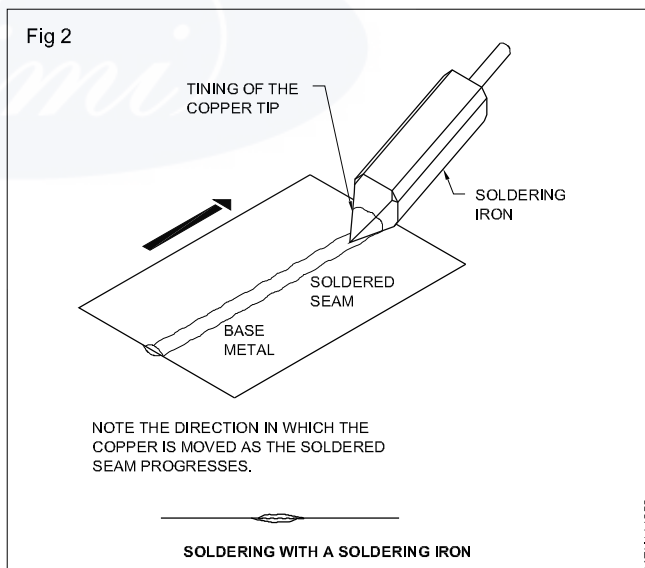
Brass, copper, brose - Zinc chloride, resin.

Basic operations in soldering

The parts to be soldered are fitted closely.

Paint, rust, dirt or thick oxides are removed by filling scraping or by using emery paper or steel wool.

The surfaces to be soldered are coated with flux to remove the films of oxide. (Fig 2)



The solder is applied with a copper soldering bit. (Figs 3a, b and c) The joining takes place due to "sweating" of the bint the hot and tinned copper tip of the soldering iron.

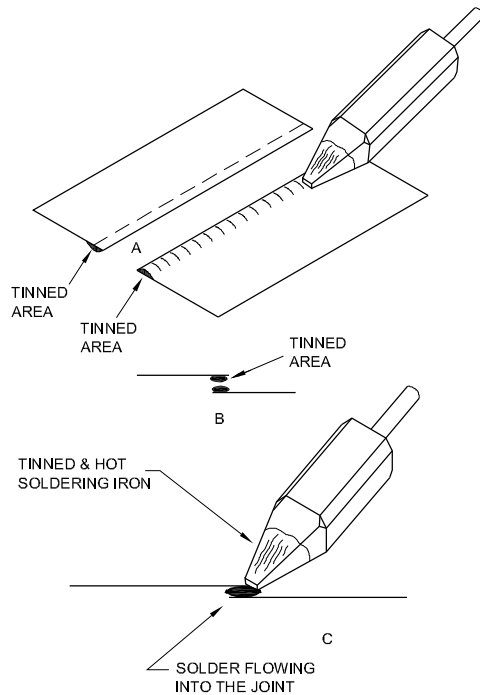
The two sheets to be soldered are adhering to each other due to sweating and bonding of the tinned area.

The excess solder present on the surfaces is removed and the joint is allowd to coo;.

Brazing: Brazing is a metal joining process which is done at a temperature of above 450°C as compared to soldering which is done at blow 450°C

So brazing is a process in which the following steps re

Fig 3



MRNF44253

used.

- Clean the area of the joint thoroughly by wire brushing, emerying and by chemical solutions for removing oil, grease, paints etc.
- Fit the joints tightly using proper clamping. (Maximum gap permitted between the two joining surfaces is only 0.08 mm)
- Apply the flux in paste form (for brazing iron and steel a mixture of 75% borax powder with 25% boric acid (liquid form) to form a paste is used. Usually the brazing flux contains chlorides, fluorides, borax, borates, fluoroborates, boric acid, wetting agents and water. So suitable flux combination is selected based on metal being used.

Brazing is employed where a ductile joints is required.

Brazing filler rods/ metals melt at temperature from 860°C to 950°C and are used to braze iron and its alloys.

Brazing fluxes: Fused borax is the general purposed flux for most metals.

It is applied on the joint in the form of a paste made by mixing up with water.

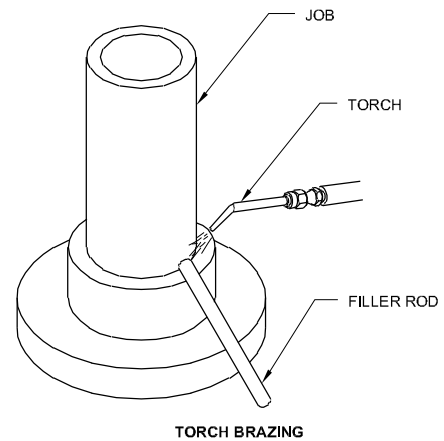
If brazing is to be done at a lower temperature, fluorides of alkali materials are commonly used. These fluxes will remove refractory oxides of aluminium, chromium, silicon and beryllium.

VARIOUS METHODS OF BRAZING

Torch brazing: The base metal is heated to the required temperature by the application of the oxy-acetylene flame. (Fig 4)

Furnace brazing: The parts to be brazed are aligned

Fig 4

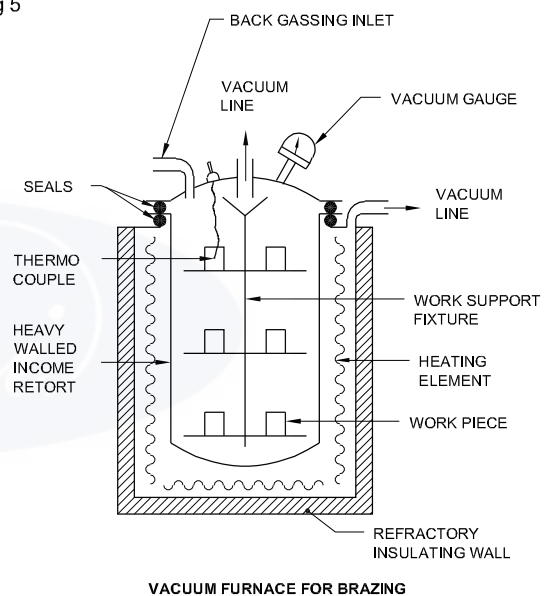


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with the brazing material placed in the joint. The assembly is kept in the furnace. The temperature is controlled to provide uniform heating. (Fig 5)

Dip brazing: The parts to be brazed are submerged in a

Fig 5

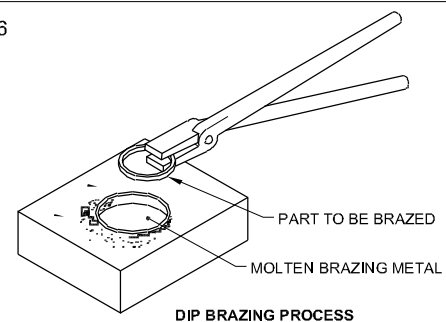


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molten metal or chemical bath (Fig 6) Of brazing filler metal.

Induction brazing: The parts to be brazed are heated to

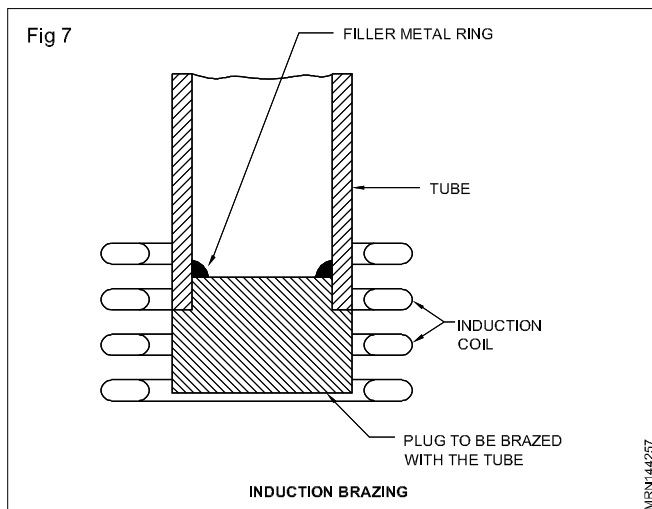
Fig 6



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the melting point of the brazing material by means of a high frequency electric current. This is done by encircling the joint with a water cooled induction coil. (Fig 7)

Conditions to obtain satisfactory brazed or soldered



joint

Wet the base metal.

Spread the filler metal and make contact with the joint surfaces. The solder will be drawn into the joint by capillary action.

Suggested joint designs for soldering and brazing are shown in Fig 8

Advantages of brazing

The completed joint requires little or no finishing.

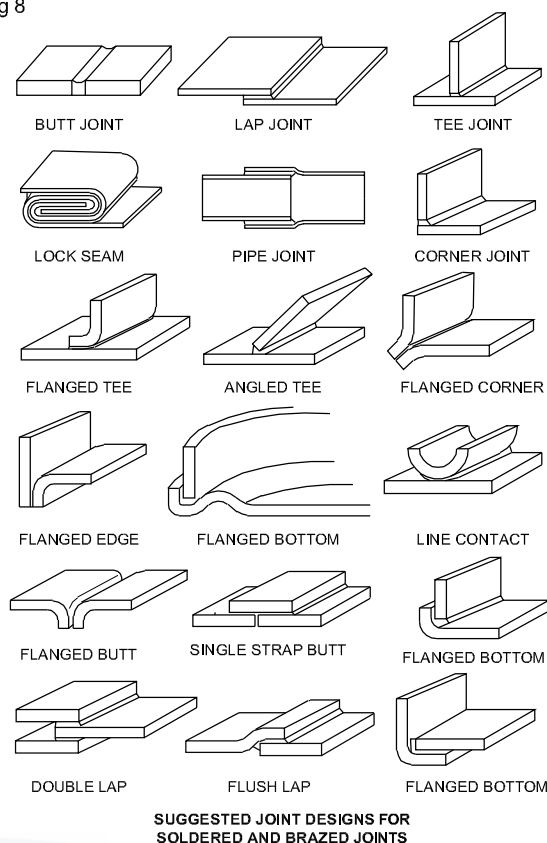
The relatively low temperature at which the joint made minimizes distortion.

There is no flash or weld spatter.

The brazing technique does not require as much skill as the technique for fusion welding.

The process can be easily mechanised.

Fig 8



The process is economical owing to the above advantages.

Disadvantages of brazing

If the joint is exposed to corrosive media, the filler metal used may not have the required corrosive resistance.

All the brazing alloys lose strength at an elevated temperature

The colour of the brazing alloy which ranges from silver white to copper red may not match the base metal very closely.

Silver brazing: Silver brazing is also sometimes called silver soldering. It is one of the best methods used to

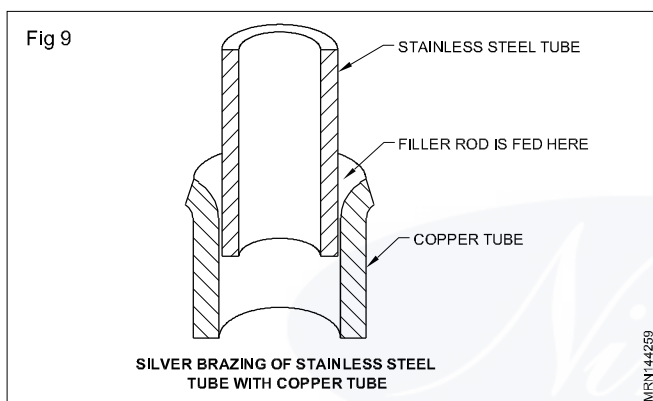
Brazing: Problems and remedies

Problem	Remedy
Filler metal 'balls up', does not melt and flow into the joint.	Use more flux. Pickling or additional mechanical cleaning to remove oxides, oils, or other surface coatings must be done, Add fresh flux. Also check for contaminated pickling acid or 'dirty' grinderwheels that could spread impurities instead of removing them.
Filler metal melts but does not flow completely through joint.	Longer preheating period required. the base metal may not be hot enough. More thorough cleaning required. A wider or narrower joint gap should be provided. Joint must not be too tight or too loose. Also check for gaps or spaces where capillarity is interrupted. Apply more flux to both filler and base metal. Use a different flux compound. Improper flux may be breaking down due to too much heat. Eliminate this fault.

Problem	Remedy
Filler metal runs out of , instead of into the joint.	Re-position (tilt) the joint so that gravity helps the filler metal to run into the joint. Making a small reservoir in the joint to start the capillary action will help. Feeding the filler metal into the joint from above rather than horizontally or from below is recommended.
Filler metal melts but will not flow.	Additional cleaning of filler metal to remove oxides is required. more flux on both filler and base metal is required.

connect/join parts which are to be leak proof and has to give maximum strength of the joint. It is a very useful and easy process for joining copper brass, bronze parts as well as for joining dissimilar metal tubes like copper to stainless steel tubes etc. The melting point of silver brazing alloy filler rods will be around 600 to 800°C which is always less than that of the base metals joined. Fig 9 shows silver brazing of stainless steel tube with a copper tube.

The process is similar to other brazing processes. The points to be remembered while silver soldering are:



- The joint must be thoroughly cleaned both mechanically and chemically.

- Fit the joint closely/tightly without any gap and support the joint. (The maximum permissible gap between the parts to be silver brazing is 0.08mm)

- Apply proper flux at the joint and on the filler rod.

- Heat the joint to the brazing temperature depending on the composition of the silver brazing filler rod. The brazing temperature may vary from 600°C to 800°. Use an oxy-acetylene blow pipe for heating.

- Apply the silver brazing filler rod coated with the paste flux at the joint using leftward technique. Heat the filler rod to the "flow temperature" which is usually 10 to 15° more than its melting temperature. i.e, for the filler metal to flow easily into the joint and for getting the wetting and capillary action, it is necessary to heat the molten filler metal to 10 or 15° more than its melting temperature.

Allow the joint to cool without removing the support given to the joint.

Clean the joint thoroughly to remove all residual flux.

Fluxes used for silver brazing may be chlorides or borax made into a paste with water.

Brazing and braze welding; Both brazing and braze welding are metal joining processes which are performed at temperatures above 840°F (450°) as compared to soldering which is performed at temperatures below 840°F (450°C)

The American Welding Society defines these processes as follows:

Brazing- "A group of welding processes which produces coalescence of materials by heating them to a suitable temperature and by using a filler metal having a liquidus above 840°F (450°C) and below the solidus of the base

metal. The filler metal is distributed between the closely fitted surfaces of the joint by capillary action" coalescence is a joining or uniting of materials.

Braze welding- "A welding process variation in which a filler metal, having a liquidus above 840°F (450°C) and below the solidus of the base metal, is used. Unlike brazing, in braze welding the filler is not distributed in the joint by capillary action"

Brazing has been used for centuries. Blacksmiths, jewelers, armorers and other crafters used the process on large and small articles before recorded history. This joining method has grown steadily both in volume and popularity. It is an important industrial process, as well as jewelry making and repair process. The art of brazing has become more of a science as the knowledge of chemistry, physics and metallurgy has increased.

The usual terms Brazing and Braze welding imply the use of a nonferrous alloy. These nonferrous alloys consist of alloys of copper, tin, zinc, aluminum, beryllium, magnesium, silver, gold and others.

Brass is an alloy consisting chiefly of copper and zinc. Bronze is an alloy consisting chiefly of copper and tin. Most rods used in both brazing and braze welding on ferrous metals are brass alloys rather than bronze. The brands which are called bronze usually contain a small percent (about one percent) of tin.

Brazing and braze welding principles: Brazing is an adhesion process in which the metals being joined are heated but not melted: the brazing filler metal melts and flows at temperatures above 840°F (450°C). Adhesion is the molecular attraction exerted between surfaces.

A brazed joint is stronger than a soldered joint because of the strength of the alloys used. In some instances it is as strong as a welded joint. It is used where mechanical

strength and leakproof joints are desired. Brazing and braze welding are superior to welding in some applications, since they do not affect the heat treatment of the original metals as much as welding.

Brazing and braze welding wrap the original metals less and it is possible to joint dissimilar metals. For example, steel tubing may be brazed to cast iron, copper tubing brazed to steel and tool steel brazed to low carbon steel.

Brazing is done on metals which fit together tightly. The metal is drawn into the joint by capillary action. (A liquid

will be drawn between two tightly fitted surfaces. This drawing action is known as Capillary action). Very thin layers of filler metal are used when brazing. The joints and the material being brazed must be specially designed for the purpose. When brazing, poor fit and alignment result in poor joints and in inefficient use of brazing filler metal.

In braze welding, joint designs used for oxyfuel gas or arc welding are satisfactory. When braze welding, thick layers of the brazing filler metal is used.



General and special refrigeration tools and their function

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

- explain about common basic refrigeration tools and their function
- explain about common instruments & equipments.

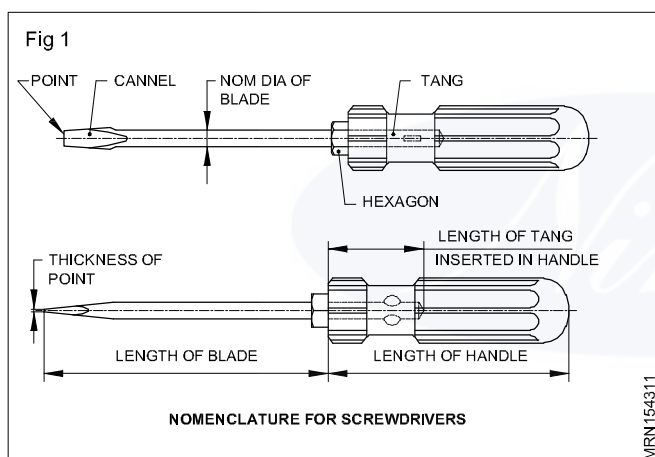
Introduction

Diagonal cutting plier: It is used for cutting small diameter wires and cables especially when they are close to terminals. It is also used to remove the insulation from cables and cords. It can be used for splitting and removing catter pins.

Screwdriver: Screw driver is used to tighten or loosen screws. Screwdrives are specified in size by the length of the blade and the width of the tip.(Fig 1)

A very small screw driver is 45mm long and 3mm in diameter.

A larger screwdriver is 300mm long and 10mm in diameter.



Combination pliers

Fig 1 shows a COMBINATION PLIERS and its application. A number of operations can be performed with these pliers.

The FLAT GRIP can be used to grip and hold parts and components and to twist wires.

Many combination pliers also have a PIPE GRIP which is used to grip and hold cylindrical objects.

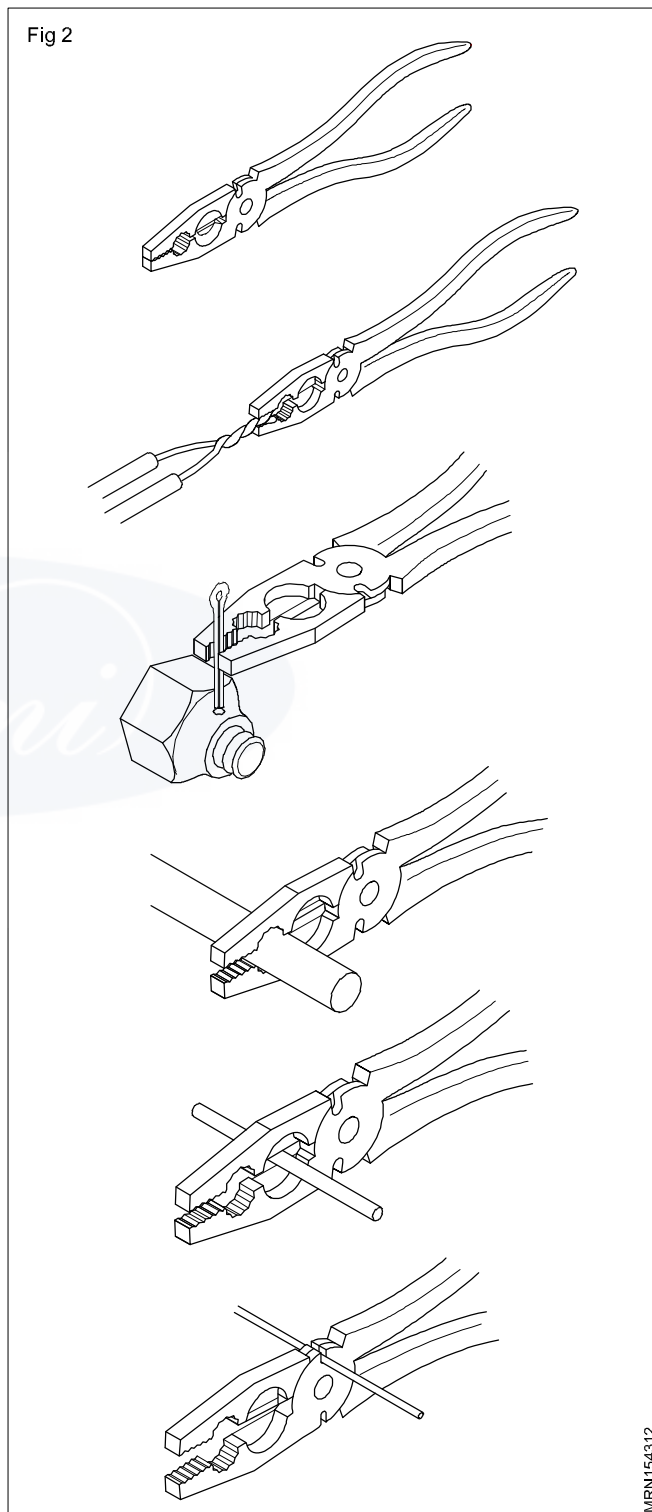
They also have a pair of SIDE CUTTERS which are used to cut small diameter wires and cables.

A pair of JOINT CUTTERS are provided for shearing off steel wires.

Combination pliers are available in the following overall lengths:

140, 160, 190, 210 and 250 mm.

Fig 2



Refer Exercise No 1.1.01 for other tools, instruments and equipments

Types of refrigeration systems

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

- explain function of refrigeration
- explain types of refrigeration system
- explain the construction working at refrigeration system.

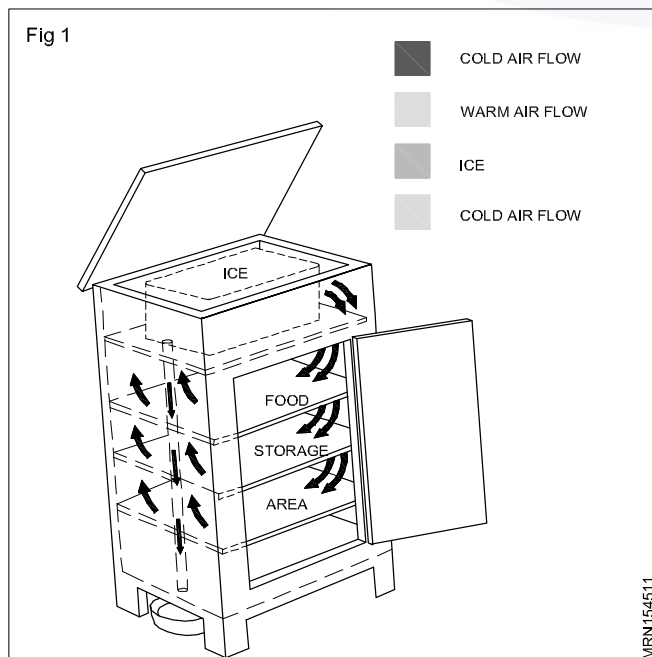
Refrigeration is a process of reducing of the temperature and preserve the perishable food stuff and medicines for future use. The different refrigeration system are given below.

- Ice refrigeration
- Dry ice refrigeration
- Water vapour system
- Liquid gas refrigeration system
- Vapour absorption system
- Vapour compression system

Ice refrigeration system

It is one of the earliest method for producing cold. Now a days this system used for preservation of fish and many other application for cooling. The main disadvantage of this is it cannot maintained below 0°C (centigrade) and refill the ice after melting.

An ice refrigeration system shown in (Fig 1) it is an insulated cabinet equipped with a tray for holding ice blocks. Foods are located below inside at the cabinet below the ice tray. The ice absorb heat from food stuff and food substance is to be cooled.

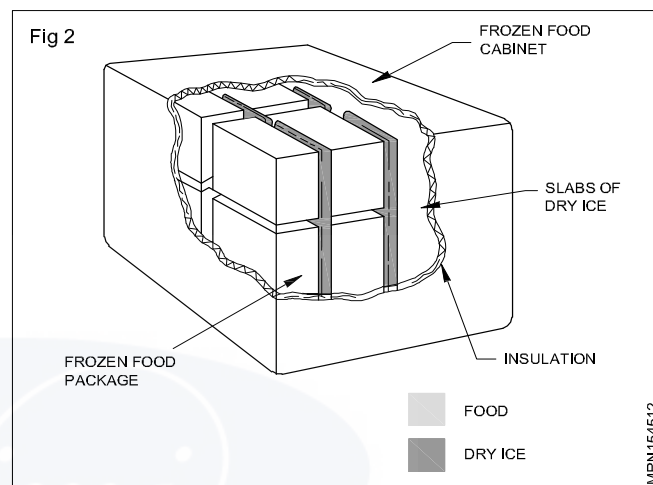


When it is necessary to use ice for cooling temperature below 32°F , ice and salt mixture may be used.

Dry ice refrigeration (Fig 2)

Solid carbon dioxide is known as dry ice. It directly change solid to vapour state by absorbing heating and maintained

a temperature at -78°C . This process is known as sublimation. The dry ice is pressed into various sizes and shapes in to food container. Dry ice is usually stored in heavily insulated cabinets. Never handle it with bare hands. It will cause instant freeze burns. Always wear heavy gloves.



Liquid gas refrigeration system

In this system the non poisonous liquid (Nitrogen) is used to cool the space. This system is called as expandable refrigerant refrigeration system also or chemical refrigeration.

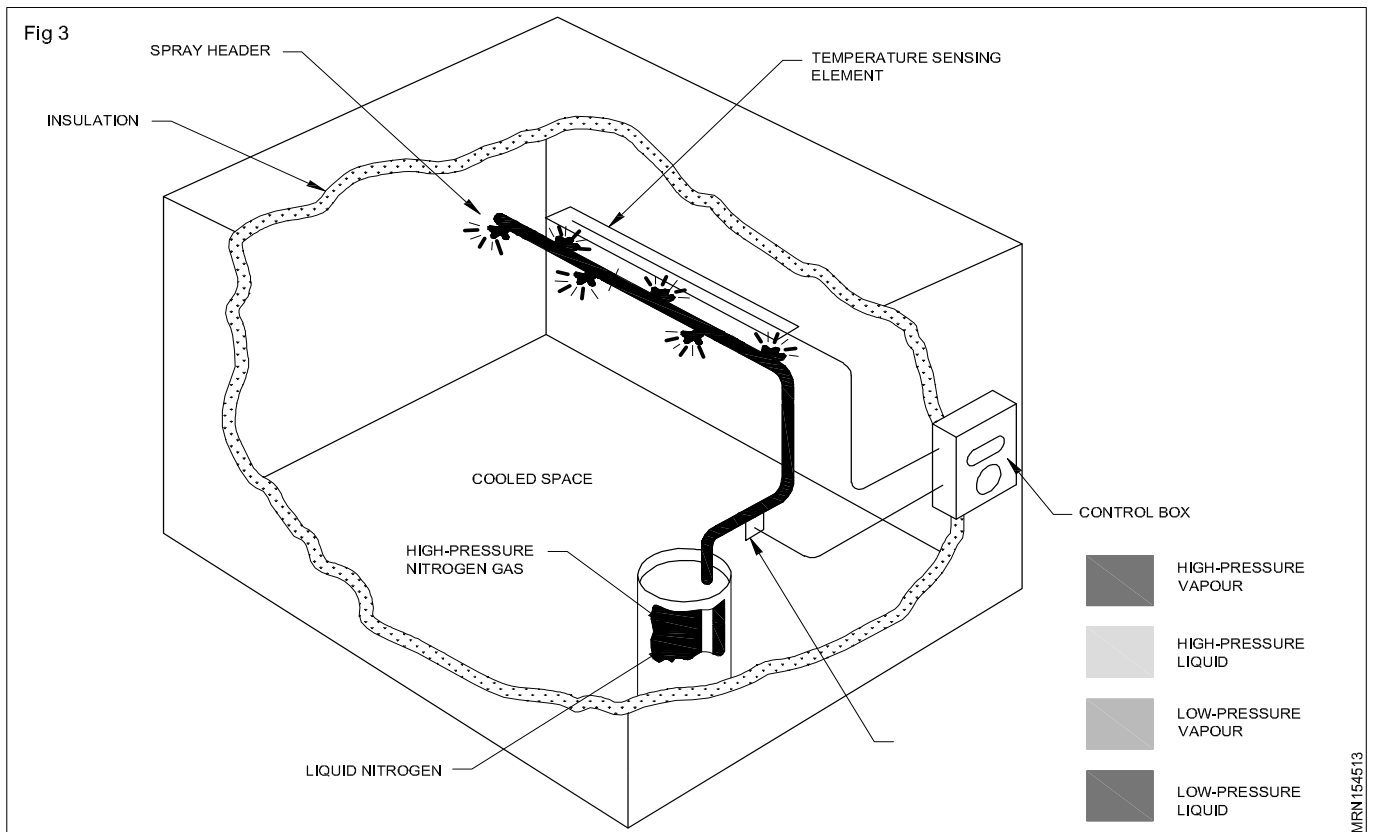
It is used on trucks and other vehicles in the transportation and storage of refrigerated or frozen foods. It has a heavily insulated space, which is cooled by either being surrounded by tubes carrying evaporating liquid nitrogen or by spraying liquid nitrogen directly into the space to be cooled. The liquid nitrogen (see fig) is supplied from a cylinder inside the refrigerated space is kept under pressure (200 psi).

An automatic pressure relief valve will open as a safety measure and allows the nitrogen vapour to escape, while the pressure exceed the relief valve setting.

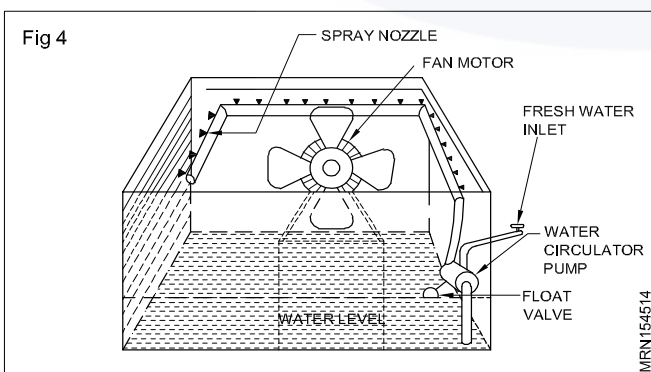
A temperature servicing element control box and liquid controls valve, control the flow of liquid nitrogen from the nozzles. They maintain the desired temperature inside the refrigerated space.

Water vapour system

It is one of the method to produce cooling. Generally it is used for air cooling in high temperature areas when some water will evaporate it absorbs heat and space is to be cooled. In construction it has a water tank, float valve, water pump, fan khass khass pad and oscillating motor. The water tank is located in the bottom and water level is maintained by a float valve. The water is circulated by a



water circulating pump. The pad are fitted on the three sides at the system when motor on the water pump sucks water from the tank and sprayed over the pad. In this time the fan draws warm air from through pads and water absorbs heat from air and air is cooled by evaporation process. The cold air is circulated in to the room. They call this system as air cooler or desert cooler. (Fig 4)



Vapour absorption system:

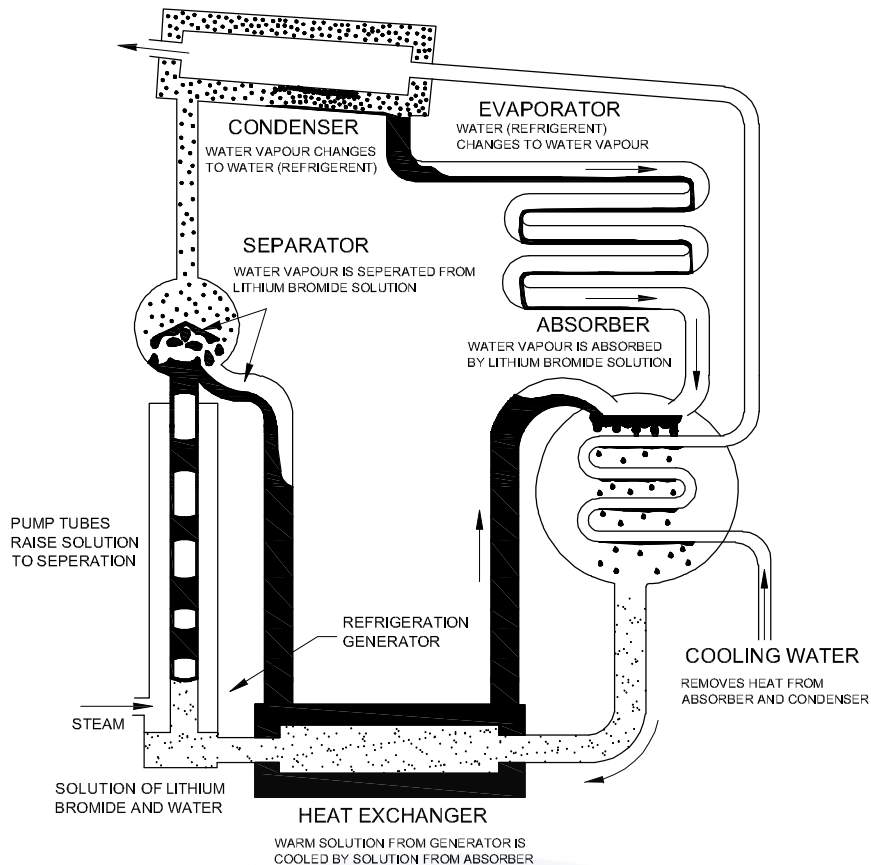
The absorption system is different from the compression system. It uses heat energy instead of mechanical to make a change in the conditions necessary to complete a refrigeration cycle (Fig 5)

The vapour absorption refrigeration is a heat operated system. It is similar to the mechanical vapour compression system. In both the systems we have the evaporator and condenser. In the absorption system the compressor is replaced by the combination of absorber and generator. A solution known as the absorbent, and the generator by a pump (solution pump). The absorbent in the absorber draws the refrigerant vapour formed in the evaporator maintaining a low pressure in the evaporator to enable the

refrigerant to evaporate at low temperature. In the generator the absorbent is heated, thereby releasing the refrigerant vapour (absorbed in the absorber) as a high pressure vapour, to be condensed in the condenser. The absorbent solution carries the refrigerant vapour from the low side (evaporator/absorber) to the high side (generator/condenser). The liquified refrigerant flows from the condenser to the evaporator because of the pressure difference between the two vessels, & refrigerant circulate through the system.

In the absorption system the refrigerant vapour from the evaporator is absorbed and condensed in the absorbent solution in the absorber from here the solution with the dissolved refrigerant is pumped up to the high side (generator/condenser). The refrigerant vapour is released from the absorbent solution by heating it in the generator. The energy input for this refrigeration cycle is the heat energy in the form of steam or hot water, instead of electrical (motor) or mechanical energy employed in the mechanical vapour compression system. The evaporator and absorber are interconnected so the refrigerant vapour formed in the evaporator is absorbed by the absorbent in the absorber to maintain the refrigerant vapour pressure in one evaporator at the low level required for continuous vapourization of liquid refrigerant to obtain refrigeration. To recover the refrigerant from the absorbent it is pumped from the absorber to the generator where it is heated using steam or hot water. In a domestic refrigerator of water ammonia system a kerosene flame or electric heater is used for the heating on getting heated the absorbent releases the refrigerant vapour as a high temperature/pressure vapour. It passes to the comparatively cooler condenser where it is condensed. The liquid refrigerant then passes on to the evaporator so completing the refrigerant cycle. The absorbent flows back from the generator to the absorber.

Fig 5



MRN154515

Heat is generated when the refrigerant is absorbed by the absorbent known as the heat of absorption or heat of dilution. Further the refrigerant vapour condenses in one absorbent solution and for this the latent heat of vaporization of the refrigerant vapour has to be removed. The absorber also needs cooling and for this the cooling medium (air or water) used for the condenser is first passed through the absorber and the condenser.

Ammonia - Absorption machines

This system employs ammonia as the refrigerant and water the absorbent.

Lithium bromide absorption system

In this system lithium bromide salt solution is employed as the absorbent and water as the refrigerant.

Three fluid absorption system

In three fluid absorption system a lighter gas compared to the refrigerant vapour is introduced into the system. The pumping system is eliminated. As such a complete leak-proof silent system is achieved. It consists of a generator where heat transfer with weak solution is bubble form moves up to the separator. The weak solution then returns to the absorber through a liquid seal, while the vapour condenses and passes into the evaporator through another liquid seal. The liquid seal prevents the light gas from escaping to the condenser side. Hence the condenser pressure corresponds to ammonia condensing temperature.

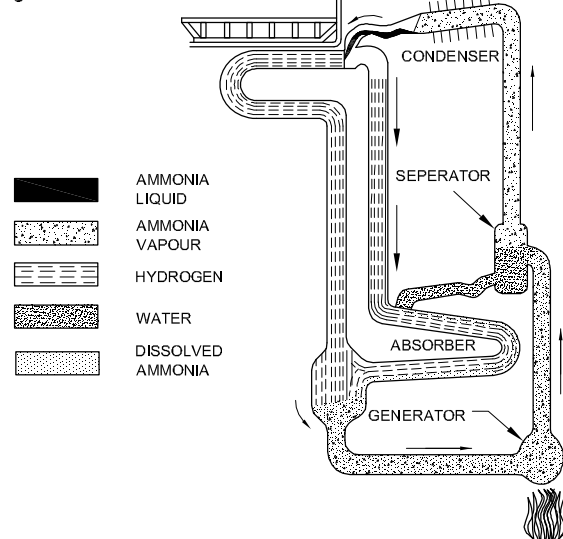
In the evaporator a light gas is charged such that the partial pressure of ammonia should give the desired evaporator

temperature. As ammonia vaporizes in the evaporator it gets absorbed on the other hand the light gas gets heated up by the weak solution from the separator. The warm light gas has tendency to move up and then come down with the ammonia vapour in order to have steady flow system. The absorber then supplies the strong solution to the generator completing the cycle. (Fig 6).

The actual three fluid system which was developed uses hydrogen as the lighter gas with ammonia water combination with molecular weight of ammonia as 17 (Fig 6)

This combination has worked very satisfactorily and as such commercial domestic refrigerators were manufactured on a mass scale basis.

Fig 6



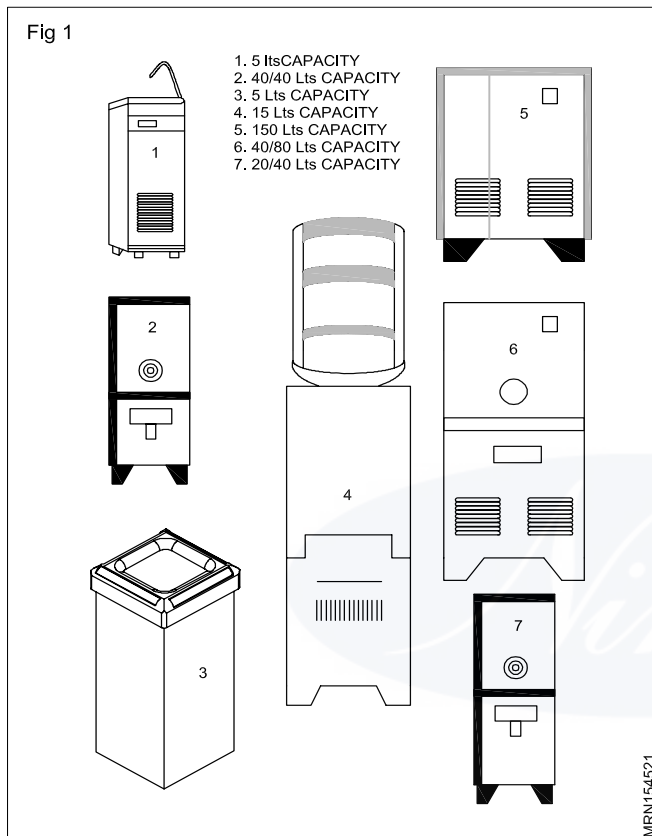
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Application of vapour compressin system

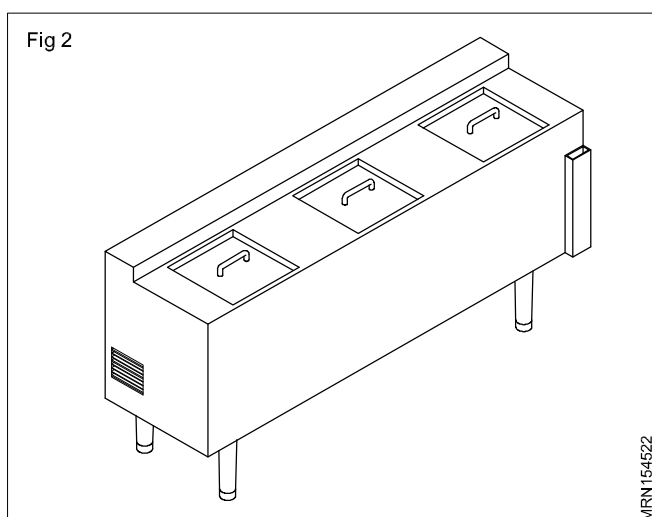
Objectives: At the end of this lesson you shall be able to

- explain the devices of vapour compression system.

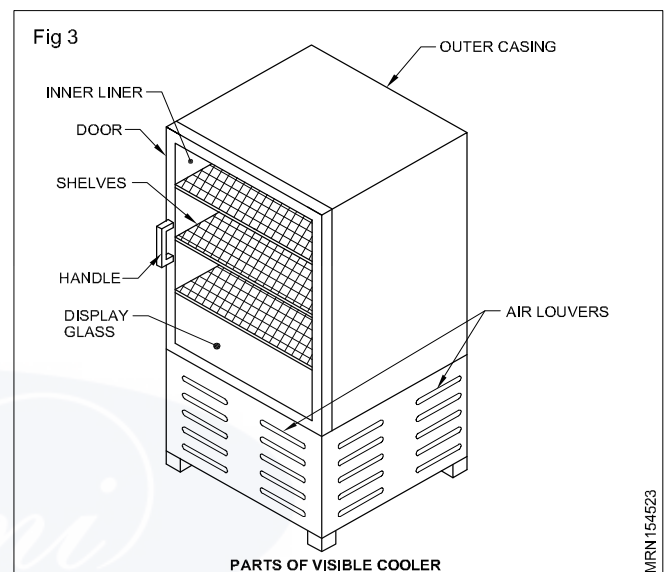
Water Cooler: Water cooler becomes an important aspect to quench thirst of human/people at various centre's such as restaurants, theatres, offices, commercial complex etc (Fig 1).



Bottle cooler: The bottle coolers are used in petty shops offices and commercial establishments. Direct expansion type bottle coolers are one in which the cooling coil is wound around the storage tank. The winding of coil in other type of bottle coolers are inside the storage tank.(Fig 2)

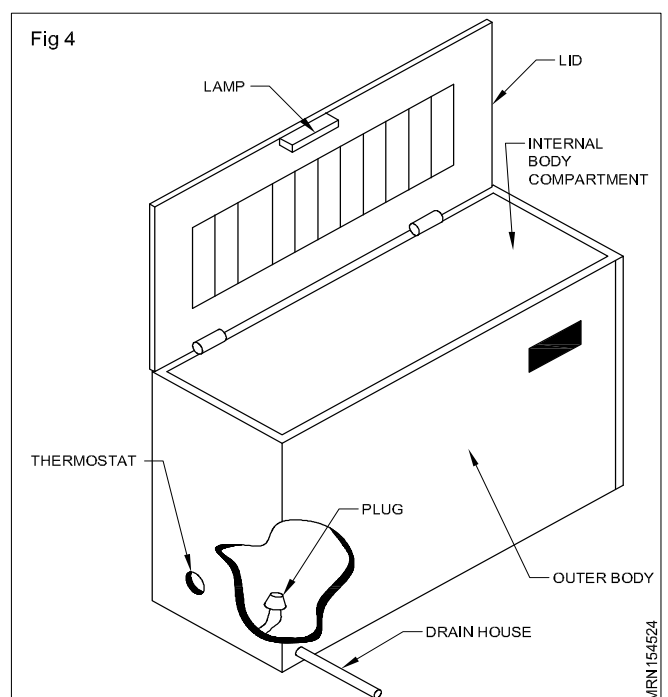


Visible cooler : Visible cooler is a type of refrigerated cabinet that displays merchandise as well as cools it. It is commonly used to keep cool the food products such as beverages, bakeries, chocolates, milk etc. Visible coolers are widely used in commercial establishments. These coolers are maintaining the temperature range between 0 to 10°C inside (Fig 3)



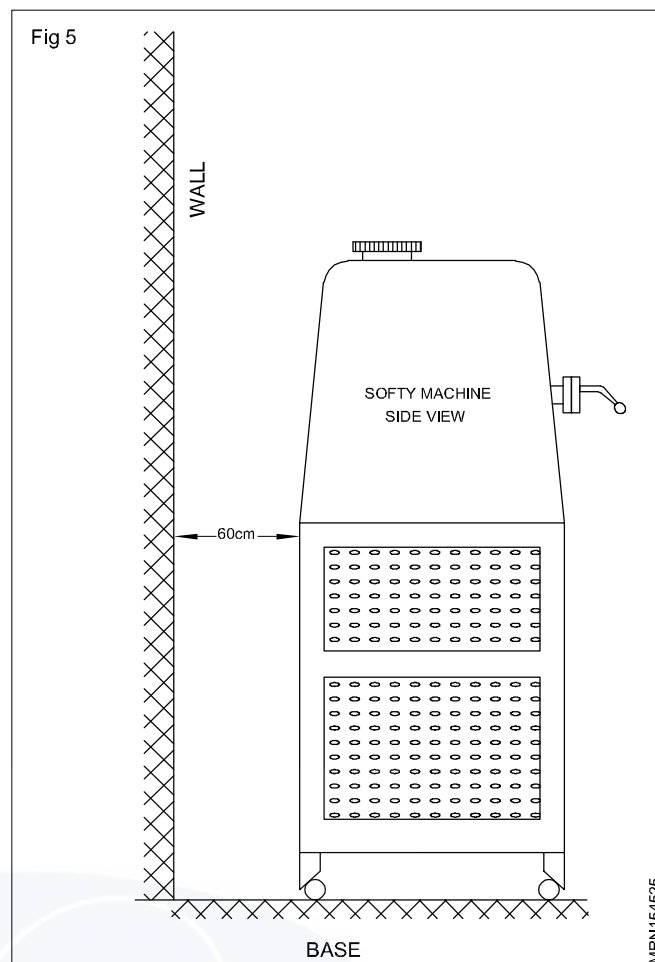
Deep freezer

Deep freezer are the refrigerated cabinets which are used to store the perishable food products (meat products dairy products etc) at the requires temperature levels (-10° C to 30° C) (Fig 4)



Softy machine

Ice cream mix containing milk cream, syrup and fruit or other flavouring ingredients. The mix is poured in the master tank and the churner is put on along with the refrigeration system and after about 15 minutes the outlet valve can be opened and check the sample. If found semi solid then the cones can be filled and served or it could be stored in a freezer. (Fig 5)



Study of vapour compression system

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

- explain vapour compression system.

Refrigeration: Refrigeration is the process of heat removal from a substance or from a space resulting in lower temperature below that of the surroundings.

Refrigeration cycle works in four phases.

- Compression
- Condensation
- Expansion
- Evaporation

Refrigeration cycle:

When the compressor starts to work, compressor suck the low temperature vapour from evaporator by suction line. Compressor compresses low pressure, low temperature vapour and it turns to high pressure and high temperature vapour. It delivers to condenser.

There it cooled by air or water. The vapour turns to liquid state. Expansion device meters out the required amount of refrigerant to evaporator. At this time due to expansion the refrigerant turn into low pressure low temperature liquid and vapour. The refrigerant absorb the heat from the space/substance to be cooled, vapourize and turns to low

pressure low temperature vapour. The same refrigerant returns to compressor suction for compression.

It is called refrigeration cycle.

Sub cooling

Sub cool the refrigerant liquid before it enters the expansion device sub cooling the liquid in liquid -suction heat exchanger, the temperature of the liquid at the inlet of the expansion valve can be brought down.

Super heating

Super heating is the heating at vapour above its vapourizing temperature. It takes place at the last coil at the evaporation.

Low side & high side of vapour compression cycle.

Accordingly to pressure difference a v.c. cycle have two sides for easy evaporation and condensation. The high side have half at compressor, discharging line, condenser liquid receiver, drier and half at expansion valve. The low side having half of expansion valve, evaporator accumulator, suction lines and half of compressor (refer fig 1 of exercise 1.4.05 typical compressors refrigeration system).

Fundamentals of Refrigeration

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

- study the refrigeration
- describe about the pressure and measurement.

Refrigeration : Refrigeration may defined as a process of heat removal from a substance or from a space resultng in lower temperature below that of the surroundings.

The refrigeration system works on vapour compression cycle.

The cycle works in four phases.

- Compression
- Condensation
- Expansion
- Evaporation

The carrier substances used to carry the heat is called a refrigerant.

Refrigeration is accomplished by various methods such as the vapour compression system, absorbtion system, steam jet refrigeration cycle etc.

Pressure measurment

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

- understand about the pressure and measurement.

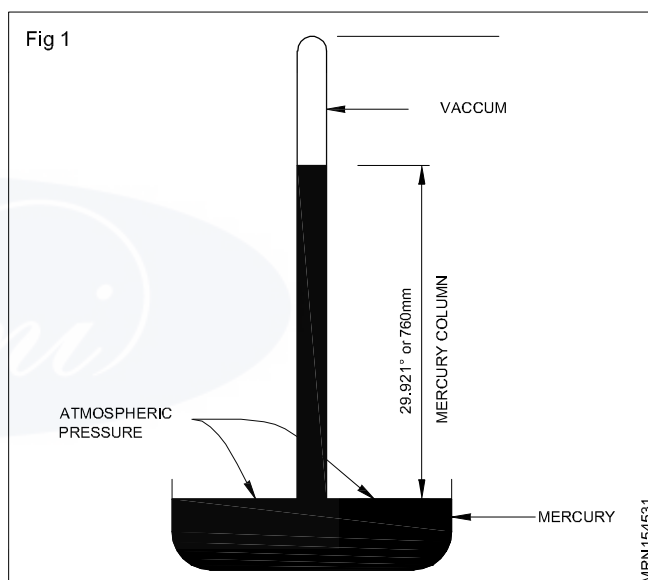
Pressure is the force exerted per unit area. Whenever a force is evenly distributed over an area the pressure at any point on the contact surface is the same and can be calculated by dividing the force by the total area over which the force is applied. Pressure is expressed in units, such as pounds per square inch (psi)pounds per square foot (p.s.f)grams per square centimeter, kilograms per square centimeter (kg/cm^2) kilograms per square metre(kg/m^2) etc.

We live at the bottom of a sea of air mixed with water vapour, some fifty miles deep. Both air and water vapour have weight. A column of this air one squar metre (one square inch) in cross section extending upwards to about 80km (50 miles) weighs 1.033 kg (14.696 lbs). So every square cm (square in) of land, sea, person or article bears aweight of 1.033kg(14.7lbs)so we say that the atmospheric pressure at the sea level is $1.033 \text{ kg}/\text{cm}^2$ [14.7lbs per square inch (psi)].

As we go up a mountain obviously the weight of the air exerted becomes less on a mountain using the same argument as we go down below the sea level. Say inside a mine, the atmospheric pressure increases. Roughly for every 300 metres (thousand feet) change i n altitude from sea level, the atmospheric pressure varies by about $0.035 \text{ kg}/\text{cm}^2$ (0.5psi).

Atmospheric pressure is measured with the help of a barometer (Fig 1).

A glass tube about 36" long and closed at one end is filled with mercury. The open end of the tube is covered with a finger and then inverted into an open dish containing mercury. When the finger is removed from the tube end, the mercury column in the tube falls down to a certain height leaving an almost perfect vacuum in the closed end of the tube. The pressure exerted by atmospheric air on the surface of the mercury in the dish causes the column



of mercury in the tube to stand. Therefore, the height of the mercury column in the barometer gives a measure of the atmospheric pressure. At sea level the mercury column will be 76 cm (29.921") The weight of 76cc (29.92 cu.in) of mercury is 1.033 kg(14.696 lb). Thus the atmospheric pressure at sea level can pushup a column of mercury in a vacuum tube to a height of 29.921" or 760mm. so we say that the atmospheric pressure at sea level is $1.033 \text{ kg}/\text{cm}^2$ (14.7 psi) or 760mm (29.921") of mercury, written as 760 mm or 29.921" Hg-'Hg' stands for the latin name hydrargyrum for mercury. Thus 1 psi pressure equals $29.921/14.696/14.696=2.036$ " (51.7mm)of the mercury column.

Thermo dynamic processes

When a substance, in any of the physical states solid, liquid or gas, is heated, it expands, i.e. its volume increases and thus its density decreases. Similarly when a substance is cooled, it contracts or its volume decreases. Water, however, behaves differently between the temperatures 0°C is heated, instead of expanding, it contracts. This contraction continues until the temperature of water reaches 4°C (39.2°F). Thereafter, further heating will result in expansion. Similarly, water at 5°C when cooled contracts, but on attaining 4°C (39.2°F), any further cooling will make the water expand and not contract until the temperature touches 0°C (32°F), solidification (formation of ice) occurs accompanied by further expansion, reducing the density of ice to a level below that of water.

As the temperature of water on the surface in a lake or ocean reaches 4°C, it becomes denser, and hence drops down, pushing the warm water from below. This process goes on till the whole mass of the water is at 4°C. When the surface temperature goes below 4°C, the surface layer becomes lighter because of expansion and thus does not go below and the top layers gradually freeze as the temperature falls to 0°C. Thus water in a lake or ocean freezes at the surface while the water below remains at 4°C. This property of water enables the aquatic animals to live comfortably even in the severest of winter.

The property of water enabling it to expand on solidification creates a tremendous expansive force, sufficient to burst water pipes in winter and in refrigeration water chillers.

Like solids and liquids, gases also expand on heating. However, there is a difference in the case of gas, because of its pressure. In the case of gas, there are three variables: (1) pressure, (2) volume and (3) temperature.

Before proceeding further on the properties of gas, it is necessary to understand the difference between gas and vapour. There is a certain temperature for every liquid/gas which is called its critical temperature any amount of increase in pressure cannot liquefy it. When the temperature is below its critical point, the gas can be liquefied without lowering its temperature by merely increasing the pressure. Vapour is defined as that which can be liquefied by only increasing its pressure, while to liquefy gas, not only an increase in its pressure but also a lowering of its temperature is required. For example, alcohol, petrol, refrigerants etc. are vapours hydrogen oxygen etc. are gases. Thus vapour behaves as gas above its critical temperature, and gas behaves as vapour below its critical temperature. In the following pages, the gas laws are described which a refrigeration mechanic should know. However, it should be understood that in

mechanical refrigeration our concern is with vapour and not gases, as they are close to the saturation curve.

BOYLES LAW

This law gives us the relation between pressure (P) and volume (V) when temperature (T) is kept constant. The law states that at constant temperature pressure varies inversely with the volume of the gas. In other words, if volume is increased two times, pressure comes down by half. This means that

$$\text{Pressure} \times \text{Volume} (P \times V) = \text{constant}$$

where, P : Absolute pressure

T : Absolute temperature

CHARLES LAW

- 1 This gives the relation between volume and temperature, with the pressure kept constant. The law states that at constant pressure, volume varies as the temperature of the gas, i.e.,

$$\frac{V}{T} = \text{constant}$$

- 2 Pressure varies as temperature if the volume of the gas is kept constant, i.e.,

$$\frac{P}{T} = \text{constant}$$

Combining these three laws, we have the general gas law, giving the equation,

$$\frac{P V}{T} = \text{constant}$$

where, P : Absolute pressure

T : Absolute temperature

SPECIFIC HEAT OF GASES

The quantity of heat required to raise the temperature of unit mass of a gas through 1°, with the volume of gas kept constant, is known as the 'specific heat at constant volume'. Again the heat required to raise the temperature of unit mass of a gas by 1° with the pressure remaining constant is called the 'specific heat at constant pressure'.

A gas undergoes a process when it passes from some initial condition to some final condition. These changes can occur in many ways and two are of interest to us, namely isothermal and adiabatic.

When during the process, there is no change in the temperature of gas, it is called an iso-thermal process.

Science related to refrigeration

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

- describe about work, power, energy, force, heat, temperature and pressure.

Work

Work (W) is a force (F) multiplied by the distance (D) through which it travels.

The unit of work is called the joule (J) The joule is the amount of work done by a force of one newton moving its point of application a distance of one metre.

Power

The rate of doing work is known as power.

$$Power = \frac{Force \times Distance}{Time}$$

Energy

Capacity for doing work is known as energy. There are two types of energy.

- 1 Potential energy
- 2 Kinetic energy

Potential Energy

The energy of a body by virtue at its position is known as potential energy.

$$PE = mgh.$$

Where M= mass

g = acceleration due to gravity

h = height

Heat

Heat is a form of energy. when we talk of heat we generally think of something hot.

That is we really think of temperature instead of heat for it is by its temperature that we recognize that an object has heat in it.

Temperature

Temperature is an indication of the level of heat in a substance. A substance at a temperature of 10°C has more heat in it than the same substance at a temperature of 0°C. The temperature of a substance however does not give an idea of the amount of heat the substance has.

A thermometer is an instrument used for the measurement of temperature. Two temperature scales are in common use today, the Fahrenheit scale and the celsius or centigrade scale.

Celsius (centigrade)

The melting point of ice is 0°C and the boiling point of water is 100°C. The interval between these two points is divided into 100 equal divisions and each division is called one degree celsius (1°C).

Fahrenheit Scale

The melting point, of ice is fixed as 32°F and the boiling point of water is taken as 212°F. The interval between the two is divided into 180 equal divisions and each division is called one degree Fahrenheit (1°F).

Absolute Temperature (Rankin)Scale

The absolute zero on this scale (expressed as °R) is -460°F. So to arrive at the absolute temperature of a substance expressed in °F, add 460 to the given temperature, e.g. absolute temperature of ice melting is 32°F+460=492°R.

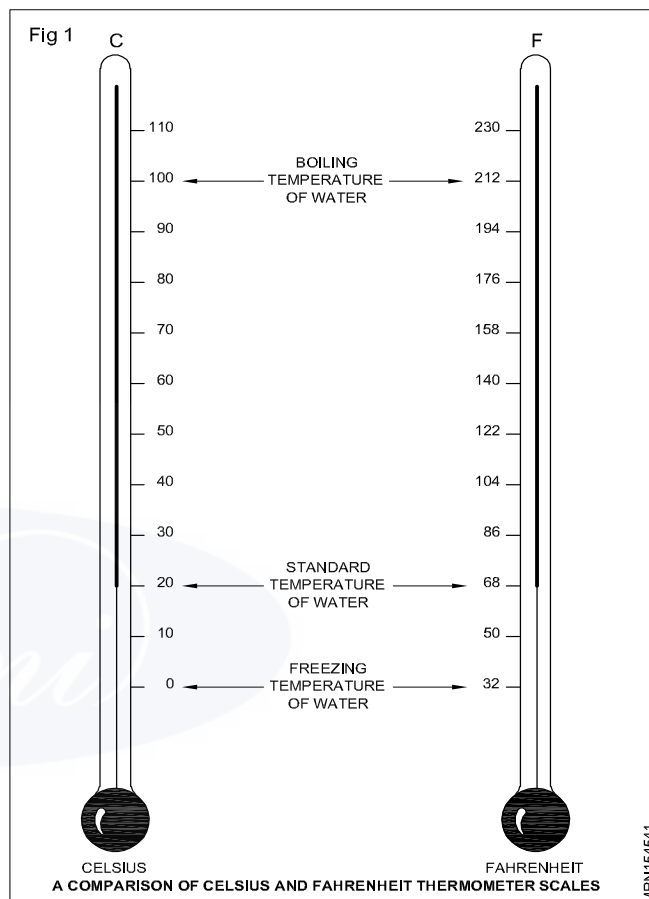
Absolute Temperature (Kelvin) Scale

The absolute zero on this scale is -273°C. So the melting point of ice on the Kelvin absolute scale is 0°C +273=273K.

Thermometer (Fig 2)

The most common thermometer scales are celsius or centigrade scale, and Fahrenheit. The two temperature determine the calibration of thermometer.

- the temperature of melting ice.
- the temperature of boiling point.



Units of heat

To measure the amount of heat, we have heat units-the British thermal unit (BTU) in the British system and calorie in the metric system.

One BTU is defined as the amount of heat to be added (removed) to raise (lower) the temperature of one pound of water by one degree Fahrenheit (1°F).

One calorie is the amount of heat to be added (removed) to raise (lower) the temperature of one gram of water by one degree celsius (1°C). As calorie is a small unit, kilocalorie (KCal) is used.

One kilocalorie is equal to 1000 calories i.e., it is the amount of heat to be added (removed) to raise (lower) the temperature of one kilogram of water by 1°C.

Melting point

The temperature at which any solid melts into liquid or a liquid freezing to solid is called the melting point of that substance. The melting point of ice is 0°C.

Sensible Heat

When a solid is heated, it gets warmer. This heat can be felt by touching the substances or measured with a thermometer. Hence it is called sensible heat, i.e., heat that can be detected by the sense of touch. Let us again take the example of ice (water in solid form) at a temperature of -10°C . Ice at 10°C when heated, rises in temperature up to 0°C (32°F). The heat absorbed by the ice to raise its temperature from -10°C to 0°C is therefore sensible heat and it takes about 0.48 kcal of heat to raise the temperature of 1 kg of ice by 1°C or 0.48 BTU for 1 lb of ice through 1°F (0.48 is the specific heat of ice).

Latent Heat

Any further heat added to ice at 0°C changes the solid ice to liquid water. During this change of state, the temperature remains constant, i.e., 0°C (32°F). It requires a great deal of heat energy for this change of state, and the quantity of heat needed for the change is called latent heat of fusion. One kg of ice at 0°C requires about 80 kcal of heat for changing its state to water at 0°C (144 BTU per lb of ice).

The liquid water at 0°C (32°F) when heated rises in temperature, taking sensible heat (one kcal for one kg of water for 1°C rise or one BTU for one lb of water for 1°F rise in temperature). This holds true up to 100°C (212°F). At 100°C (212°F) any further addition of heat does not raise the temperature of water, but instead goes to change the liquid water to its gaseous form, namely steam. This heat

is called latent heat of vaporization'. One of water requires 538.75 kcal of heat to change its state from the liquid to the gaseous state at $100^{\circ}\text{C}/212^{\circ}\text{F}$ (970 BTU/lb of water).

Specific Heat

The heat required to be added/removed to raise/lower the temperature of unit mass of a substance by unit degree varies from substances to substance. Water required the highest amount of heat as compared to any other substance. The heat required to raise the temperature of unit mass of a substance by unit degree as compared to that required by water is the 'specific heat' of that substance. Since by definition the heat unit (calorie/BTU) is the quantity of heat required to raise the temperature of unit mass of water (1gm/1lb) by unit degree ($1^{\circ}\text{C}/1^{\circ}\text{F}$), the specific heat of a substance is the heat required (calorie/BTU) to raise the temperature of its unit mass (1gm/1lb) through unit degree ($1^{\circ}\text{C}/1^{\circ}\text{F}$).

Super Heat

Let us assume that the cylinder in our example had only a very small quantity of R-22 liquid and that even the last drop of liquid had boiled off just when the temperature touched 32.2°C (90°F). At that time the pressure would have been 11.8 kg/cm²G (168.4 PSIG) - the saturation pressure at 32.2°C (90°F). Any further increase in the temperature of the cylinder above 32.2°C (90°F) will only heat up the vapour inside the cylinder.

Difference between Heat and Temperature

Heat	Temperature
It is a form of energy.	This tells the state of heat.
Its unit is calorie.	Its unit is degree.
Heat is measured by calorimeter.	Temperature is measured by thermometer.
By adding quantity of heat of two substances, their total heat can be calculated.	By adding two temperatures we cannot find the temperature of the mixture.
By heating a substance the quantity of heat is increased regardless of increase in temperature.	Two substances may read the same temperature though they might be having different amount of heat in them.

Sub-Cooling

If the temperature of the refrigerant liquid is less than its saturation temperature, the liquid is said to be in sub-cooled condition. If the pressure of a liquid, say R-22, is 13.8 kg/cm²G (195.9 PSIG) from the tables we can find that its saturation temperature is 37.8°C (100°F). But if the liquid is cooled to 35°C (95°F) without allowing the pressure to drop down below 13.8 kg/cm²G (195.9 PSIG) by some means, the liquid is said to be sub-cooled by $37.8-35=3.8^{\circ}\text{C}$ ($100-95=5^{\circ}\text{F}$).

This condition can exist at the bottom portion of a condenser or in the liquid line where a heat exchanger is used. The pressure will be kept constant in the condenser by the compressor. The liquid can get sub-cooled below the saturation temperature in the condenser because the temperature of the water/air at the inlet to the condenser is low. In the liquid suction heat exchanger the liquid gets sub-cooled below the saturation temperature because of

the cooling of the liquid line by the cold suction vapour.

As it is obvious, the pre-requisite for the sub-cooling of a liquid and the super heating of a vapour is that the liquid and vapour should not be in contact with each other. Liquid sub-cooling is obtained in water-cooled and air-cooled condensers which have separation arrangement between liquid and vapour. Also, the liquid can get sub-cooled in the condenser as it is moving away from the point of contact with the vapour. Likewise the suction vapour gets superheated in moving away from the point of contact with the liquid in the evaporator.

Saturation temperature

In a closed container such as a cylinder if a quantity of refrigerant is available in the liquid form, a pressure gauge connected to the cylinder will show a pressure corresponding to the saturation temperature of the liquid. This temperature will be the same as the

Study of tube cutting bending, swaging, flaring and pinching technique

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

- explain about the types of tubing
- study of tube cutting and bending
- explain swaging and flaring
- study of pinching technique.

Types of tubing: Most tubing used in refrigeration and air-conditioning is made of copper. However some aluminium, steel, stainless steel and plastic tubing is being used. All tubing used in air-conditioning and refrigeration work is carefully processed to be sure that it is clean and dry inside.

The following are the applications of each type of tubing.

Soft copper tubing: It is used in domestic work and in some commercial refrigeration and air-conditioning work. Since it is annealed (heated and then allowed to cool) it is flexible easy to bend and flare. It is most often used with flared fittings, clamps and brackets because it is easily bent.

It is sold in rolls of 25, 50 and 100 feet long sizes, most commonly used are 3/16"(4.5mm), 1/4"(6mm), 5/16"(7.5mm), 3/8"(9mm), 7/16"(10.5mm), 1/2"(12mm), 9/16"(13.5mm), 5/8"(15mm) and 3/4"(16.5mm) in outside diameter.

Hard drawn copper tubing: This is used in commercial refrigeration and air-conditioning application only. It should not be bent. Use straight lengths and fittings to form necessary tubing.

Copper tube sizes used in refrigeration work, both soft and hard drawn sizes are the same as the measurements listed in table. OD size for this tubing is the actual outside diameter of tube.

Steel tubing: Some thin wall steel tubing is used in refrigeration and air-conditioning work.

Copper or brass tubing should not be used with R717 (Ammonia). Here steel tubing is essentially used.

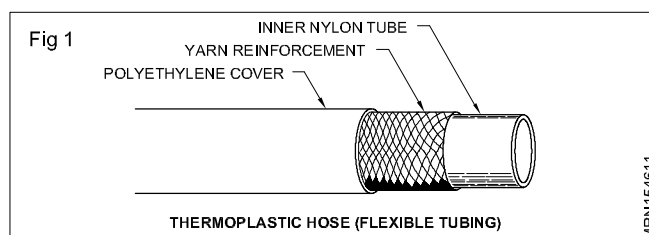
It is also available in all sizes as copper tube.

Stainless steel tubing: It is strong, very resistant to corrosion and may be made easily connected to fittings by either flaring or brazing. It is often required in food processing like ice cream manufacture, milk handling system and the like.

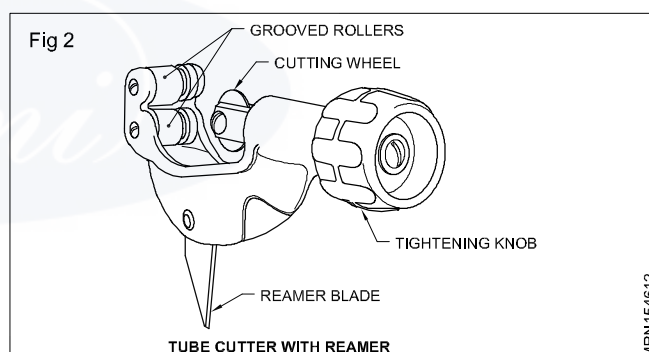
Plastic tubing: In general polyethylene tubing is not used in refrigerating cycle. It can be easily cut with a knife. It may also be easily bent. In cold water lines and in water cooled condensers to carry out the water and acid cleaning this is most suitable.

Flexible tubing (Fig 1): In many refrigeration and air-conditioning applications the liquid lines and suction lines must be flexible. It is very well suited in motor vehicle air-

conditioning. Hose for this purpose is usually made from a variety of special materials. Such materials do not age, remain flexible, allows very low leakage and they are easy to attach to fittings.



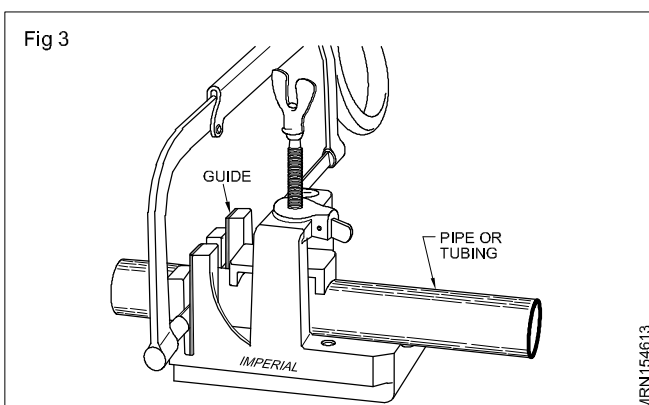
Tube cutting (Fig 2): To cut a tube use either a hacksaw or a tube cutter. The tube cutter is usually used on smaller, annealed (soft). Copper tubing while the hacksaw is preferred for cutting the larger hard copper tubing.



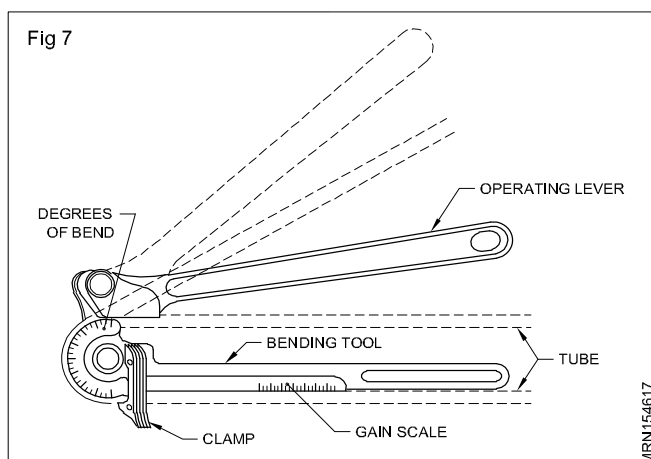
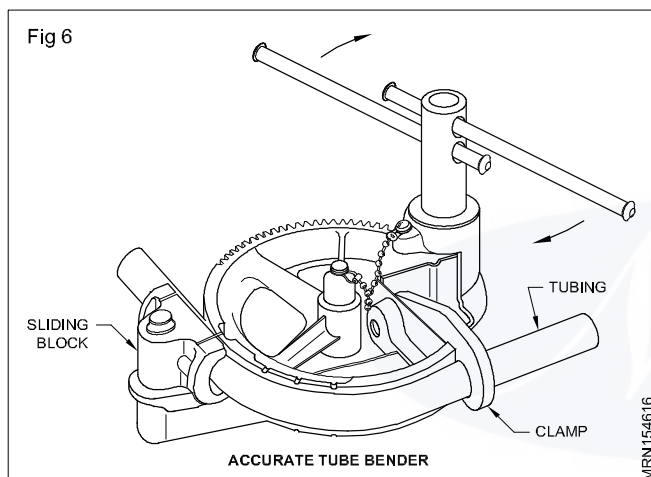
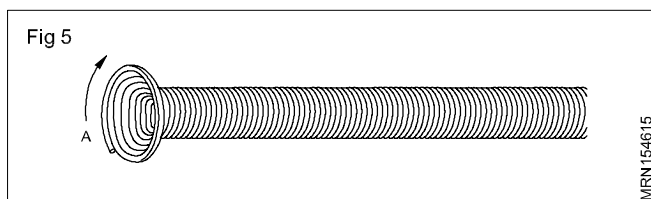
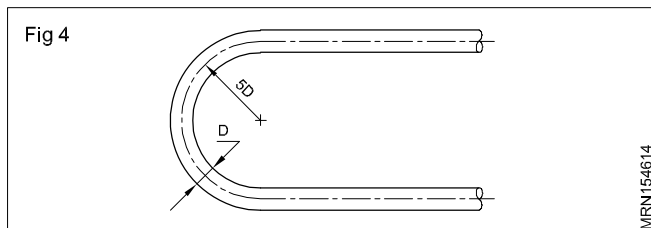
When cutting soft tubing with tube cutter of bigger size, hold the tubes in the vice with special guide. If saw is used a ware set blade of 32 teeth per inch will do the best job.

It is important that no fillings or chips of any kind enter the tubing.

A sawing fixture is used when a hand hacksaw is utilised to cut tubing. (Fig 3)



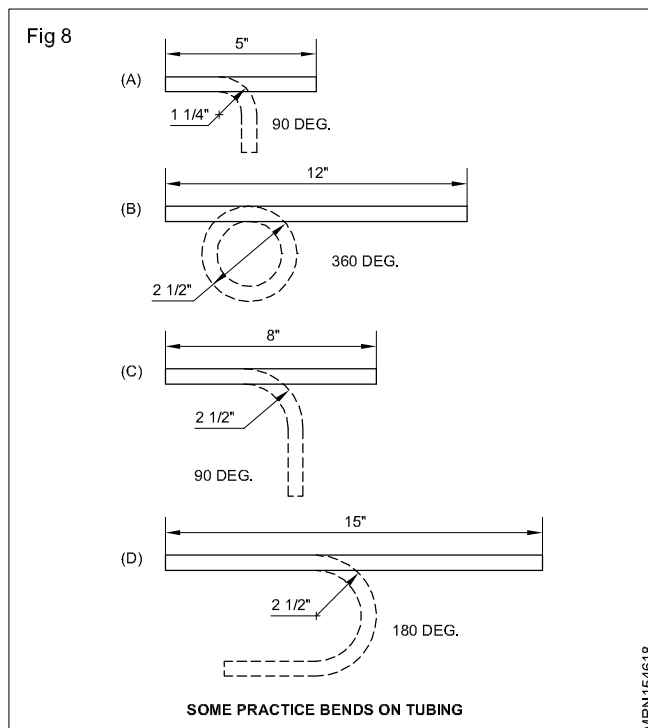
Bending tubing (Figs 4, 5, 6 & 7): The tubing should be bent so that it does not place any strain on the fittings after it is installed. The tubing at the bend should not be reduced in cross section area (kinked). Do not allow it to flatten or buckle. The minimum radius for a tubing bend is between 5 and 10 times the diameter.



An external bending spring for 6mm OD tubing may be used as an internal bending spring for 12mm OD tubing.

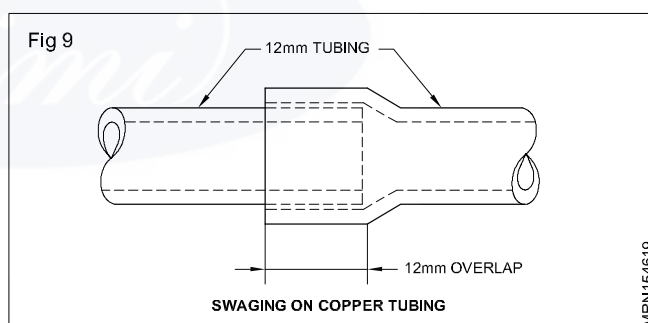
Bending springs tend to bind on the tubing after the bend. It may be easily removed by twisting the spring. This causes the portion on the outside of the bend to expand causing the part of the spring on the inside to contract.

A lever type bender for accurate bending to within 1/32 inch is shown in (Fig 8). It can be purchased in six different sizes to match the diameter of the tube to be bent.



Swaging on copper tubing: Swaging permits two pieces of soft copper tubing of the same diameter to be joined together without the use of fittings. It is more convenient to solder one joint than to make two flared connections.

The length of overlap of the two pieces of tubing is equal to the outside diameter of the tubing. (Fig 9)



Two types of swaging tools are commonly used. The punch type and the lever type. In both cases, different tool sizes are available.

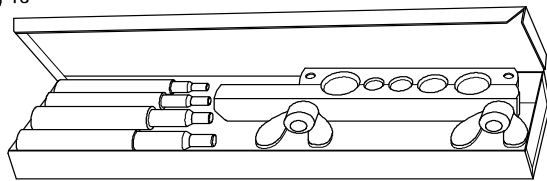
When punch type is used, the copper tubing is inserted into the correct hole size in the flaring block. Then a punch is inserted into the copper tubing and hammered down until it has entered the tubing the desired distance.

When using the lever type tool, the tubing is placed over the expander. Squeezing the lever expands the tube to the proper size.

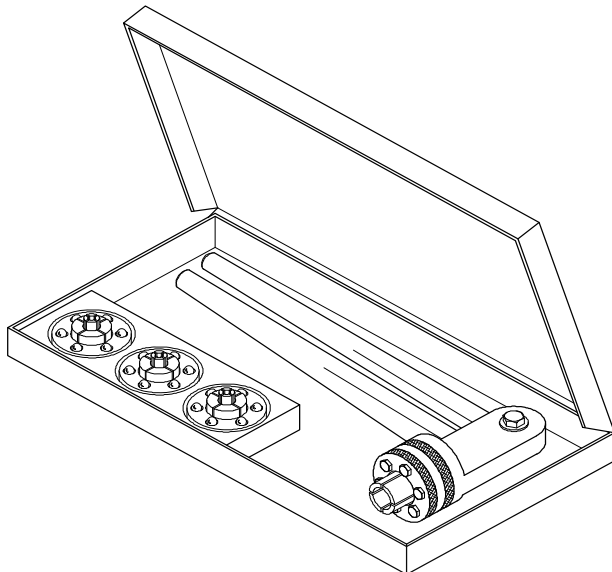
(Fig 10) illustrates the end of the tubing expanded and the pieces fitted together ready for soldering.

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

Fig 10



PUNCH TYPE SWAGING TOOL



LEVER TYPE SWAGING TOOL



TUBE EXPANDED AND FITTED TO ANOTHER
SWAGING TOOLS

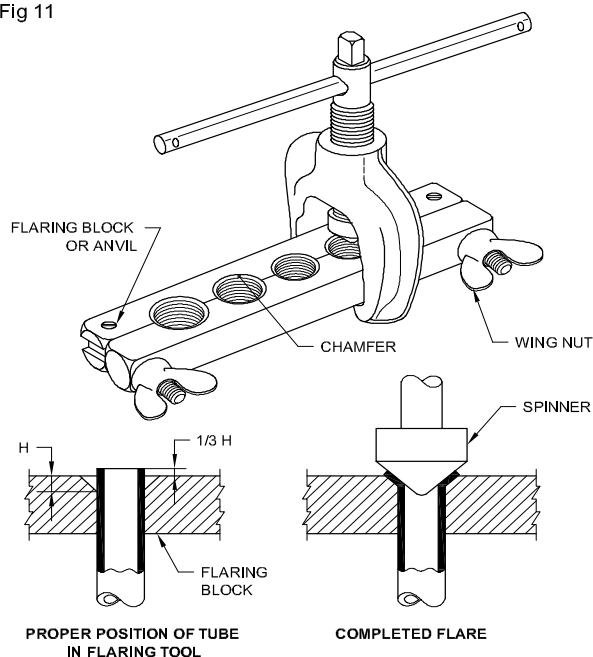
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Types of flaring: There are two types of flaring

- Single thickness flare
- Double thickness flare

Single thickness flare: It can be made on smaller size copper tubing. (Fig 11)

Fig 11

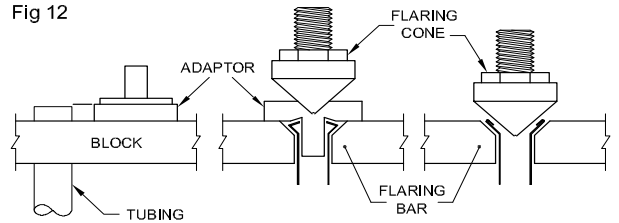


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Double thickness flare: Double thickness flares are recommended for only the larger size tubing 5/16 inch (9 mm) OD and over. Such flares are not easily formed on smaller tubing. The double flare makes a stronger joint than a single flare.

The Figs (12 & 13) shows some defects and correctly made flare. This also shows how defective flare made the fitting mismatched.

Fig 12

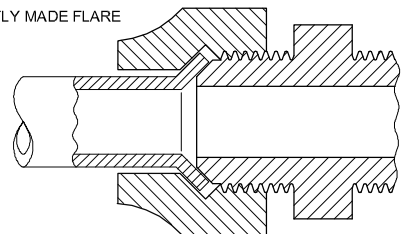


CORRECT PROCEDURE FOR FORMING DOUBLE FLARE

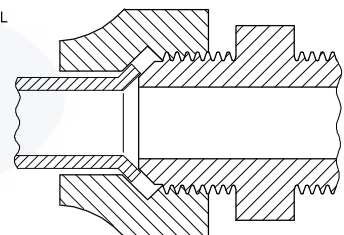
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Fig 13

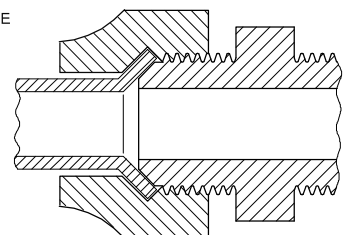
A) CORRECTLY MADE FLARE



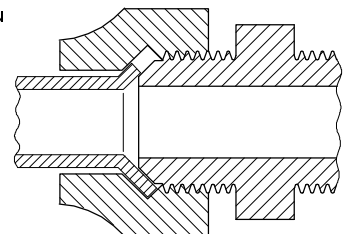
B) FLARE TOO SMALL



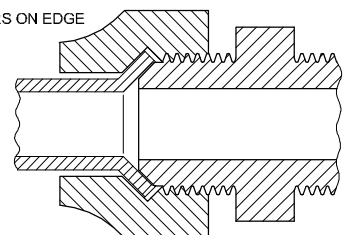
C) FLARE TOO LARGE



D) FLARE IS UNEVEN



E) FLARE HAS BURRS ON EDGE

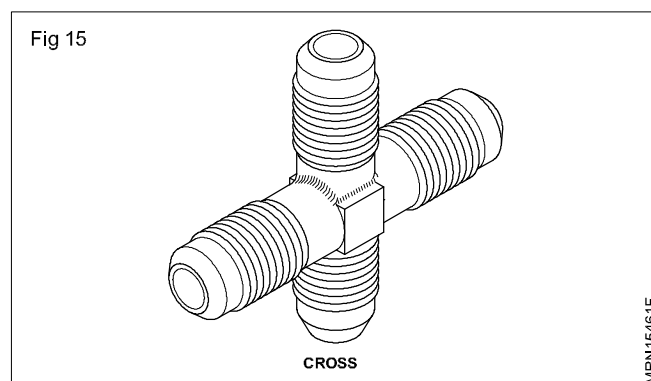
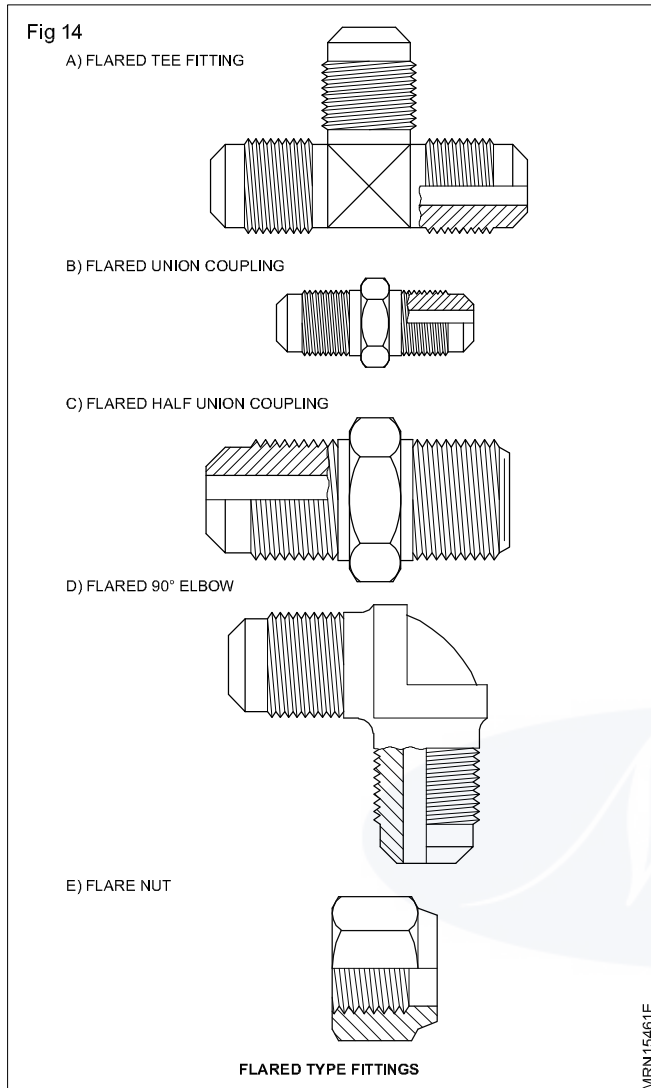


FLARED FITTINGS

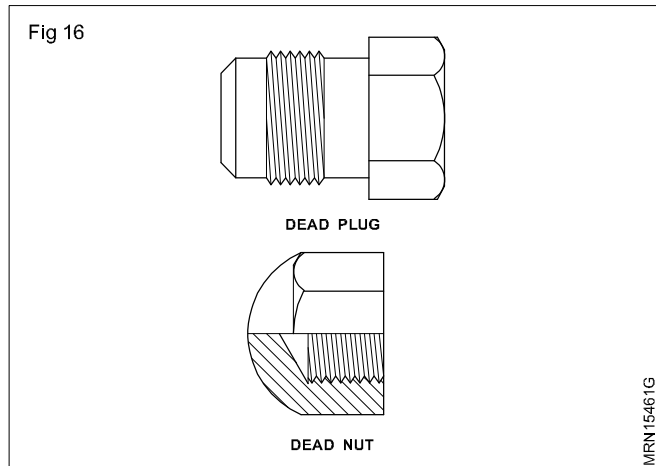
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Flared tubing fittings: To attach a fitting to soft copper tubing, a flared type connection is generally used.

The following are some of the more common flared type fittings. (Figs 14, 15 & 16)



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



Air pressure from

Air compressor — 150 PSIG

or

10 Kg/cm²

The gas which is employed can be used for testing.

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

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

Application & description: Pinch off tool is used whenever, it is necessary to seal off copper tubings, so that no pressure can pass from one side of the pinched tube to the other.

Figs (17 & 18) shows one type of the pinch off tool. It has screw type action shaft with a ball bearing on the end which presses against the tube. Slowly the handle of the tool is rotated clockwise. After pinching the tubing end is sealed by brazing.

When isolation of parts of the refrigeration system is required it is necessary to use pinching.

Brazing: The end of the tubing after pinching is to be braze.

Test for leaks: Check for the leaks with soap water solution, if there is any leak, rework is necessary.

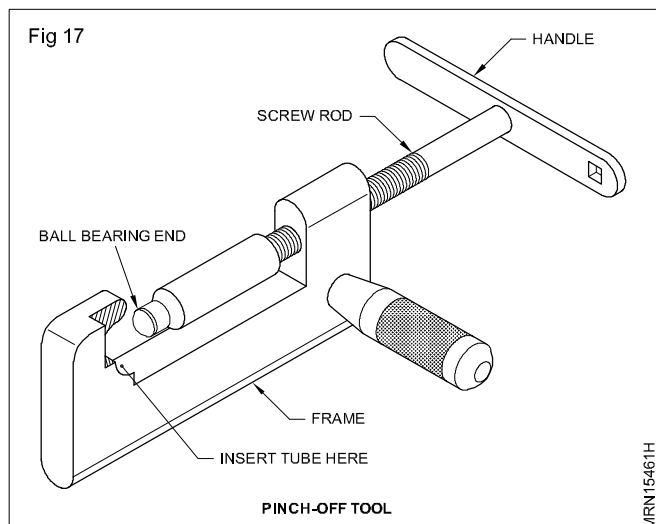
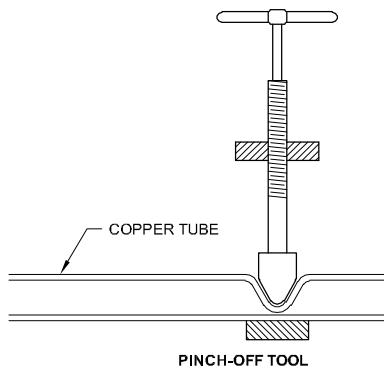


Fig 18



Ton of refrigeration

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

- explain about ton of refrigeration.

Refrigeration Capacity Measurements British Method (FPS)

The cooling effect is measured by a unit known as ton of refrigeration.

A refrigeration is obtained when one ton (2000lbs) of ice at 32°F is melted to water at 32°F in 24 hours. If it is remembered that the latent heat of fusion is 144 BTU per pound, it follows that the ton represents a unit cooling effect of 144 x 2000 (or) 2,88,000 BTU per 24 hours.

$$= \frac{288000 \text{ BTU}}{24 \text{ hours}} = 12000 \text{ BTU/ Hour}$$

$$= \frac{12000 \text{ BTU}}{60 \text{ Minute}} = 200 \text{ BTU/ Minute}$$

Thus for air conditioning calculation the size of the required condensing unit expressed in tons can be obtained by dividing the heat gain of the structure, expressed in BTU per hour by 12000.

Therefore

$$\text{Refrigeration (in tons)} = \frac{\text{BTU per hour heat gain}}{12000}$$

Convert kilo watt to tons

One refrigeration ton is equal to 3.5168525 kilo watts (or) 3.516 kw.

One kilowatt is equal to 0.28434517 RT

So the power P in refrigerations (RT) is equal to the power in kilowatts (kw) divided by 3.516

Example 10 kw to tons

$$\begin{aligned} P (\text{RT}) &= 10 \text{ kw} / 3.5168525 \\ &= 2.8434516 (\text{or}) 2.84 \end{aligned}$$

One ton is approximately 907 Kg and latent heat value 337 KJ/Kg. So one ton of refrigeration is 907 Kg into 337 KJ/ Kg ie 305659 KJ. One kilowatt is equal to 1 KJ/sec. Therefore one ton refrigeration capacity is 305659 by 24 hours and 36000 second. So ITR is 3054 KJ/sec is equal to 3.54 KW.

One ton of refrigeration is equal to 3024 kcal/ hour.

Joining tubes with lockering

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

- explain the principle of operation in lockering connection.
- selection of correct lockering size and material
- installing lockering fittings on Capillary tubes.

Principle of operation

Lockering is the only non brazing tool approved for seal systems. This is hermetically joins sealed system tubings. Without the need for a torch or solder.

When working with flammable refrigerant like R600a, the ability of join sealed system without flame is this lockering connection. This system is capable of making connection anywhere in the refrigerator and it is easy to learn even for new technicians.

The lockering system uses a fitting consisting of two lockerings and one tubular join to join two tube ends. Before compression, lokprep, anaerobic sealant (Fig 1) in applied to fill and seal microscopic imperfection in the tubing of lockering fitting (Fig 2)

Selection of correct lockering size and material:

It is important to select the appropriate size and material to ensure a long lasting, leak free joint.

It is highly recommended that technicians use a digital caliper set in the millimeter mode to determine tubing size. (Refer Fig 3).

According to the measurement select proper size of lockerings from the various sizes of lockrings. (Fig 4). Refer Fig 5 for joining tubes with lockering tool.

Measuring the Tube

Use the center of the inside measuring blades to measure the tube outside diameter (OD). Tubing can often be oblong or out of round. Taking two readings, 90 degrees apart helps ensure the appropriate size is selected.

It is critical to zero your calipers before taking any measurements. If you skip this step, your subsequent measurements may not be accurate. Measure the OD of the first tube and record.

Rotate the digital calipers, 90 degrees. Measure and record this second reading of the OD.

Add these numbers and divide by 2 to get the average OD.

Repeat these steps on the second tube to get the average OD.

Use the conversion chart on the following pages to select the correct size fitting.

If the OD measurement is between two sizes, try the smaller size fitting first. Tubes should be measured using a digital caliper set to the millimeter mode.

Example 7,8 to 8.2 D.D. Uses a 8mm Lockering connector
8.3 to 8.7 uses a 8.5. Lockring connector.

Installing lockring fittings on capillary tubes.

First prepare the connection with capillary tubes.

Then inset the capillary tube right through (Fig 6) bend the capillary tube slightly to creating a stop for the capillary tube. Pull the capillary tube back slightly (3 mm around). Allow single drop of lokprep where the tube meets the fitting. Tubing smaller than 6 mm apply lokprep while tubing is partially inserted in the lockering. (Refer 7)

Too much of sealant may block the ned of capillary tube. Rotate the fitting 360° to disperse lokprep evenly around the tubing. Now compress it for leak proof joint with hand lockering tool.

Now a days in flammable gases tubes like Hydro-carbon, these fittings are not used. Since if there in any leak, fire hazards may be created. Lockering was beneficial for use with traditional refrigerants, readucing repair time and defects.

Brazing Techniques

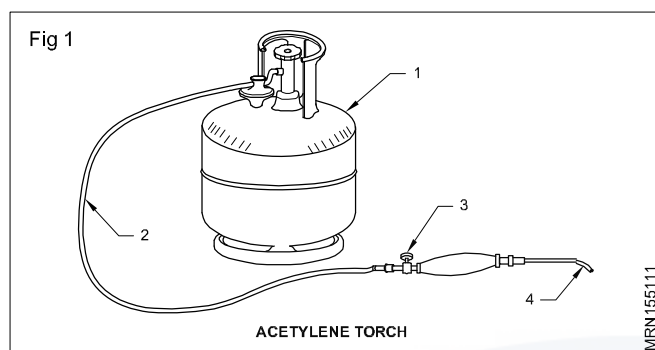
Objectives: At the end of this lesson you shall be able to

- explain the brazing technique
- study copper to copper pipe brazing swaged joint
- study braze copper with MS tube.

Explain the brazing technique

How to use a brazing torch

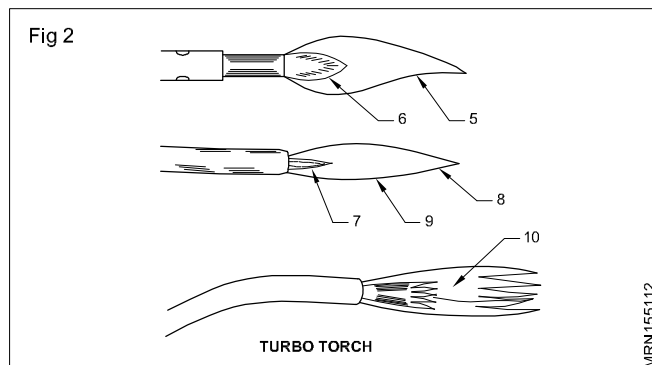
Acetylene torch (Fig 1): (Danger : Acetylene is very inflammable. Do not allow anyone to smoke while you are brazing)



- Connect the torch with a flexible hose to the gas regulating valve of the acetylene cylinder. Make sure that all of the connections are tight to prevent gas leakage. Check all connections for leaks with soap water before lighting the torch.
- Open the cylinder valve one turn only. Open the regulating valve fully. Open the torch control valve just enough to give a flow of gas. Light the escaping gas at the tip of the torch.
- Adjust the torch control valve to get the correct flame. The flame should be blue. It should have a sharp bright cone in the middle with a pale outer flame. If the flame is yellow more gas is required. Open the control valve.
- The size of the torch tip or nozzle determines the size of the inner cone. Use a cone size that gives the required amount of heat.

Propane turbo torch (Fig 2): (Danger : Propane is very inflammable. Do not allow anyone to smoke while you are brazing)

- This gives a smaller outside flame. The tip of the inner cone is much hotter than an acetylene flame of the same size. Always work with a smaller flame than acetylene.
- Connect, adjust and use this torch in the same way as acetylene described above. check all connections for gas leaks with soap water before lighting the torch.
- Follow exactly the instruction supplied with the torch.



- 1 This is the cylinder that holds the gas for brazing
- 2 Check the connections for leaks at each end of this hose with soap water.
- 3 Use this torch control valve to control the gas flow.
- 4 Fit a torch tip which gives the correct flame.
- 5 This is an acetylene flame suitable for pipe brazing.
- 6 & 7 The bright cone is the hottest part of the flame work with the tip of the cone.
- 8 This is an acetylene flame suitable for capillary tube brazing required.
- 9 The other flame should be pale tube. If it is yellow,
- 10 This is a prone turbo torch flame. The end tractions will tell you what size of flame to use.

Kerosene blow lamp

- This gives a larger flame than a propane or acetylene torch.
- When lighting, follow carefully the instructions supplied with the torch. Wherever possible light the blow lamp in an open space for safety.

Silver brazing: One of the best method of connecting copper pipes after swaging or by the use of coupling, in a leak proof manner is by silver brazing. By this method the copper pipes can be connected to the compressor, service valves and the other parts also.

Silver brazing can be easily done if the correct procedure is followed.

Clean the inside and outside of the tube end using sand paper or wire brush. Fit the joint closely and support the joint. Apply flux required for the brazing rod. (Flux is used to prevent chemical action during heating the metal. The flux used for soldering refrigeration fittings is made of alcohol and resin).

There are various silver alloys in the market. The rod used to join copper pipes is called 'copper to copper brazing rod'. These have 35 to 45 percent silver content. This material melts at 1120°F and flows at 1145°F.

Precautions: Do not apply the solder at the joint if it is not red hot

Any oxy acetylene torch is excellent heat source for silver brazing. While using blow lamp the joint is to be heated longer time.

To join copper pipe to steel pipe and any pipe to the compressor dome only oxy acetylene torch can be used. This torch can also used for refrigerator cabinet patch work.

While brazing keep away the flame from rubber plastic parts and insulating materials of the refrigerator or AC.

The pipes joined by brazing can be separated by heating it again.

Flux: Flux is a substance which works as an agent to help the solder to flow easily. It cleans the surface and prevents oxidation. Melting point of flux is much less than that of solder.

Various types of flux and their uses are given below.

Ammonium chloride NH_4Cl	– for soldering cast iron
Hydrochloric acid HCl	– for soldering G.I sheets
Zinc chloride ZnCl_2	– for soldering mild iron sheets

Tallow	– for soldering lead and electrical joints
Resin	– for soldering electrical joints
Phosphoric	– for soldering stainless steel

Braze a copper tube with swaged joint

Fit two pipes to braze. If it is a loose fit the joint will be weak. Insert the end of one pipe into the swage of the other. Apply a small amount of flux to the surfaces to be joined. With the help of blow torch heat the joint. The brazing rod starts to melt the joint is at the right temperature. The brazing rod must be melted by the heat. Complete ring of brazing material can be seen at the end of the swage remove the torch and allow the joint to cool.

Braze copper with MS tube: In most tube and fitting connections are made by either soldering or silver brazing. Soldering joints are used for water pipes and drains. Silver brazed joints are used for refrigerant pipes and tubing.

The best methods of making leak proof connection while providing maximum strength is to silver braze the joints. These joints are very strong and will stand up under the most extreme temperature condition.

An oxyacetylene torch is an excellent heat source for silver brazing. The proper silver brazing temperature will be indicated by the colour of green shade.

Gas Welding (Brazing) with oxy-LPG

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

- explain about O²- LPG flame
- state the importance of wetting
- describe about capillary action.

O² LPG Flame

Liquid petroleum gas (LPG) is fuel gas as combustion gas for welding. Oxygen (O²) is used as supporter of combustion gas for welding. The selection of the flame is based on the metal to be welded.

Natural flame is the most commonly used flame. The flame temperature can reach up to 2700°C to 2800°C. It is mostly used for gas cutting of steel, and for heating.

In air-conditioning field, to braze copper lines (tubes) soft neutral flame is used. The oxygen in the air alone can support the combustion (LPG) gas. Whenever the repair is done on the spot, the mechanic uses the LPG gas also.

When the control valve of LPG gas is opened the pressure of LPG gas pulls the natural air (surrounding) to the nozzle and if the nozzle is ignited the flame appears.

That temperature of the flame is enough to melt the copper at the same time the filler rod touches and joins the tubes by brazing.

Importance of wetting

Before welding or brazing we have to preheat the base metal. As we are heating the metal it gets its critical temperature. At that time a thin layer of liquid like acid forms on the metal. This process is called wetting. This fluid trapped on the metal surface as an adhesive bond.

At that moment only the brazing or welding joint will be a strong joint. If it is not wetted properly the brazing joint won't have strength. So wetting plays a very important role in welding or brazing.

Capillary action

When the metal is preheated it expands and opens the minute holes of the metal surface. While brazing these micro holes get filled up with filler material and perform strongly. The ability of a substance to draw a liquid upwards against the force of gravity. This capillary action causes a filler metal to be drawn into the space between work pieces in the brazing process.

Fundamental operations and simple analysis of V.C system

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

- explain about Vapour compression cycle
- describe about the terms and definitions on the study of Enthalpy (Ph), Entropy (Ts) relationship of an ultimate V.C system
- describe about pressure - volume (PV).

The study of V.C system is greatly simplified by the use of charts and diagrams in which the cycle can be graphically shown. The refrigerant undergoes the major processes of V.C system and analyse the performance improvements, though it varies with each and every refrigerant practically. There are two types of diagrams in use. They are:-

- i Pressure - enthalpy (Ph) diagram. (also known as - Mollier chart)
- ii Pressure - entropy (Ts) diagram

The most commonly used diagram (or) chart is, pressure-enthalpy (Ph) and is explained in this topic. The Ph. chart depicts the properties of refrigerant under varying conditions and facilitates the easy representation of the refrigeration cycle.

Basic thermodynamics:

Internal Energy

Every system has a particular energy at a specific state

due to its movement and position of atoms or molecules. This energy is called internal energy. Addition or removal of heat to this system varies the temperature and hence its internal energy. Say the system's energy is also changed from one state to another and it is called a process in the system. At a particular state initially the internal energy is denoted by 'U', (i.e) KJ or Kcal or BTU. The specific value of the substance is given by KJ/Kg or Kcal/Kg or BTU.

The change in internal energy is denoted by ΔU .

General gas Law:

As we have discussed the relationship among the pressure, volume and temperature of a gas by combining the Charles and Boyle's Laws in earlier studies, here, we do represent the following process diagrams that deal with internal energy, change in energy and work involved.

- i Pressure-volume diagram of constant pressure process

Note: The cross lined area between process diagram and base line represents external work (change in internal energy) done during the process.

ii Pressure-volume diagram of constant volume process

Note: There is no area between the process diagram and the volume axis, there is no work done during a constant volume process.

Enthalpy

It is a calculated property of matter that is sometimes very loosely defined as total heat content. More specifically, the enthalpy (H) of a given mass of material at any given thermodynamic condition is the summation of all the energy supplied to it to bring it to that condition from some initial condition arbitrarily taken as the zero point of enthalpy. Whereas the total enthalpy, 'H' represents the enthalpy of 'm' pounds, the specific enthalpy, h is the enthalpy of '1' pound. Since it is usually the specific enthalpy rather than the total enthalpy that is of interest, herein after the term "enthalpy" shall be used to mean specific enthalpy. Mathematically, enthalpy is defined as

$$h = u + \frac{Pv}{J}$$

Where h = the enthalpy in BTU/lb

u = the internal energy in BTU/lb

p = the absolute pressure in pounds per square foot

v = the specific volume in cubic feet per pound

J = the mechanical energy equivalent (778 ft.lb/BTU)

For heating and steam power using water as the medium, the accepted base temperature is 32°F (0°C). For refrigeration calculations, the base temperature is -40° (-40°C)

Entropy

It is also a calculated property of matter, (i.e) the heat available measured in BTU/lb/°F change for a substance. Entropy calculations are used generally used in research and engineering for very low temperatures with a base temperature lower than -40° (-40°C) may be selected.

Enthalpy and Entropy tables and charts have been worked out and are found in most engineering hand books which is prepared to avoid tedious calculations. Enthalpy diagrams deal with refrigerants properties and their processes and available for each refrigerant. We describe the P.h diagram to illustrate the V.C system and processes, that is of interest for RAC-fluids and refrigerants.

Analysis of vapour compression using Ts & Ph diagrams on refrigerating effect, compression work - C.O.P. Effects of super heating, sub cooling and operating pressures, their advantages and disadvantages.

Askeleton Ph chart is illustrating the three regions of the chart and the direction of phase changing. It is self explanatory conditions of a fluid.

The following chart illustrates a simple saturated cycle using R-134a

In simple theoretical saturated cycle, the following assumptions are made and in actual refrigeration cycle, how the performance is deviating based on processes of V.C system will be discussed.

Assumed saturated cycle or Theoretical V.C system is useful to understand a comparative study with the actual V.C. systems on different operating parameters on different refrigerants.

In saturate V.C cycle

- 1 No pressure drop in the evaporator.
- 2 The compression process is isentropic and there are no pressure drops at suction and discharge valves.
- 3 Refrigerant leaves the condensor and enters the expansion valve as saturated liquid at condenser pressure.
- 4 Refrigerant leaves the evaporator and enters the compressor as a saturated vapour at the evaporator pressure.

Note: These above conditions are varying in actual V.C system for every individual refrigerant.

The following cycles are represented in Ts and Ph diagrams. The pressure-enthalpy diagram is of our interest and the V.C system's operations and processes are to be discussed, here after.

Let T_1 , P_1 , h_1 and S be the temperature, pressure, enthalpy and entropy of the vapour refrigerant at point 1.

1 Compression process

- a Isentropic compression of dry saturated vapour.
- b Pressure increased from P_1 to P_2
- c Temperature increased from T_1 to T_2
- c Workdone (W) = $h_2 - h_1$

2 Condensing Process

High pressure and temperature of vapour refrigerant is condensed to liquid.

- a $P_2 = P_3$
- b $T_2 = T_3$

3 Expansion Process

High pressure liquid refrigerant expanded through expansion valve by isentropic process (Throttling Process). During this process no heat is absorbed (or) rejected by the liquid refrigerant.

- a $P_1 = P_4$
- b $T_1 = T_4$
- c Pressure is reduced from P_3 to P_4
- d Temperature is reduced from $T_3 = T_4$

4 Evaporation Process

Heat removed by the state, liquid_vapour mixture to vapour at constant pressure and temperature is the Refrigerating effect (R_E)

$$R_E = h_1 - h_4 = h_1 - h_{f3} \quad (h_{f3} = \text{Sensible heat of } T_3)$$

$$\text{COP} = \frac{\text{Refrigeration effect}}{\text{work done}} = \frac{R_E}{\text{Heat of compressor}}$$

$$= \frac{h_1 - h_{f3}}{h_2 - h_1}$$

Mass flow rate of refrigerant (m)

$$= \frac{\text{Refrigerating Capacity}}{\text{Refrigerating effect}}$$

$$m = \frac{\text{KW}}{\text{KJ / Kg}}$$

Power consumption = m x Work done

$$= m \times (h_2 - h_1)$$

Piston displacement of compressor = m x Specific volume of vapour refrigerant at suction.

A simple saturated V.C cycle operating at a vapourising temperature of 20° F and a condensing temperature of 100° F is given for the refrigerant - 134a.

Note: In actual refrigeration system, the conditions of pressure, temperature, enthalpy, refrigerating effect differ with each and every refrigerant. Some operating condition are already worked out and are available in table and chart forms.

- 1 The effect of super heating the vapour on suction line of V.C system
 - a Increase the refrigerating effect.
 - b Increase in specific volume.
 - c Increase amount of work done in the compressor.
 - d C.O.P is low. (Increase in refrigerating effect is less as compared to increased work done).
 - e Avoid liquid entry to compressor.
- 2 Effect of sub cooling the liquid in liquid line of V.C system
 - a Increase the value of C.O.P.
 - b Flashing of the liquid refrigerant is avoided.
 - c Correct sub-cooling requires optimum compression work.
 - d Increase the compression work because higher condensing pressure and temperature.
- 3 Effect of suction pressure in V.C system
 - a Evaporator pressure drops due to frictional resistance of internal tubes to the flow of refrigerant.
 - b Decreases the refrigerating effect
 - c Increases the compressor work.
- 4 Effect of discharge pressure in V.C system
 - a Discharge pressure increases due to frictional resistance to the flow of the refrigerant.
 - b Decreases the refrigerating effect.
 - c Increase the work required for compression.
 - d Effect of increase in discharge pressure is similar to effect of decrease in suction pressures.

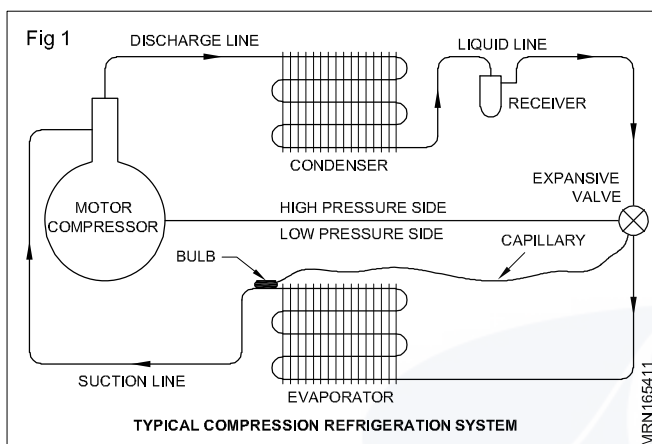
Conventional and frost free refrigerators

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

- explain the functions of all the parts and controls of a Conventional type refrigerator
- explain the functions of all the parts and controls of Frost free refrigerator
- list the specifications of Conventional and Frost free refrigerators
- distinguish between Conventional and Frost free type refrigerators.

Refrigeration: Refrigeration may be defined as a process of heat removal from a substance or from a space resulting in lower temperature below that of the surroundings

The refrigeration system works on vapour compression cycle shown below in (Fig 1).



The cycle works in four phases

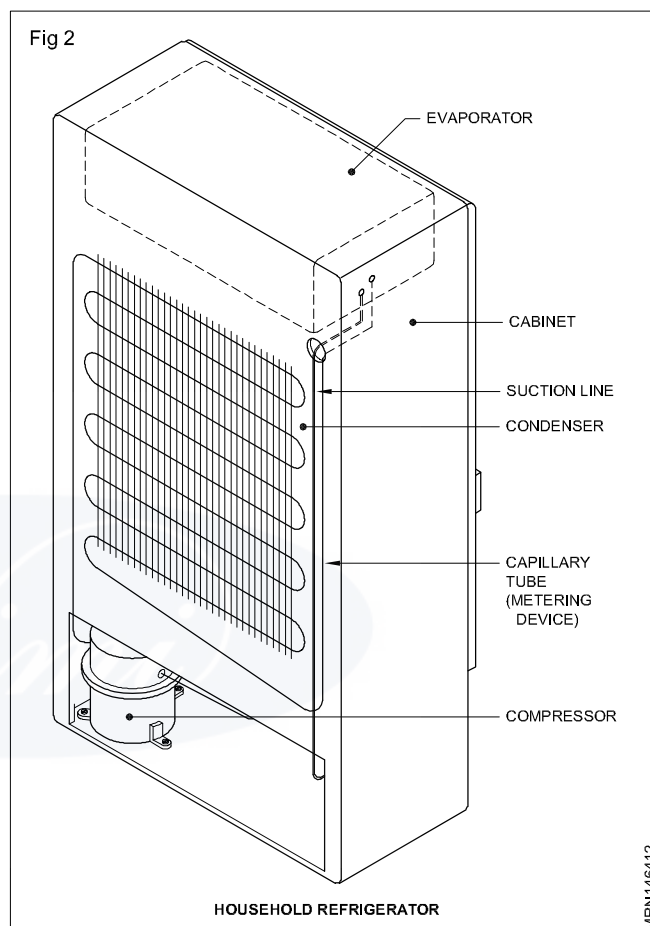
- compression
- condensation
- expansion
- evaporation.

Conventional refrigeration: The important parts of the refrigerator are shown here in (Fig 2).

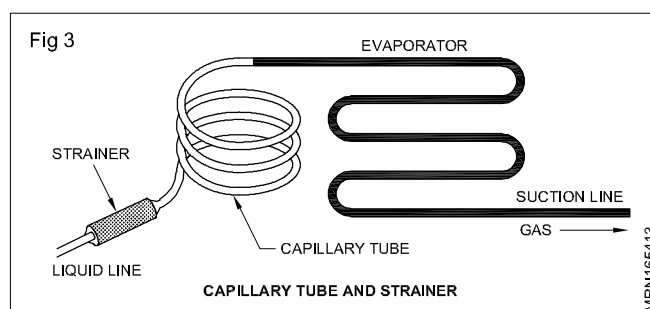
Compressor: The function of the compressor is to provide the necessary pumping action to the refrigerant. It draws cool refrigerant in through the suction line from the evaporator. It compresses it and discharge it into the condenser, where it is liquified. The compressed gas has rise in temperature and pressure at the time of entering condenser.

Parts of a conventional refrigerator (Domestic refrigerator)

- **Condenser:** The function of the condenser is to remove the heat carried by the refrigerant and return the refrigerant to the control enabling the system to repeat the cycle.
- **Receiver:** It is the reservoir for excess liquid refrigerant not being in the system. The receiver should have sufficient capacity to hold the total amount of refrigerant in the system.



- **Capillary tube or metering device (Fig 3):** It meters out the required amount of refrigerant to pick the heat from the evaporator. It consists of a long, small diameter copper tube. As the liquid from the condenser is pushed through a small passage way, the friction between the refrigerant and the tube causes pressure drop.



Controls of a Conventional refrigerators and Frost free refrigerators

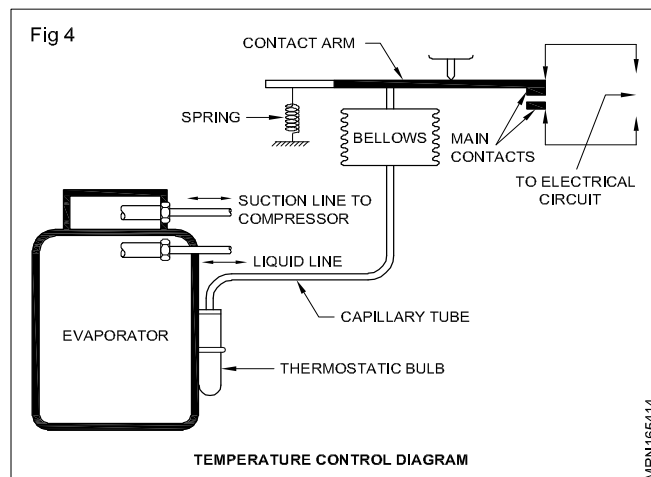
Capillary tube: It controls the refrigerant flow by metering out the required amount of it to pick up the heat in refrigerator and to regulate the pressure of the refrigerant by reducing the pressure of the refrigerant.

Thermostatic control: The common method of temperature control employed in house hold refrigerations units.

These are electro mechanical switches actuated by a temperature sensitive refrigerant sensor. It tells the cooling system when to run and when to shut off. The arrangement is shown in the (Fig 4). The bulb and the tube are charged with a highly volatile fluid. The gas expands and contracts in line with cabinet temperature. Corresponding pressure variations cause bellows to expand or contracts of a diaphragm to move and this movement on a temperature rise or breaks it on a temperature fall. Temperature settings can be varied by a regulating knob and thermostat operates at line voltage to run the compressor motor.

Starting relays: A protection device for the compressor. Further details can be studies in later chapters.

Suction line: The line through which refrigerant from evaporator to the compressor. This is towards the low pressure side of the system. This is made out of copper.



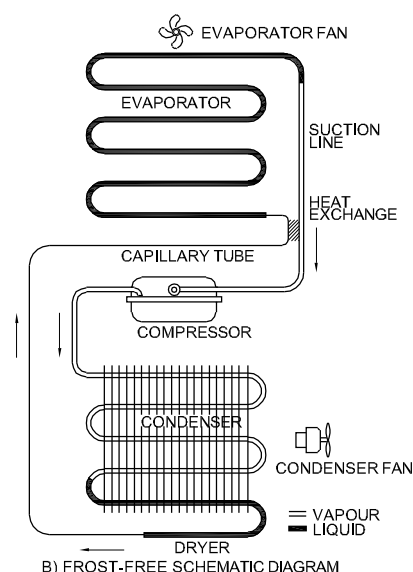
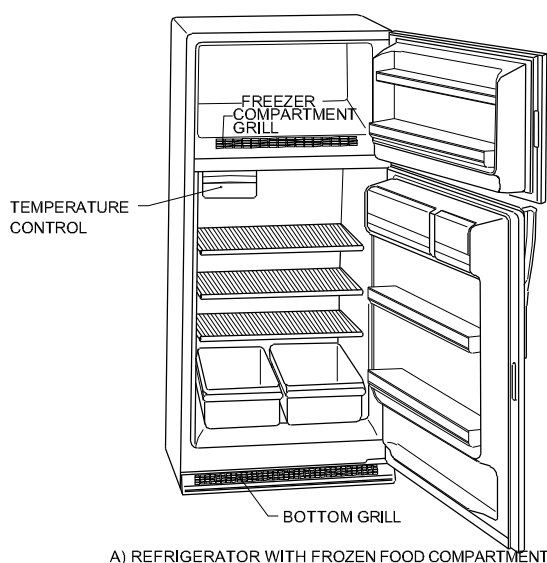
Discharge line: The line between compressor and the condenser is called discharge line, which is towards the high pressure side of the system.

Frost free refrigerator: It is a development over the Conventional refrigerator. The task of defrosting the evaporator is eliminated in this refrigerator. The evaporator is in the upper back part of the cabinet and the condenser is along the lower back part. A fan moves cold air from the evaporator in the frozen food compartment and another fan circulates room air. Through the grill at the bottom of the cabinet and over the condenser. The parts of the system is shown in Figs (5a & 5b). For functions of the parts refer to the parts of the domestic refrigerator.

Difference between the Conventional type and Frost free refrigerator

	Conventional type	Frost free type
1	Periodical cleaning of frost formation has to be made	The automatic defrosting is provided
2	Initial investment is less	Comparatively costly
3	Consumption of current is less	Consumption of current is more
4	Freezing time of a product in conventional is more	The freezing time is less
5	The cooling is not uniform cooling/freezing	You can expect uniform cooling
6	No fan is provided inside.	Two additional fans are used – evaporator fan – condenser fan

Fig 5



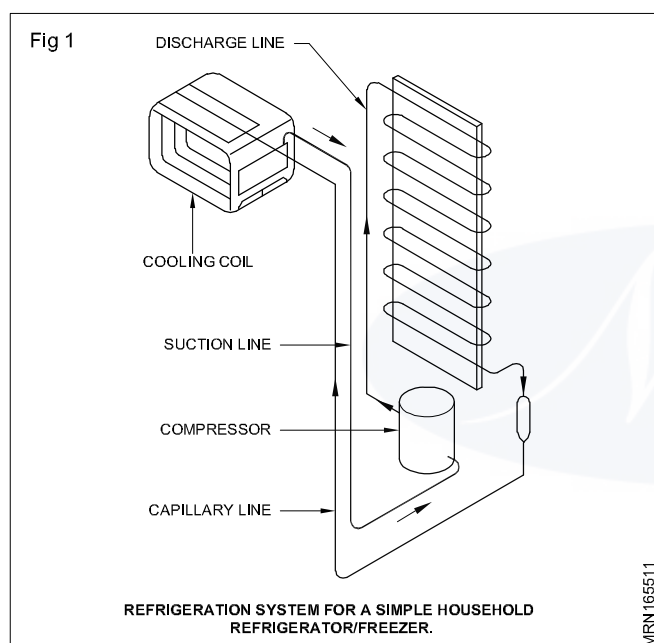
Components of Conventional type refrigerators

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

- explain refrigeration cycle in refrigerator
- explain preserve food by refrigeration
- describe the inside arrangements and manual defrost of the refrigerator
- explain the service and maintenance of the refrigerator.

Refrigeration cycle in refrigerator: The conventional type refrigerators mechanism is simple. A hermetic compressor placed in the bottom of the cabinet. The air cooled condenser (either plate type or fins type) is located normally at the back side of the refrigerator.

An evaporator is placed inside the top of the cabinet. These typical mechanism arrangement is called by the mechanics as skeleton of the refrigerator. Ref. (Fig 1).



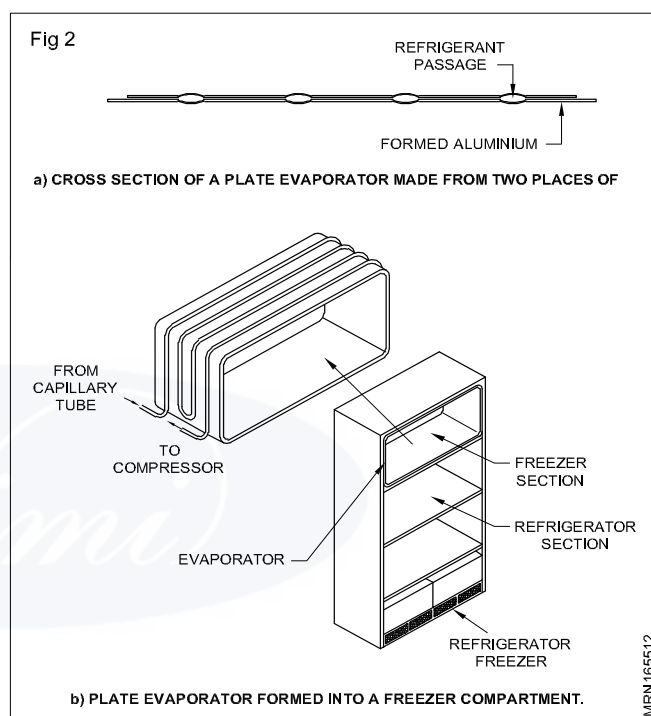
These arrangement can be fixed inside the cabinet of the refrigerator. When there is any major repair or work has to be carried out only the skeleton can be removed, behind the cabinet and shifted to workshop and the outer cabinet can make it to stay there itself. After rectifying the problems in the skeleton, it can be fixed back to the cabinet.

The cycle operation is the compressor, compress refrigerant vapour to a high pressure and temperature, then the vapour flows into condenser by discharge line: when it passes through the condenser, due to natural draft air cooling vapour condense to liquid.

The liquid is purified through filter drier and enters to the capillary tube. Here the pressure as well as temperature of the refrigerant reduces and increase the heat absorbing ability of the liquid refrigerant. The low pressure and temperature liquid enters the evaporator.

As the refrigerant boils and absorbs heat in the evaporator turns to vapour state. There vapour is drawn by suction line, come back to the compressor for recycle.

The evaporator of the conventional refrigerators normally plate type coils. The freezer section inside a refrigerator is actually a plate type evaporator formed in the shape of a box. (Fig 2 a&b)



Two separate embossed aluminium plates brazed together to form a plate with internal passages for the refrigerant.

The earlier methods are the evaporator coil will be brazed on the plate type box of the freezer.

Preserving food by refrigeration: Food products like vegetables, fruits etc last longer when kept at temperature just above freezing. The low temperature slows down the oxidation of the food, reduce the growth of bacteria in the living cells and fibers.

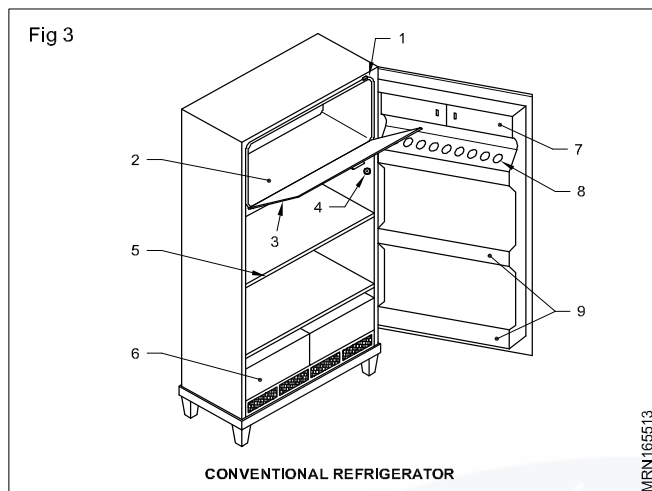
The air inside the refrigerator is dry. When the refrigerator is in operation, the moisture in the food containers should be kept covered. Since these moisture will collect and condense on the evaporator surface and make thick coating of ice frosting.

Unfrozen meat and fish should be stored at close to 0°C as possible. Fruits and vegetables should be washed and kept dry to keep in refrigerator.

It is very important the frozen foods should be covered with moisture proof containers (which is in the freezer). Hence there is more possibilities for the moisture in the frozen food

get condensed in evaporator surface and start freezing. It will affect the heat transfer of the evaporator coils and the refrigerator has to run for long time or continues running.

Inside arrangements and manual defrost of the refrigerator: The evaporator at the top of the cabinet and has a place to store food that is called freezer (2). (Fig 3). It is provided with the freezer door (3) normally spring tension close, for cooling not to escape. The light switch (1) is located on the top right corner, sometimes at the side makes the inside light to glow when we open the door. While the door is shut, the door will press the switch and the light is put off.



A simple method of defrost the frosting in evaporator is just to put off the unit. When the temperature raises the frosting ice will start melting and collected down the tray by a drain pipe, it will go to the tub kept on the compressor behind the refrigerator. These water will get vapourize while the compressor is running due to the heat of the compressor.

If you want the defrosting to be done soon, can keep warm water (with the metal container) inside the freezer and keep the refrigerator door open (while the fridge put off).

Modern refrigerators have manual defrost switch provided with (4) thermostat knob itself. When you push the center red button it will disconnect the supply and the refrigerator will stop. After the ice melted with raise in temperature the contact of the thermostat become close position and the refrigerator starts immediately.

In the cabinet shelves (5) we can place the food items or other things which need less cooling. At the bottom of the inner cabinet the crisper (6) or vegetable tray is provided, covered with glass plate. It will reduce the aspiration (removal of fluid) from the fresh vegetables. Therefore crisper is used exclusively to preserve vegetables.

Some additional storage facilities are provided by the door.

Butter conditioner is a container with sliding door to keep butter

Eggs shelf provided with a shape for the eggs to keep and

Cool drinks rack to keep cool drinks, ice water bottles and medicine bottles.

Service and maintenance of the refrigerator: For a proper function of the refrigerator, atleast twice a week it should be de-frost. After complete defrost the inner and outer cabin can be cleaned. This can be done by the users or customers themselves.

As per the components cleaning and service whenever necessary it has to be carried out by the refrigeration mechanic.

Proper maintenance will extend the life of the refrigerator and it will give best performance.

Relay and Over load protector

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

- explain types of relays and functioning
- explain overload protector
- explain start winding and run winding and their uses.

Starting Relay: Starting relays are found on the outside of hermetic system.

These relays are usually one of the following types.

- Current (Magnetic) [used for refrigerator compressor]
- Potential (Magnetic) [used for air-conditioning compressor]
- Solid state (electronic) or PTCR (used for refrigerator compressor)

The relay permits electricity to flow through the starting winding of the motor until the motor reaches about two thirds of its rated speed. Then disconnects or opens the starting winding circuit.

The starting winding should be energized only for three or four seconds at a time. If current flows through it for a longer period, the winding may overheat. Many relays have current and or thermal protection devices to prevent the starting winding from abuse.

To operate correctly, these relays must be the right size for the motor. When replacing one, be sure it has the same electrical specification as the original.

It is impossible to use open electrical contacts inside a sealed system.

Current (magnetic) relay: Current relays are usually found on low torque, smaller horse power motor.

The magnetic type relay uses the electrical characteristic of the motor to operate it. The running winding consumes more current when the rotor is not running or is turning slowly. Than it does when it reaches full speed. As the motor picks up speed, the magnetic field build up and collapse in the motor producing a bucking or counter electro magnetic force (e.m.f) or voltage on the running winding. Current operated relay switches used to close and open the starting winding, operates on the change in current flow of the running winding as it goes from a start condition to run.

Current relay are some times called amperage relay. Since it is the ampere draw on the circuit that operates the relay.

Potential type starting relay is wired with a capacitor. Unlike the current relay the switch in the potential relay is closed while the compressor is de-energized.

When line voltage is applied, there are immediately two complete parallel circuits. One is through the starting winding and other is through the run winding. As the compressor comes up to speed the starting winding begins acting as a generator and generates backed e.m.f. It is the voltage that is applied across the coil of potential relay.

When the motor is almost up to speed the back e.m.f. generated by the start winding is strong enough that the magnetic field around the coil can pull open the switch to the starting winding. With the start winding out of the circuit, it continues to generate sufficient voltage for the coil to hold to open the switch. The potential relay can be recognised by its terminal numbers. Usually 5, 2 and 1. The rhyme 5-2-1; common-start-run may help to remember how it is wired into the circuit.

Solid state relay: The solid state relay does not actually use a switch to take out the start winding. This relay is actually ceramic device that has the characteristic of a resistance that varies with its temperature. When the compressor is idle, the relay is cool and its resistance is very low (like closed switch). When the voltage is applied, the start and run windings are energised simultaneously and the compressor starts within a few seconds, the start winding current that is passing through the relay causes the relay to set quite hot. This causes its resistance to increase dramatically at it then acts almost like an open switch. The only disadvantage of this solid state relay is that HS operation is not closely related to the starting of the compressor. It is more closely related to time only. Therefore the solid state relay may leave the starting winding in the circuit longer than either of the other two types of relay. The advantage of solid state relay is its universal application. A single solid state relay can be used to replace all current and potential type relays on compressor from 1/12 hp to 1/3 hp. This characteristic has

made it quite popular with service technician. Basically it is not relay but serve the purpose. Its familiar by name PTCR.

Over load protector: A motor over load protector is designed to detect when the compressor motor is drawing too many amps and stop the compressor motor operation. The overload must therefore sense compressor motor heat or current and open a switch. The switch may open the power circuit or a control circuit that will in turn shut down the compressor. The line break over head is used in virtually all household refrigeration type compressors.

It consists of a bimetal disc and a resistor that carry the current being carried by the compressor when too much current is being drawn, the resistor heats the bimetal and opens the switch. (with audible pop sound) It will reset within one or two minutes and will try to start the compressor again.

Compressor winding: Any single phase induction motor is not self starting. It requires additional torque to rotate the rotor. To provide additional torque starting winding is necessary.

Single phase compressor have two motor windings. The start winding and the run winding. These two windings are wired together in series inside the compressor shaft. Three wires are attached to these winding. One at each end and one at the common junction of the two winding. These three wires are routed through the compressor usually terminating at three pins. When any sort of wiring is done, you will need to be able to identify which of these pins is attached to the free end of starting winding which is attached to the free end of the running winding and which is attached to the common junction of the two windings.

The pins are called the start, run and common pins. The key fact you need to know is that the starting winding always has a higher resistance than the running winding.

There is one clue that will often give you a hint of which pin will be common which start and which run. The most commonly used colour scheme for the wiring attached to the compressor is black for common, red for run and white for start.

Current Relays

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

- state the meaning of a relay
- list the types of relays
- explain the functions of relay.

Relay: Relay is an electrically operated switch used to disconnect the starting winding or starting capacitor from the circuit when the motor reaches at its rated speed.

Types of relay

- Current relay or ampere relay
- Voltage relay or potential relay
- Thermal relay or hotwire relay
- Solid start relay (PTCR)

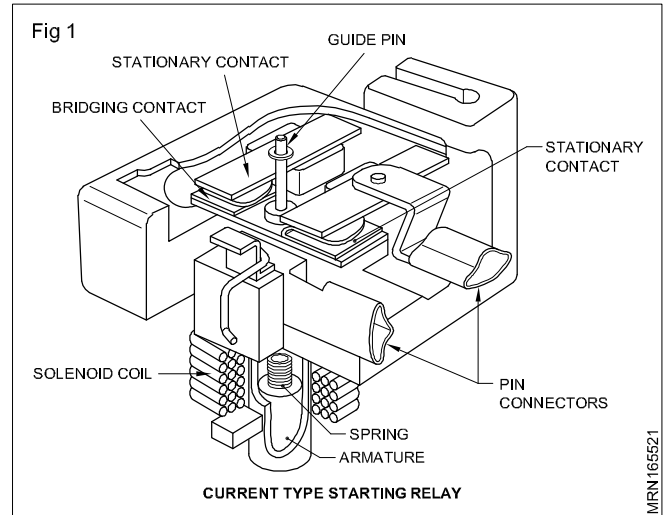
Current relay are three types

- box type relay
- I.M.S relay
- pin type relay

Functions of relay

Current relay: RSIR compressor motors require the use of current type relays with normally open contacts by the weight of the plunger. The relay coil is connected in series with the running winding and contact points are connected in series circuit of starting winding.

When the motor (compressor) is energized the high amperage current flows through the running winding and relay coil. At the time of starting it produces a strong magnetic field around the relay coil which attracts the plunger upward, closes the contact points and energizing the starting winding. At this the rotor begins to rotate and reduces the current through the running winding and relay coil. As the the current flow through the relay coil decreases, the coils magnetic field becomes too weak to hold the plunger up. In this way the plunger falls out of the coil by weight opens the starting contacts and disconnects the starting winding and starting capacitor. Then the motor runs on the running winding. (Fig 1)



Leak testing methods

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

- explain about nitrogen leak testing
- explain about refrigerant leak testing
- list the leak detecting methods with instruments.

Introduction

Leak testing in refrigeration and air conditioning systems may be categorized into 2 ways

- 1 Nitrogen leak testing
- 2 Refrigerant leak testing

Nitrogen leak testing

This method is applicable/ used when the system is under processing/reprocessing before charging refrigerant

This method requires dry nitrogen cylinder set and soap solution to perform bubble test

Alternatively 'dry air 100%' can be also used in the place of nitrogen gas

Refrigerant leak testing

This method is applicable when the system (existing) is affected with the problem/complaint 'short of gas/ poor cooling effect'.

This method requires some instruments according to the refrigerant type

The methods which can be used with specific refrigerants are as follows in increasing order of efficiency.

Leak testing

Sulphur Candles

It is applicable for ammonia refrigerant vapour; when it is exposed to air containing ammonia vapour, these give off a white cloud of ammonium chloride or ammonium sulphite.

The draw back of this method, it cannot be used to pinpoint leaks

Litmus paper

This is also applicable for ammonia only; When it is exposed to ammonia vapour, moist red litmus paper will turn blue.

The draw back of this method, it cannot be used with any of halogen family refrigerants.

Bubble tests

This method is followed in most common areas on pipes and fittings. Soapy water (mixture of soap and water) will indicate the locations of leaks by the formation of bubbles by escaping the gas/vapour /air.

The draw back of this method is applicable on the pressure

of the system more than atmospheric pressure (1.01325 bar). When test solutions applied to low temperature, low pressure (below than atmospheric level) suction lines could cause considerable damage due to the test solution could be drawn into the system.

Halide test lamp/Halide torch

This kind of leak detection is used to locate - fluoro carbon refrigerant leaks by the fuel like propane, butane or methylated spirits which is filled into the fuel tank.

The fuel tank supplies pressurised fuel at a steady and controlled pressure and a jet to admit the fuel to a burner. When lit, the burner flame is supported by oxygen in the air which is drawn through a tube used as a sensing probe. The probe is passed slowly over the joints or surfaces being leak tested. If any fluoro carbon refrigerants are drawn into the tube, the colour of the lamp flame will change to green or blue depending on the quantity of gas passed over the burner element.

Electronic leak detectors

This type is highly sensitive and operated by batteries. The refrigerant is sensed by a plug in element exposed to air drawn through a probe or tube. Its pressure will be indicated by a flashing lamp an audible 'bleep or buzz' or a meter reading, each increasing in speed or intensity as more refrigerant passes over the element.

The halide torch and electronic leak detector are difficult to use around urethane insulation. Since urethane uses refrigerant as the expander such detection devices show a leak trace all the time. In this case the soap bubble test is best.

Test Pressure

Test pressure limit is important in the trade because it facilitates leak testing process useful.

Normally test pressures are based on the discharge pressure of the system/appliance. The discharge pressure will vary corresponding to the condensing temperature. Similarly the condensing temperature will vary according to the condensing medium (air, water or both).

For air cooled systems, the compressor manufacturers suggests the condensing temperature is 55°C maximum. The condensing pressure at 55°C for R 12 is 12.9 Kg/cm² gauge (180 psig) and for R 22 is 21.25 Kg/cm² gauge (300 psig).

Vacuumizing in hermetic system in refrigerators

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

- describe vacuumising methods
- specify the level of vacuum
- assess vacuum pumps
- list the vacuumising accessories.

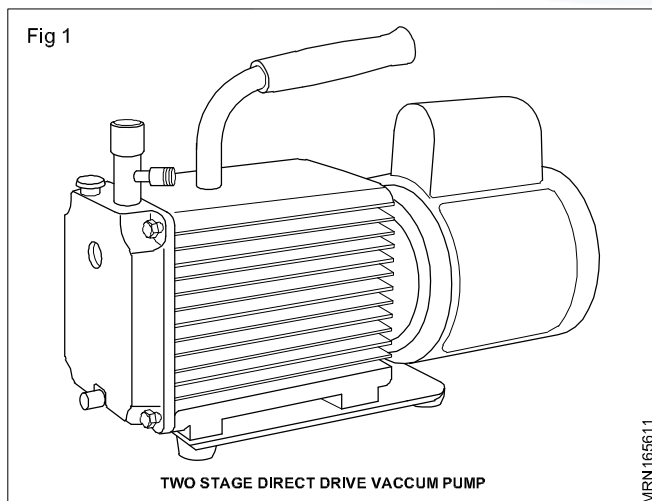
Need of Vacuum: Vacuum is a pressure but below atmosphere level (below 1.01325 bar). Vacuumising process followed in the refrigeration and airconditioning trade removes air, moisture, non condensable gases from the system to facilitate pure refrigerant change.

So proper care should be taken during vacuumising process, since vacuumising is one of the process of system processing. Day to day many system appliances fails but 'poor system processing' may be the main cause of most of system failures.

Vacuumising methods: Vacuumising process can be achieved normally by 3 ways which are as follows.

- 1 By low pressure side
- 2 By high pressure side
- 3 By both low and high pressure sides

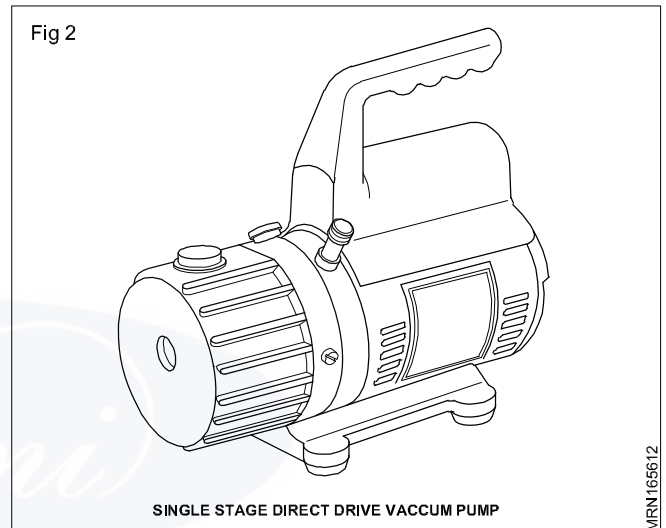
All the above three methods are approved and each method may applicable according to the type of system (sealed air cooled/Semi sealed air cooled/ open type air cooled etc.) Normally in hermetically sealed units (Refrigerators/window air conditioners) vacuumising is achieved by low side through the compressor process/charging tube. In split air conditioners vacuumising can be done by both high and low pressure sides through the liquid and suction service valves.



Similarly in semi sealed and open type units vacuum can be created by the system (compressor) itself through proper setting of service valves (suction service valve back seated and discharge service valve front seated with gauge port open to atmosphere). But this method (achieving vacuum by compressor of the same system itself) is not approved by compressor manufacturers and technically also. Because this method will not produce sufficient level of vacuum. So it is advisable a vacuum pump must be used to create vacuum for this type of systems (semi

sealed/open type). This system vacuum can be achieved by both suction and discharge sides through the service valves of the compressor.

Each vacuumising method may take their own time (subject to size / capacity of the system and efficiency of the vacuum pump) but it should be minimum 3 hours. Technically 'vacuumising by both high and low pressure sides' is approved. Because this method may require less time compared to other method to produce perfect vacuum.



Vacuum level: There is a scale to measure vacuum / vacuum level. Normally it will be in microns or inches of Hg. The recommended vacuum level should be 150 microns/30 inches of Hg. Any system kept vacuumising it should reach this particular level. Then only the process will complete and it is called 'perfect vacuumising'.

Vacuum pumps : Vacuum pumps are electro-mechanical equipment which are used to produce vacuum in the system. It consists of two main sections which are pump and motor. The pump is driven by a motor through belt and pulley or directly coupled. (Fig 3) The vacuum pumps have two important ratings. c.f.m capacity and microns of vacuum deepness. Cubic feet per minute (In metric units c.m.m cubic metre per minute) or c.f.m refers to volume displacement, how fast the pump can move air when not pumping against any pressure differential. While vacuum microns refers to how deep a vacuum can be created by the pump when not pulling against a closed container.

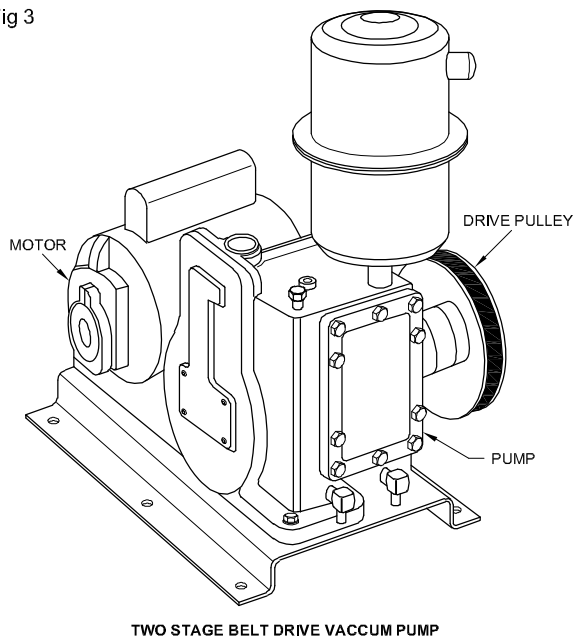
The vacuum pumps are available in two/three categories.

It is classified as under:

Vacuum pump

Direct drive	Belt drive
3 stage 2 stage	1 stage

Fig 3



MRN165613

Single stage vacuum pump is capable of attaining a vacuum level of 200 microns. This pump is most suitable for use in all air-conditioning and appliance service work. In a two stage pump one pump draws a vacuum from the system. The discharge from that pump is internally routed into the suction side of the second stage. Similarly in three stage pumps, the output of second stage will be the input of third stage. With this arrangement, vacuums of 10 microns are attainable. The two stage deep vacuum pumps are used in low temperature applications when the removal of air and moisture is more critical.

The larger flow rate pumps are used on physically larger systems to save time. Direct drive (I stage / II stage) vacuum pumps are most compact and portable with moderate cost. But the belt driven pumps are heavy and bulky. The cost will be lesser than direct drives models.

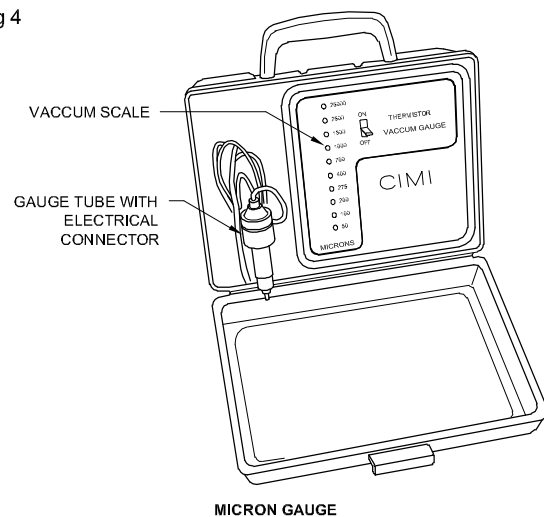
Accessories : The accessories are most helpful to find the level of vacuum during / after the process. The accessories are listed below.

- 1 Vacuum gauge
- 2 Micron gauge
- 3 Non-Return Valve (NRV)

Vacuum gauge is a instrument which is used to show the level of vacuum when the unit is under evacuation. The construction will be 'Bourdon tube' type and available in different diameters (dial). This vacuum gauge may be built in some vacuum pump itself. It is also available with refrigerant charging stations.

Micron gauge is a advanced instrument for determining the system has been properly evacuated and prepared for gas charging. (Fig 4) Its scale range will be 50 microns to over 20000 microns. The micron gauge takes the portion of the manifold gauge scale between 29 in Hg and 30 in Hg and expands it into full scale.

Fig 4



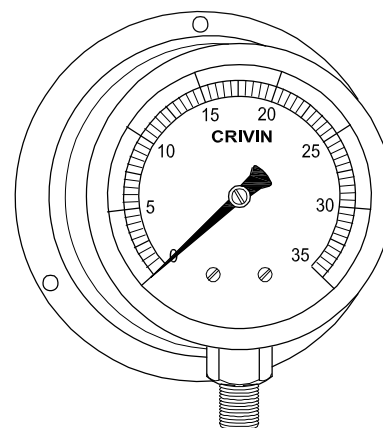
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The usage of this micron gauge is to show any loss in vacuum after the evacuation process is completed. This would indicate that either there is a leak or that there is moisture in the system which is boiling and creating water vapour. Micron gauge is electrically operated and it works under the principle of thermocouple.

Check valves or Non Return Valves (NRV) allow fluid flow in only one direction. It is used in many places in the refrigeration and Air conditioning system especially at multiple evaporator/ heat pump installations. It is used in the vacuum pumps to prevent the entry of air/moisture into system during interruption (power failure) in vacuumising process.

It is functioning by a permanent alnico magnet which is built in the valve. Some types of vacuum pumps (belt drive) may available with these valves built in. All non return valves will have direction mark embossed on its body to identify the flow direction.

Fig 5



VACCUUM GAUGE (BOURDON TUBE TYPE)

MRN165615

Refrigerant charging methods and classification of refrigerants

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

- explain different methods of charging refrigerant
- list the points before charging
- describe refrigerant charging accessories
- specify the operating pressures (high & low) of a refrigerating/air conditioning appliance/system
- analyse the performance of the system.

Refrigerant charging

Generally every refrigerating/ air conditioning system/ appliance is properly charged with refrigerant upon delivery/ commissioning (large capacity plants), the main service due to refrigerant troubles usually consists in evacuation and charging. So complete care must be taken during charging /commissioning of a system of course the efficiency (refrigerating effect) of the system/appliance is mostly based here.

Methods of refrigerant charging

Refrigerant charging can be done through either low side or high side of the system. Normally major refrigerating and air conditioning appliances like refrigerators, water bottle coolers, deep freezers, window/split air conditioners will be charged by low side (as vapour state through

compressor suction) only. In some cases (especially for large capacity plants like cold storages, ice plants, chilling plants 100TR load and above) where a large amount of refrigerant is to be added, it is advantageous because of time saving to charge the refrigerant as liquid state into high side of the system instead of pumping it into low side. Because the density (Kg/m^3) of any refrigerant will vary for liquid and vapour states. The table 1 explains about the charging procedures in practice.

It is also in practice of charging refrigerant for appliances through low side (compressor process tube) in liquid state to make the charging process faster. But this method requires complete skill and perfect observation power to the service technician. Because in this method liquid refrigerant to be sent to the system slowly and step by step by closing/opening charging valves at proper intervals.

TABLE -1 - Refrigerant charging methods

Nature of system	Charging location		Physical state	
	High side Liquid line	Low side Suction line	Liquid More density	Vapour Less density
Domestic/ commercial appliances		✓		✓
Medium/Large capacity plants	✓		✓	

In some circumstances if the liquid refrigerant is sent to the system (through compressor process tube) continuously, it may lead failure of compressor needs or any mechanical damage.

Charging accessories

The equipment for charging refrigerant is mostly the same as that used for evacuation except refrigerant cylinder. When charging a system it should be taken care that the amount of refrigerant to be charged is so selected that it maintains desired (designed) suction and discharge pressures does not make liquid to flood back to the compressor and also the super heat at compressor suction is not excessive. Charging without the aid of any equipment requires a high level of skill and judgement. sometimes charging is done without the aid of any equipments. This system uses suction and discharge pressures as indicative of the charge quantity.

The suction pressure varies from season to season due to change in ambient conditions.

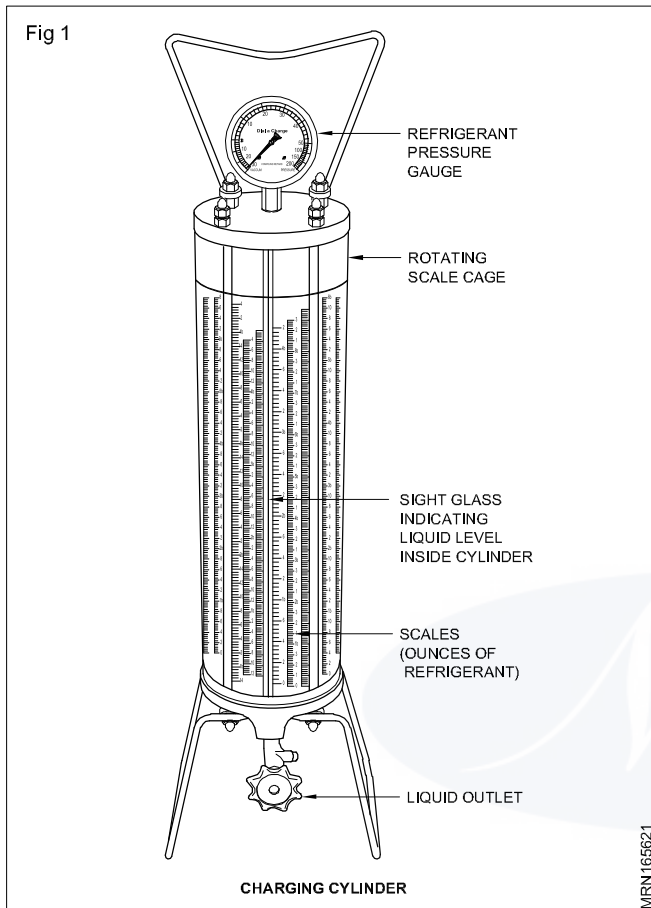
Charging cylinder

The charging cylinder (Fig 1) is nothing but more than a calibrated refrigerant storage tank. Some are furnished with an electric heater in order to add heat and pressure to the refrigerant which is stored inside. The graduations on the side of the cylinder indicate the quantity of refrigerant contained in the cylinder. There are separate scale for different refrigerants. Each refrigerant in turn has several scales, corresponding to the pressure in the cylinder at the time the weight is being read.

When preparing to charge refrigerant from the charging cylinder the outside barrel of the cylinder is rotated so that the appropriate scale lines up with the liquid level in the cylinder. The initial quantity of liquid is noted, refrigerant may then be dispensed either as vapour state (through top

valve) or as liquid state (through bottom valve). When the charging process is completed by closing the dispensing valve and reading the quantity of refrigerant remaining in the cylinder. By subtracting the final quantity from the initial quantity value, total quantity of refrigerant charged (ounce/kilograms) can be find out.

When charging cylinder becomes empty, it can be refilled with refrigerant from the main cylinder.



Charging board

Charging board/panel is nothing but it is a ready made assembly of the equipments/instruments which are required to carryout vacuumising/ charging processes. The board will have the equipments like vacuum pump, Mcload (vacuum) gauge, high and compound/LP gauges, hand shut off valves, refrigerant cylinder (portable/service cylinder) etc. All equipments/instruments will be interconnected with copper tubes, flare unions, nuts, charging hoses etc.

Charging board is most commonly used in the medium/ small scale industries to charge the refrigerant into the system/appliance. By using this charging board, refrigerant is charged by volumetric method.

Refrigerant Containers/Cylinders

It is also in practice in the trade, charging will be complicated by using refrigerant cylinder (service/portable cylinders) and gauge manifold etc. This technique is followed in the places outdoor charging/spot charging. (Split/ packaged refrigerating plants upto 10 TR capacity).

Automatic refrigerant charging meter

This is the most advanced instrument/equipment which is used to carryout the charging process.

It works under 'Microprocessor control' system and this instrument will charge refrigerant into the system as per the program set in.

The main advantages of this instrument is

- Compact size
- Less weight (4 Kg)
- Accurate charging (plus or minus 1/4 oz)
- Measurement of charged quantity in two scales (pounds or kilograms)
- moderate level of refrigerant handling quantity (upto 50 Kg)

Important instructions before charging

It must be ensured that the accessories/equipments which are required for charging process should be in good/ clean condition.

Charging lines/hoses charging manifold, handshut off valve/angle valves should be free from dust, dirt, moisture, air, processing chemicals etc.

High and low (compound) pressure gauges are without errors.

Charging hoses should be with rubber bushes at both ends and should not have any cracks/cuts/ holes etc.

Refrigerant cylinders should be having required quantity (pre-determined value) of refrigerant.

Refrigerant cylinder should be with required type of refrigerant.

Sometimes, refrigerant compressor oil will be charged into the compressor after evacuation and dehydration but before charging of refrigerant.

Refrigerant cylinders should be weighed before and after charging without fail.

Using filter/driers in charging lines is preferred to eliminate dust/dirt particles/moisture, if pressure in the refrigerant itself.

It is preferred that charge refrigerant by weight than by volumetric method.

System performance

It is the most important required factor applicable for all refrigerating and air conditioning system/appliance. It is nothing but the 'measured output' of the system/appliance during functioning. Refrigerant charge is playing a major role in system performance. Each and every system/appliance will require a particular charge quantity of refrigerant based on the application (high, medium or low temperature) and size of the components (condenser, receiver, evaporator, accumulator etc.)

System performance can also be defined as the ability of the system/appliance to remove heat from the space being cooled.

It is expressed in the unit Kcal/hr (metric) or KW (SI unit) which is found from the following formula.

System capacity = Mass flow of refrigerant x refrigerating effect

$$\text{Kcal/hr} = \text{Kg/s} \times \text{Kcal / Kg}$$

(or)

$$\text{KJ/s (Kw)} = \text{Kg/s} \times \text{KJ/Kg}$$

Mass flow of refrigerant is based on volume flow rate of refrigerant (volume displacement of compressor), density of refrigerant (at particular evaporation temperature) and charge quantity of refrigerant.

Refrigerating effect can be found using pressure enthalpy (ph) chart of each refrigerants. Evaporator efficiency is based by refrigerating effect.

Setting high and low pressures

It is the most essential value which will require for any system/appliance to handle operation/service. It is mainly depends upon the 'Heat Rejection ratio' of the system. These pressure values are the refrigerant pressures which are maintained at suction and discharge sides of the compressor. These pressures also called as back (low)

and head (high) pressures.

The suction pressure will change according to the applications like

High temp. e.g. air conditioners, water coolers etc.

Medium temp. e.g. Bottle coolers, visicoolers etc.

Low temp. e.g. refrigerators, deep freezers etc.

The back pressure will also change refrigerant to refrigerant and ambient dry bulb temperature.

The discharge pressure will change according to the ambient dry bulb temperature for air cooled condensers and the ambient wet bulb temperature for water cooled condensers. This will also change refrigerant to refrigerant.

The heat rejection (HR) factor will increase for low temperature applications and decrease for high temperature applications. The HR factor will be different for different type of compressors. (Ref. Table 2.A & B)

Selection of refrigerant and its pressure ratio (absolute discharge pressure divided by absolute suction pressure) will also change according to the application.

Table 2A

Heat rejection factors : suction cooled hermetic compressors

Evaporator temp. (°F)	Condensing temperature (°F)					
	90	100	110	120	130	140
-40	1.66	1.73	1.80	2.00	*	
-30	1.57	1.62	1.68	1.80	-	
-20	1.49	1.53	1.58	1.65	-	
-10	1.42	1.46	1.50	1.57	1.64	
0	1.36	1.40	1.44	1.50	1.56	1.62
5	1.33	1.37	1.41	1.46	1.52	1.59
10	1.31	1.34	1.38	1.43	1.49	1.55
15	1.28	1.32	1.35	1.40	1.46	1.52
20	1.26	1.29	1.33	1.37	1.43	1.49
25	1.24	1.27	1.31	1.35	1.40	1.45
30	1.22	1.25	1.28	1.32	1.37	1.42
40	1.18	1.21	1.24	1.27	1.31	1.35
50	1.14	1.17	1.20	1.23	1.26	1.29

* - outside of normal limits for single stage compressor application.

TABLE 2B

Heat rejection factors : Open compressors

Evaporator temp. (°F)	Condensing temperature (°F)					
	90	100	110	120	130	140
-30	1.37	1.42	1.47	*	-	-
-20	1.33	1.37	1.42	1.47		
-10	1.28	1.32	1.37	1.42	1.47	
0	1.24	1.28	1.32	1.37	1.41	1.47
10	1.21	1.24	1.28	1.32	1.36	1.42
20	1.17	1.20	1.24	1.28	1.32	1.37
30	1.14	1.17	1.20	1.24	1.27	1.32
40	1.12	1.15	1.17	1.20	1.23	1.28
50	1.09	1.12	1.14	1.17	1.20	1.24

* - outside of normal limits for single stage compressor application.

TABLE 3

Suction & discharge pressures for different applications and with different refrigerants

Sl. No.	Appli- cation	Refri gerent	Evaporating		Condensing				Temp ambient °C	Pressure ratio
			Temp °C	Press. Kg/cm³	Air cooled		Water cooled			
					Temp. °C	Press. Kg/cm³	Temp. °C	Press. Kg/cm³		
1	High Temp.	R-22	7	5.41	55	21.09	-	-	35	4.18
2.	High Temp	R-22	7	5.4	-	-	42	15.5	35	4.18
3.	High Temp.	R-12	7	2.9	55	12.9	-	-	35	4.3
4.	High Temp.	R134A	7	2.8	55	13.2	-	-	35	4.5
5.	Med Temp.	R12	-1	2.02	55	12.9	-	-	35	
6.	Med Temp.	R134A	-1	1.85	55	13.2	-	-	35	
7.	Low Temp.	R12	-23	0.34	55	12.9	-	-	35	
8.	Low Temp.	R134A	-23	0.15	55	13.2	-	-	35	

Refrigerants

Refrigerants are the medium (Chemical compound) of heat transfer in a refrigerating system which picks up heat by evaporating at a low temperature & pressure and gives up heat by condensing at a higher temperature & pressure.

Refrigerants over the years

The early refrigerants used were Sulphur-Dioxide and Methyl-Chloride in small domestic & commercial machines and subsequently Methylene chloride in centrifugal system. Ammonia was also used & continues to be used, today also, in bigger plants & equipment.

All the above refrigerants were toxic/flammable and the quest for a safe, non toxic, non-flammable refrigerant ended with the discovery of refrigerant - 12 (CFC-12) around 1930 and became very popular in domestic refrigerators and other appliances. It was derived from Methane (CH₄). Subsequently R-22 and R-13 (also derived from methane) were discovered and R-22 is used today in Air-conditioning & Refrigerating machines/appliances. They are all safe, non toxic, non-flammable refrigerants. Refrigerants were also derived from Ethane (C₂H₆) like R-114 and recently HFC-134a.

Identifying Refrigerants by number (Ref. Fig 1 & 2)

Methane & Ethane based refrigerants that are made by the substitution of Halo carbons which are chlorine, Fluorine, Bromine. These refrigerants that contain fluorine and are currently used refrigerants which are known as Fluoro carbons.

The meaning of the numbering system is as under:

Refrigerant - 12 (R-12)

(Derived from methane CH₄, Formula CHClF₂ - Dichloro-difluoro methane)

The digit 2 in R-12 indicates that there are two fluorine atoms.

The digit 1 less 1, that is zero indicates the number of hydrogen atoms. (in this case, none)

The digit 0 (in front of 12) plus 1, that is 1 indicates the number of carbon atoms.

As methane is CH₄, and R-12 is derived from methane it continues to have one carbon atom and the 4 Hydrogen atoms are replaced by two fluorine atoms (as determined above) and the remaining two hydrogen atoms are replaced by chlorine (we have seen earlier that there are no hydrogen atoms in R-12) atoms as the formula indicates.

Refrigerant - R - 22

(Derived from Methane CH₄, formula CHClF₂, Mono chloro difluoro methane)

The digit (first) 2 in R-22, indicates two fluorine atoms.

The digit 2 (second), less 1, that is 1 (one) indicates the number of hydrogen atoms.

The digits 0 (in front of 22) plus 1, that is 1 indicates the number of carbon atoms.

As methane has 1 carbon atom and 4 hydrogen atoms of which it can be seen that they have been replaced by two fluorine and one hydrogen atom, the balance is replaced by a chlorine atom and hence the formula CHClF₂ or Mono chloro difluoro methane.

Refrigerant - R - 134A

(Derived from Ethane (C₂H₆) - formula CF₃CH₂F - Tetra Fluoro Ethane)

The digit 4, indicates the number of fluorine atoms.

The digit 3, less 1 (one), that is 2 (two) indicates the number of hydrogen atoms.

The digit 1, plus 1 (one), that is 2 (two) indicates the number of carbon atoms.

As Ethane has two carbon and six hydrogen atoms of which are replaced by four fluorine atoms, the balance two hydrogen atoms remain as fully are and hence the formula is CF₃CH₂ or C₂H₂F₆.

Other numbering codes

- 1 Refrigerants which are numbered starting with the digit 4 like R-404A, R-407C, R-410A are zeotropic mixtures, that is a mixture of two or more refrigerants, components, which exhibit the properties of both the components.
- Refrigerants which are numbered starting with the digit 5 like R-500, R-502, R-507 are Azeotropic refrigerants, that is a mixture of two refrigerants / components, but which behave like a single component refrigerant.

Classification according to toxicity & flammability

Refrigerants are also classified according to three levels of Toxicity & Flammability.

TOXICITY - Two group A & B, according to degree of toxicity.

A - Denotes refrigerants not much toxic in concentrations up to and including 400 ppm.

B - Identifies refrigerants that show evidence of toxicity at concentration below 400 ppm.

FLAMMABILITY:

Class 1: Denotes refrigerants that do not propagate flame when tested at air at 14.7 psia and 21°C.

Class 2: Denotes refrigerants having lower flammability (LFL) of 0.1 kg/m³ at 14.7 psia & 21°C plus heat of combustion less than 8174 Btu/kg (19,000 KJ/kg)

Class 3: Denotes refrigerants that are highly flammable, with LFL equal or less 0.1 kg/m³ at 14.7 psia & 21°C plus heat of combustion equal or greater than 8174 Btu/lb (19,000 KJ/Kg)

Example, R-11, R-12, R-22 are classified as A1 (includes R-134A)

R-717 (Ammonia) is B-2 (Toxic & medium Flammability)

R-600 A & R-290 (Hydro carbons) is A-3 (Highly flammable)

Other classifications:

Primary Refrigerants:

This refrigerants which cool by the absorption or extraction of latent heat from the substances to be refrigerated. This is mostly used in DX (Dry expansion) systems in a vapour compression refrigeration system like refrigerators, Air conditioners (Domestic / commercial & Industrial applications)

Example : R-12, R-13 (CFC group)

R-22, R-23 (HCFC group)

R-134A (HFC group - single compound)

R-404A, 407C (HFC group - zeotropic mixture)

Secondary Refrigerants:

This refrigerants which cool the substances by absorbing their sensible heats from the substances to be refrigerated. This is mostly used in indirect expansion systems of a vapour compression system in Brine/water/Glycol chilling

plants, Roof top chiller units as secondary coolants.

Example : Water,

Brine : Sodium chloride

Calcium chloride

Glycol : Ethylene Glycol

Propylene Glycol

Desirable properties of refrigerants: (Ref. Table 1 & 2)

As desirable refrigerants should possess chemical, physical and thermodynamic properties which permit its efficient application in refrigerating systems.

The characteristics of a good refrigerant should have the following properties:

- 1 Low boiling point
- 2 High latent heat value
- 3 Easy to liquify at moderate pressure & temperature
- 4 Operation on a positive pressure.
- 5 Mixes well with compressor oil.
- 6 Non-corrosive to metals / parts & motor winding insulation, other materials.
- 7 Not-affected by moisture.
- 8 Non flammable and non-toxic
- 9 High Dielectric strength
- 10 Environmentally safe (No ozone depletion, No greenhouse effect)

ENVIRONMENTAL IMPACT OF CFC & OTHER REFRIGERANTS:

Ozone Depleting Potential (ODP):

By the mid nineteen eighties it was clear that CFC's and HCFC's which had chlorine in their composition were major contribution to depleting the ozone layer in the stratosphere (10 to 25 km) of the earth's atmosphere. It was discovered that the chlorine atom in CFC's, which gets freed in the stratosphere due to the U.V (Ultra violet) rays of the sun, cause depleting of the protective ozone layer by converting the ozone (O₃) into oxygen (O₂). One chlorine atom damages 100,000 ozone molecules and the ozone depletion potential (ODP) of any refrigerant is stated with reference to the ODP of CFC - 11 which is reckoned as 1.00, CFC-12 has an ODP of 1.00 whilst HCFC-22 has an ODP of 0.05.

Ozone layer thinning or depletion allows harmful U.V. radiation from the sun to strike the earth's surface and causes diseases like cataract, skin cancer and immune system deficiency apart from affecting crop-yields and marine life. This is a major threat to mankind and over 170 countries including India have signed the Montreal protocol to phase out CFC's. The CFCs are also came under the group of 'ODS' (Ozone depleting substances) which apart from CFCs, also includes Halons (for fire fighting) & Solvents (CTC, Methyl chloroform)

Global Warming Potential (GWP):

CFCs and to a lesser degree HCFCs and HFCs (which are like substitute for CFCs) also contributes to global warming. Apart from CFCs, gases like CO_2 , methane, Sulphen Hexa Fluoride (SF_6), Nitrogen oxide and HFCs have been named as Global Warming gases absorb some of the solar radiation reflected from the earth's surface and cause the earth's surface temperature to rise, a phenomena known as Global Warming. The GW can lead to floods, irregular climatic condition / changes, etc.

The GWP of a substance is defined with reference to carbon dioxide (CO_2), that is the mass of CO_2 needed to create the same level of Global Warming as one unit mass of the substances. Thus R-12 has a GWP of 8500, R-11 of 7300, R-22 of 1700 and R-134 A of 1300.

Phase out of CFCs:

As mentioned earlier & for the above reasons, developing

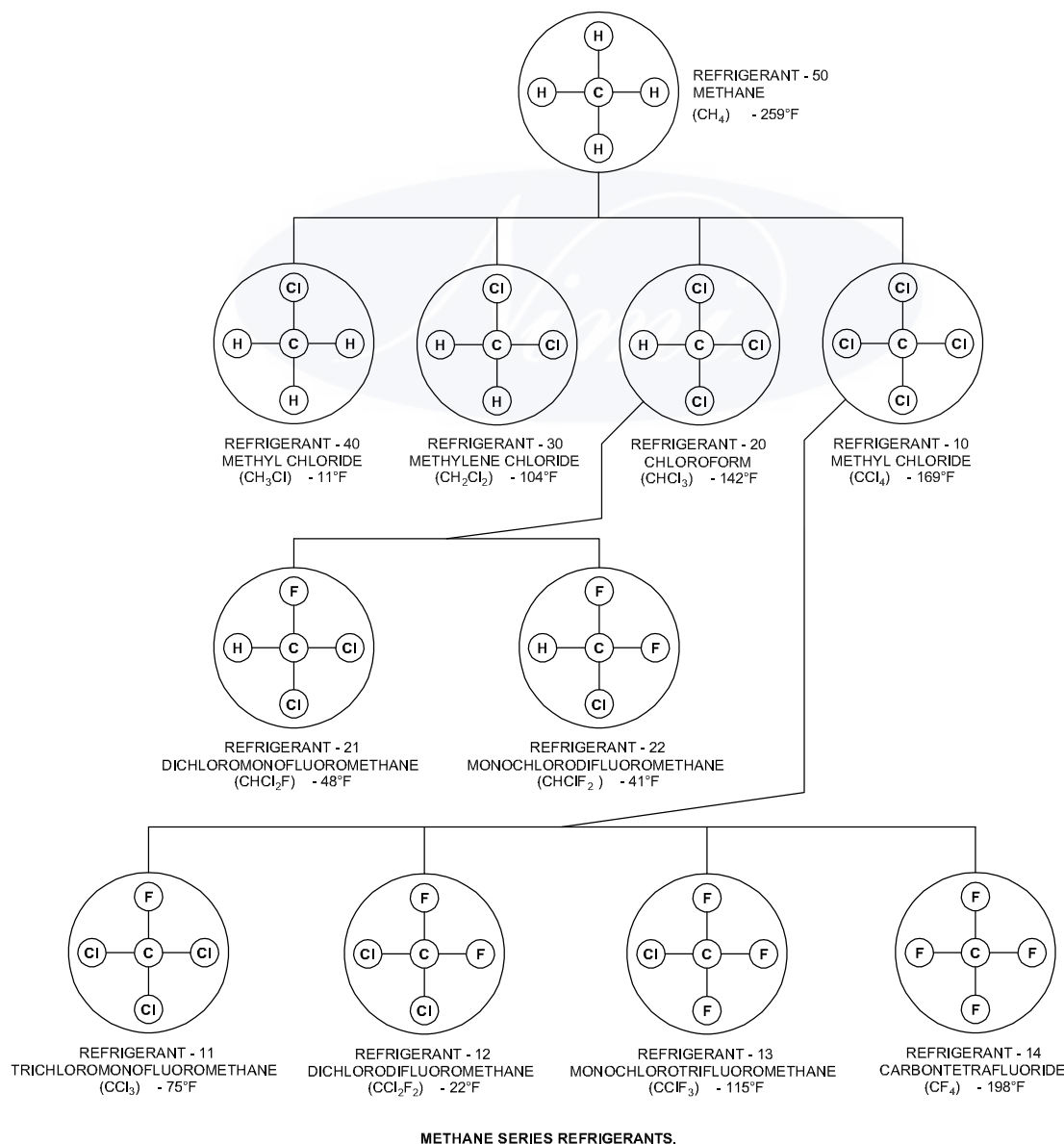
countries like India will phase out CFCs completely by 2010 and HCFCs by 2030. Developed countries have already phased out CFCs in 1996 and will phase out HCFCs by 2030, though Europe is already in the process of phasing out HCFCs. Even HFCs which have a GWP of 1300 are being replaced by Hydrocarbons (HCs), Ammonia, and carbon-dioxide (CO_2) in Europe.

- 1 R-12
- 2 R-1-34a
- 3 HC blend

These Refrigerants are used in vapour compression system refrigerators HC blend of refrigerant is a equal blend (R290)propane and booa/ISO-butane) in 50/50 ratio.

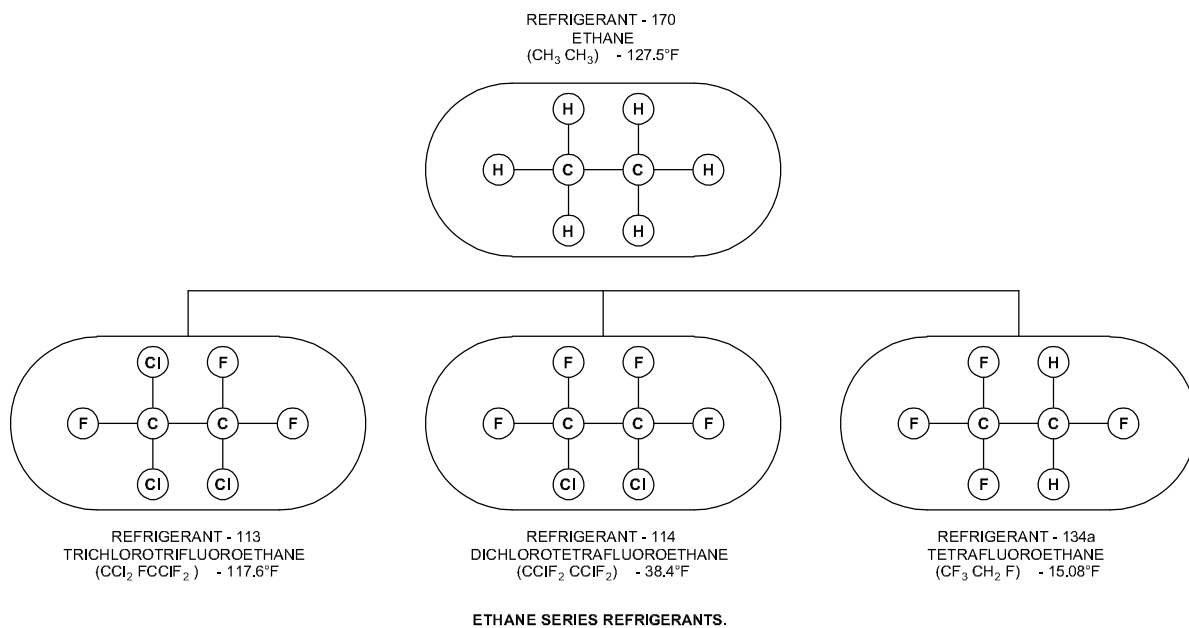
Density of HC's are as low, equallent to 40% of the CFC when charged by weighing.

Fig 1



MRN165631

Fig 2



MFN 165632



Check electrical wiring in new Direct cooled refrigerator

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

- the function of compressor motor winding (sealed compressor).
- the functions of relay and OLP.
- the function of thermostat switch.

PROCEDURE: In sealed compressor, compressor is fixed in a motor rotor shaft and rotate in a sealed dome. This motor winding is specially designed. The starting and running coil is fixed in a stator.

This type motor winding is called CSR winding and it is capacitor start and run. This type of motor use starting capacitor for start in load. High torque in external use with centrifugal switch. As soon as the motor starts, the speed increases and then disconnects the starting capacitor by centrifugal switch. This is worked in mechanical system but in sealed compressor instead of centrifugal switch the function of centrifugal switch will be done by a potential type relay.

In this type of compressor, as soon as it is switched on the relay coil and compressor motor starting coil start run soon. Full speed will be picked up. Relay plunger will drop down and disconnect the starting winding after get full speed in compressor with running winding.

For conventional type refrigerator reciprocating and rotary compressor are in use. The following HP are used in conventional type refrigerator - 1/10, 1/8, 1/6, 1/5, 1/4, 1/3.

Function of current coil box type relay

Construction of current coil relay are Bobin with small winding, contact points, plunger weight, spring, relay coil winding gauge.

The relay coil and motor starting winding are connected in series. As soon as the power is switched on, the starting winding energises through the relay. The motor picks up full speed and then the running winding gets energised, the motor takes full load current. The relay will disconnect the starting winding.

Compressor motor run only with running coil and OLP (Overload Protector)

Construction of OLP in a round housing small heater coil, bimetalic disc, and contact points. the working method of OLP is in two ways,

- 1 The OLP is fixed on compressor body. If motor gets overheated, this OLP stops the motor running due to overheat. The OLP disc opens the contact point and stop the motor.
- 2 If there is any mechanical fault (or) electrical fault the motor draw high current (AMPS), so the heater coil of OLP will get red hot. The disc will open the contact points and stop the motor.

Thermostat switch

Construction of thermostat switch - one metal box with contact points, switch, bellow attached, capillary sensing bulb, cut in and cut out adjustment screws and temperature adjustment.

Function of thermostat

When the temperature reaches low, the thermostat sensing bulb refrigerant shrink and open the contact by bellow action.

As soon as the cooling coil gets warm, the bellow will get expanded. The toggle point will move forward up which is attached with bellow and make electrical points gets contact. As soon as the electrical contact get on, the compressor decrease the cabinet temperature. Thermostat knob can be adjusted for required temperature.

Refrigerator light and light switch

Refrigerator light bulb and light switch are connected in series.

Light bulb is fixed in side of the cabinet and light switch is fixed at the side of the cabinet next to the main door.

The purpose of the refrigerator-light when using Refrigerator in night time the things kept inside the refrigerator are easily visible. When refrigerator is in on position, if open the door, the light switch will close (contact) and the cabinet bulb will be on. When the door is closed after use, the light switch get open the contact and off the light.

CSIR circuit used in refrigerator wiring

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

- list the electrical parts and electrical circuits of CSIR.

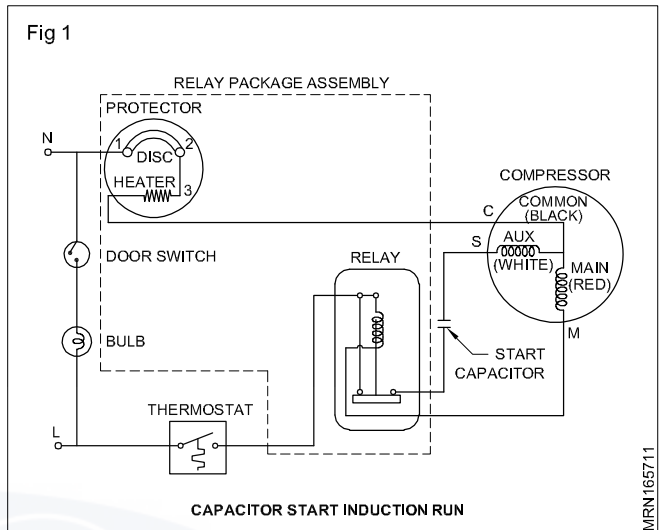
Electrical parts and circuit of CSIR: The electrical circuit as shown in (Fig 1) consists of door switch, cabinet bulb, OLP, thermostat, relay, starting capacitor and compressor.

(Fig 1) shows a simple refrigeration electrical circuit. It would apply to a household refrigerators or small commercial water cooler, bottle cooler and deep freezers. The line voltage thermostat senses the cabinet temperature and closes to turn on the refrigeration system. The compressor is series with thermostat.

The start relay used with the compressor is a current relay. It disconnect the starting capacitor from the circuit after compressor getting start. The overload is in the compressor circuit only. It is wired in series with the common terminal of the compressor and it will detect too much current through either the start winding or the run winding. If an overload condition is sensed and the overload switch contacts open the compressor will be shut down.

The cabinet light is operated by a door switch. It is normally closed momentary switch that will energize the cabinet light whenever the door is opened.

The operation of the cabinet light portion of the circuit is totally independent from the refrigeration portion of the circuit. The cabinet light is wired in parallel. Door switch and bulb in series. The door switch on a refrigerator is a manual switch. Its operation depends upon opening and closing the door in order to move the contact of the switch.



Installation factors - system performance

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

- **assess the problems behind poor installation.**

Installation: It is true and proven, Installation is one of the important aspect behind the failure of any refrigerating and airconditioning appliance. Good installation make the appliance working efficiently and trouble free.

There are few factors to be kept in mind when installing a appliance successfully such as flat floor level, good location, proper power supply etc.

Poor installed appliance may have the following problems, which are as follows.

- Vibration (objectionable level) water leakage out, door closing uneasy are due to uneven flat surface.

- Low cooling unit tripping frequently, unit continuous running are due to insufficient air space/gap around the unit(200 mm at back, 250 mm at other sides). This is caused by poor condensation due to lack of cooling medium (air). Poor condensation also caused by heat sources (Gas stoves, sunlight etc.) near by the unit.
- Unit tripping due to high current drawn due to low voltage (insufficient level) or any other electrical problems/poor condensation.
- More time for forming ice or not forming ice due to short of gas in the system, which caused by minute leak during transport/loading/unloading/ mis- handling of appliance.

Installation of refrigerator

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

- **explain the care & maintenance of refrigerator**
- **care and maintenance of refrigerator.**

- 1 Clean off the condenser or coils twice per year. Condensor coils are responsible for removing heat from refrigerators and freezers.
- 2 Clean and replace the gasket (Rubber door seal) as needed.
- 3 Defrost in time completely.
- 4 Clean the interior cabinet with soap water and wipe with clean water.
- 5 Deodorize with recommended spray to remove odour or cut an lemon and keep inside. It will absorb the bad smell.
- 6 Replace the ice maker or water dispenser water filter if available.

Replace thermal insulation material of refrigerator cabinet

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

- **describe insulating materials**
- **state the property of insulation materials**
- **list the types of insulating materials.**

Insulating materials : Heat will flow from high temperature to low temperature . Heat flow by radiation, conduction and convection method through the wall, door, ceiling and glass door to the refrigerated space.

The material which restricts such heat flow is called insulating materials.

Properties of insulating materials

- 1 It is low conductivity
- 2 Resistance to fire
- 3 Less moisture absorption
- 4 Good rigidity
- 5 Odourless

- 6 Vapour permeability
- 7 Light in weight
- 8 Easy of handling
- 9 Low cost

Types of insulating materials

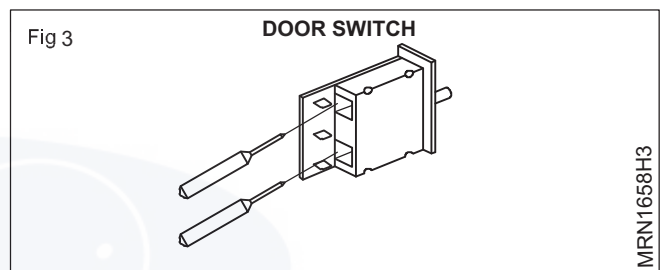
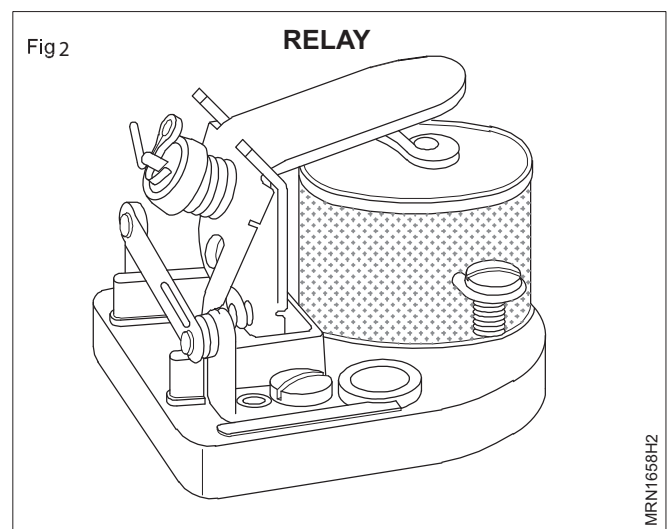
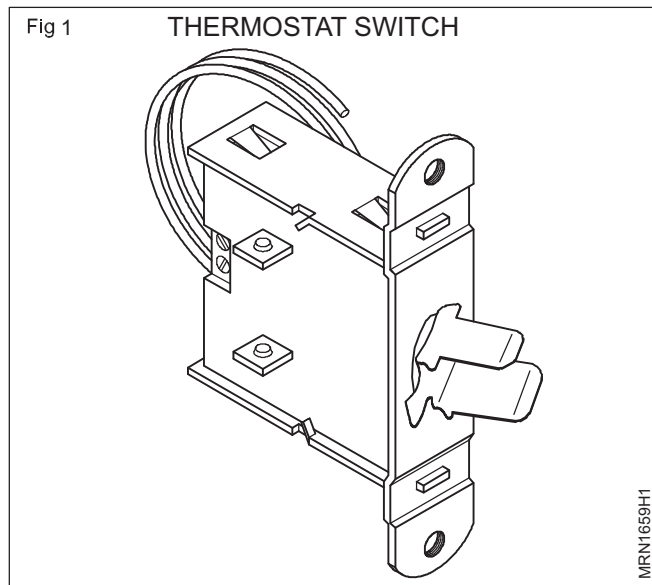
Glass wool, PUF, Cork sheet, Thermocole, Insulating foil, Fiber glass.

Heat exchanger : While removing insulating material you can find the heat exchanger. It is a device used to transfer heat suction line and capillary tube is soldered together to act as heat exchange. Due to heat exchange the efficiency of refrigeration cycle be increased.

Identify the electrical component of direct cool refrigerator

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

- identify the electrical parts/components of refrigerator.



Identify the mechanical component of direct cool refrigerator

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

- Identify the mechanical component of refrigerator

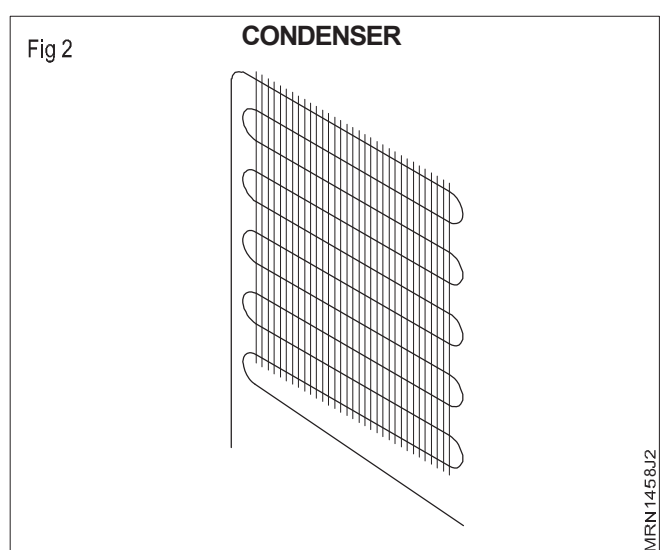


Fig 3

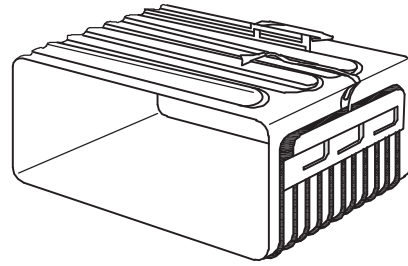
DRIER



MRN1458J3

Fig 5

EVAPORATOR



MRN1658J5

Fig 4

CAPILLARYTUBE



MRN1458J4



Refrigerator's Door Assembly

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

- explain the importance of the door seal
- how to check the door seal leak and the use of magnetic gasket
- describe the use and functions of the hardwares in refrigerators.

The importance of the door seal: The refrigerated place inside the refrigerator, unless it is leak proof only, the efficiency of the refrigerator will maintain. The poor seal results many problems like:

- Cabinet sweating inside
- Excessive frosting on the evaporator
- Running time of the compressor will be more
- High power consumption, due to excess load is adding.
- Ice freezing (Ice trays) process will take very long.
- Cabinet air temperature will raise continuously.
- Sweating may form possibly by the front side by the door of the cabinet.

To avoid all these problems the door seal should always be tested before a refrigerator is placed in for first operation or whenever the refrigerator been serviced.

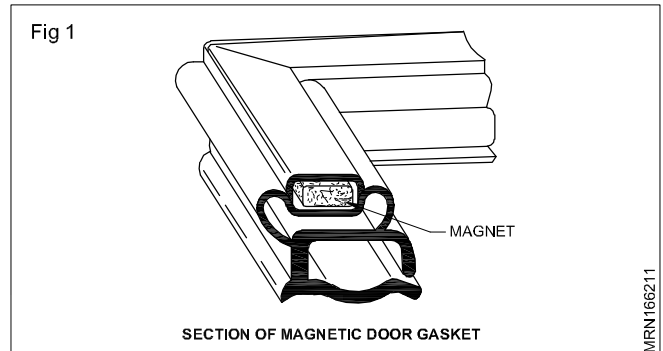
The Method of checking door seal leak: There are different methods to check the tightness of the door seal.

- 1 Place a strong flash light (battery operated) inside the cabinet, as the light is facing the inner door of the inner cabinet. Now close the door, and see wherever the light is visible, that shows the weakness of the seal in the door gasket not sealed properly.
- 2 The another method to check improper door seals, use of 0.5 mm plastic feeler, can check the entire seals, use of 0.05mm plastic feeler, can check the entire circumference, where the gap is wide (Ref. Task 1 of exercise No.1.4.62)
- 3 The easy and quick method to find out the condition of the gasket, open the door and note carefully the pull required to open, to half a way, hold for 10 seconds and close it. After 15 seconds again open and note the effort to pull the door. If it takes more effort, than that of 1st time, we can be sure that the sealing is alright. Hence the first time when you open the door, cold air escapes out and warm air rushed in. When the door left close, these warm air get cooled and contracts the inside pressure also become lesser, than the outer atmospheric pressure.

This results you have to give more effort to pull and open the refrigerator door.

The use of magnetic gasket: The magnetic strip in between the synthetic rubber gaskets gives a uniform and tight close of the seal. If you balance the door moment to

close on its own, when you open and leave the door, the magnetic force pull the door and make a tight close. See the cross section of the magnetic door gasket (Refer Fig 1)



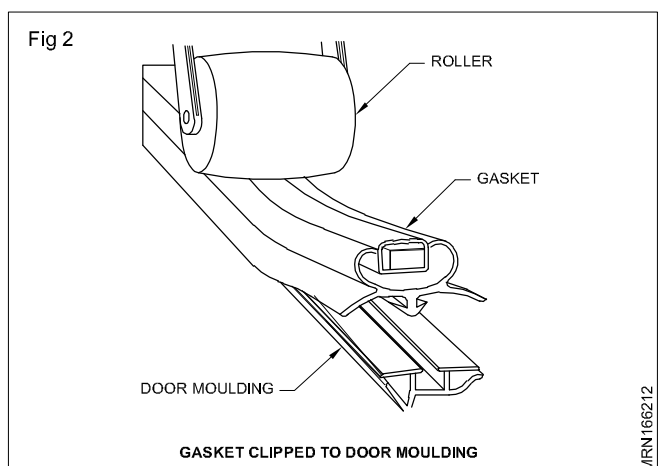
To rectify the problems: The door gaskets are usually made of flexible synthetic rubber. They have an air-cushion design, and have magnets built into the plastic or rubber gasket to hold the door tight close.

Due to wear and tear and long use, the gasket may wear or perish. This weak sealing can be rectified by placing paper strips or sticking plaster (Ref: Task 2 of exercise No 1.4.62).

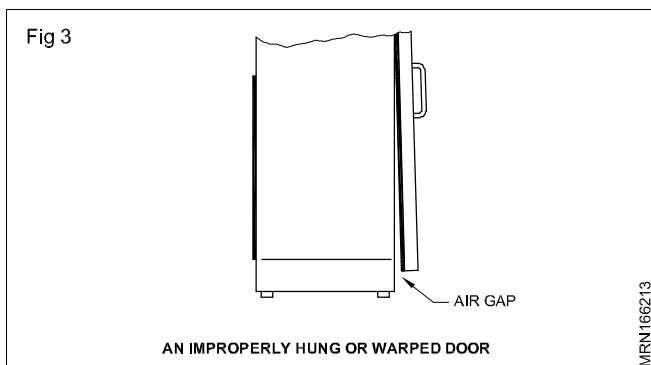
If the gasket is totally worn out, better to change a new one. In some models the gaskets will be tightened with the edge of cabinet inner door by self-threaded screws. You can remove the screws and replace the new gasket and fasten the screws.

In other models, will have a groove or slot in the inner edge of the door moulding, for the gasket to rest and fit correctly.

There is a roller which can be used to press the gasket to fit on the door moulding's groove or slot (Refer Fig 2).

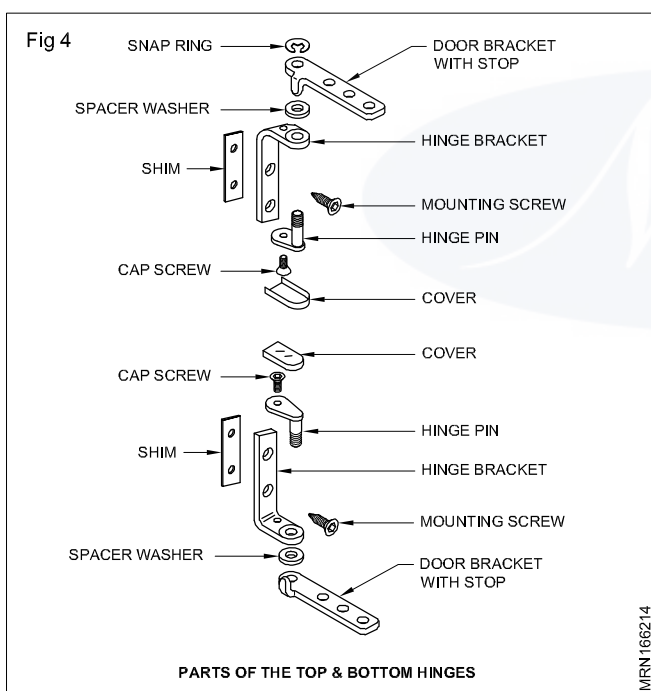


The doors may be twisted some time due to the heavy load of the bottle racks. These twisted or warped door can be adjusted. These doors would not coincident to the cabin in line, and cause poor sealing between the door and the cabinet. (Fig 3)



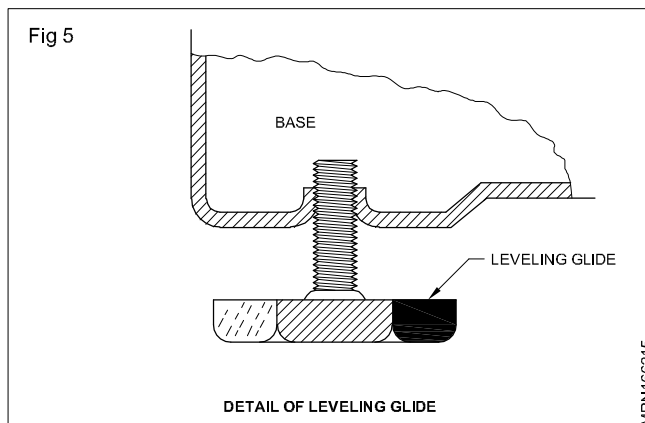
The twisted door can be corrected by a gentle twist or push as explained in Task2 of Exercise No. 1.4.20

Use and functions of the hardware in refrigerator: Cabinet hinges usually uses ball or nylon bearings. These need little lubrication, while servicing. The hinges are adjustable, so that the doors can be well fit to the cabinet without seal leak. For the parts of the hinges Ref.(Fig 4).

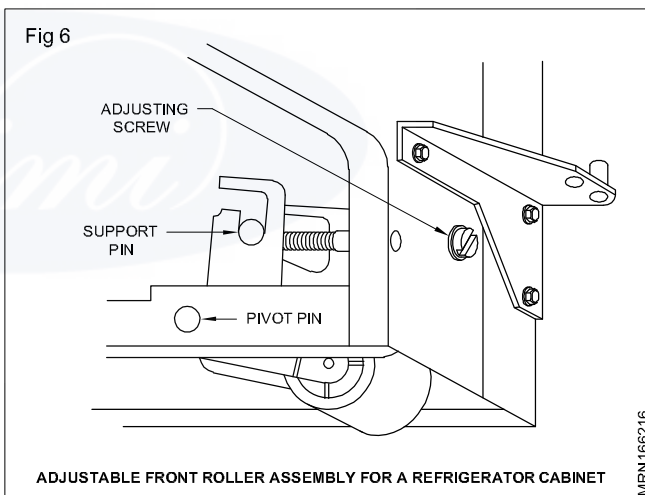


Modern refrigerators use magnets to close and hold the door shut. The cabinet should be carefully levelled, since the shelves inside should not be fitted, and the door should have easy moment to close. It is possible to adjust its feet in such a way, that the weight of the door will be tend to swing and the door is closed from the minimum open position. It reduce the door exposure time and useful to the customers.

The levelling glide arrangement (Fig 5) is fixed at the rear bottom corners of the bottom (feet) cabinet. According to ground level, these levelling screws can be adjusted to raise (or) bring down the feet. Which helps for the door to close on its own.



The higher capacity, double door, frost free model refrigerators are mounted on roller wheels to help, move the unit easy for service. The front roller helps to move the refrigerator to its position, and adjustment of the roller helps to level it (Fig 6). The adjusting screw helps the body to rest on the feet, keeps the Refrigerator from moving after it is placed.



The batch helps to lock the refrigerator for customers need, to avoid unnecessary opening by unauthorised persons or while transporting the refrigerator to some other place.

The handle fixed to the door helps for open and close of the door. Now in latest models, the door is shaped, inwardly made a provision of semi-circled (shaped dent) to handle by hand, tend to open and close and there is no separate handle is projected out.

Mechanical components in refrigeration system

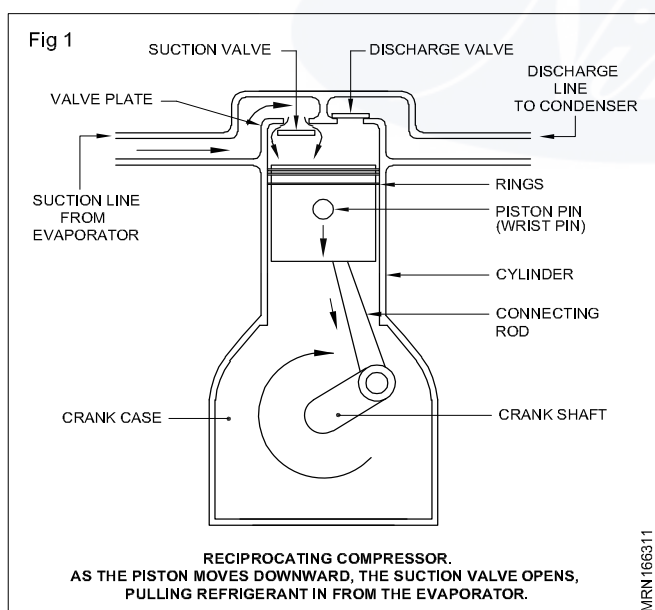
Objectives: At the end of this lesson you shall be able to

- list the types of compressor
- study the functions of reciprocating compressor
- study the functions of components in reciprocating compressor
- study the various types of evaporators
- study the essential internal cleaning of evaporator and condenser.

Compressor types: There are four common compressor designs in use today. They are

- Reciprocating
- Rotary
- Screw
- Centrifugal

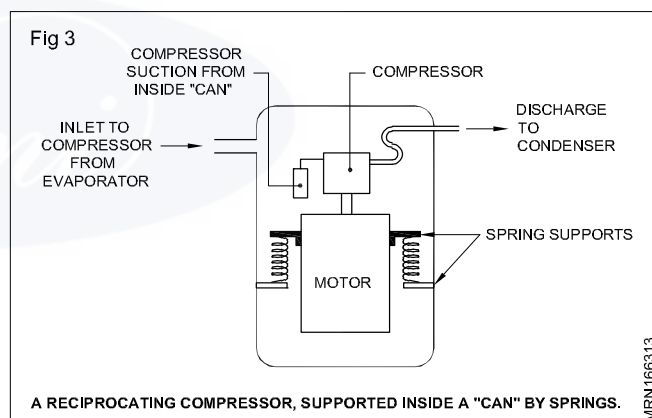
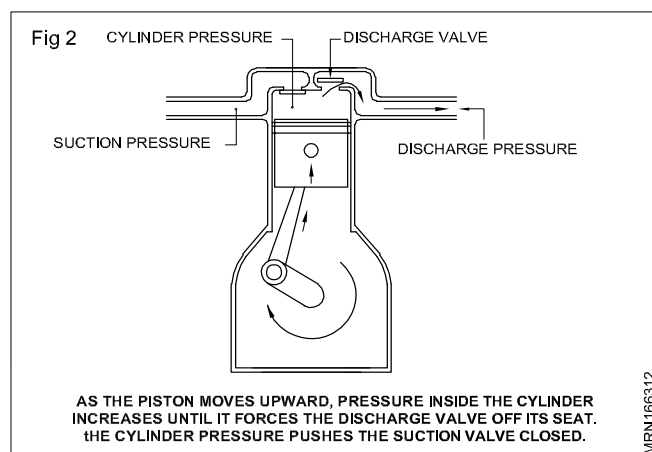
Functions of Reciprocating Compressor: Reciprocating compressors are the most common type of compressor used in Refrigeration and Air conditioning. Compressor used to suck the refrigerant vapour from the evaporator in the form of low pressure, low temperature saturated vapour and compressed. After compression it increase the pressure and temperature of saturated vapour into high pressure. High temperature super heated vapour and discharge in the condenser. Refer Figs (1 and 2)



Component functions of Hermetically sealed fractional horse power compressor used in Refrigerator (Fig 3)

List of components

- Suction valve
- Discharge valve
- Crank shaft
- Connecting rod
- Piston pin (or) wrist pin



- Process tube
- Suction tube Discharge tube
- Oil cooled tube
- Mounting spring

Suction valve: During suction stroke piston moves down word and refrigerant vapour drawn into the cylinder through valve Ref.Figs (1 & 2).

Discharge Valve : During compression stroke piston moves upward the pressure increased until the refrigerant is forced past the discharge valve to the condensor Ref.Figs (1 & 2).

Crank Shaft : Drive assembly of compressor, extended shaft from rotor assembly Refer Figs (1 & 2)

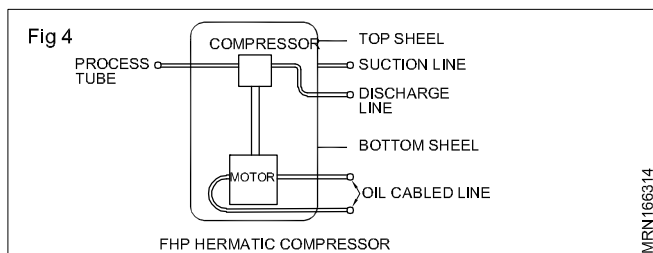
Connecting rod : Connecting rod coupled with crank shaft to transmit the drive to the piston in to and fro motion. Refer Figs (1 & 2).

Piston pin : Couple piston and connecting rod. Refer Figs (1 & 2).

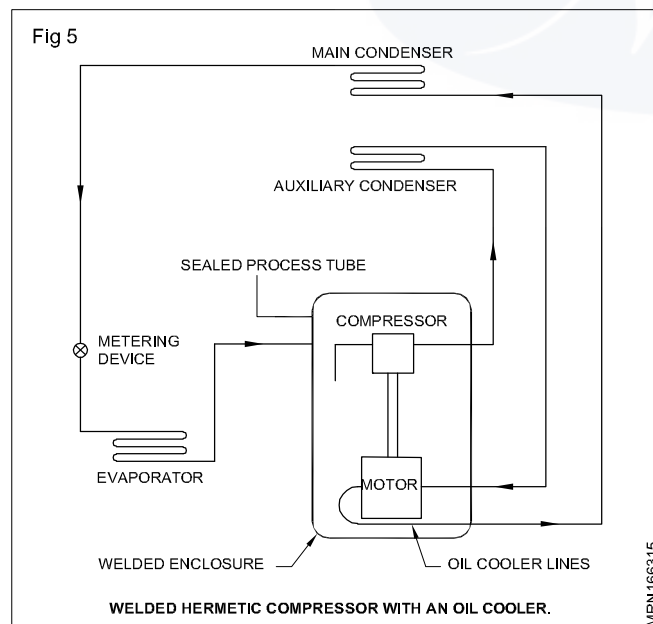
Process tube : This tube welded at top of bottom dome or at top dome of the compressor. Through this tube only all process like leak testing, vaccumizing, and gascharging, topping and purging will be done. Refer (Fig 4).

Suction tube : During the suction stroke refrigerant vapour from the evaporator enter into the compressor through this line. Suction tube located top of bottom dome Refer (Fig 4).

Discharge tube : During compression stroke refrigerant vapour compressed and delivered to the condenser through this tube. Refer (Fig 4).



Oil cooled line : Located at the bottom of the compressor shown in (Fig 4) immersed in the oil. At the compression stroke high pressure, high temperature superheated vapour discharged to the auxillary condenser (Refer Fig 5). In the auxillary condenser refrigerant lets a part of heat of condensation and then enter into oil cooled line and absorb the heat from the oil gets heated then enter into main condenser.



Mounting spring: Hold the motor assembly and compressor assembly.

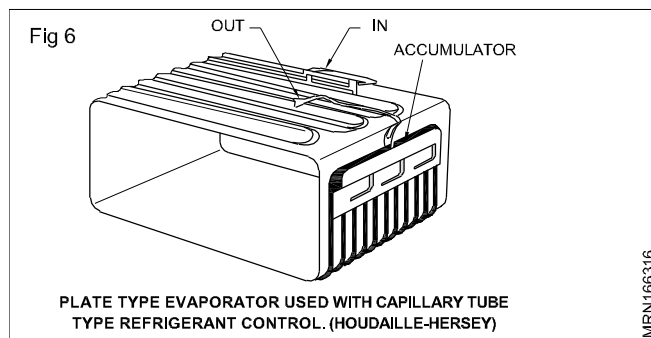
Types of evaporator used in domestic refrigerator

1 Static

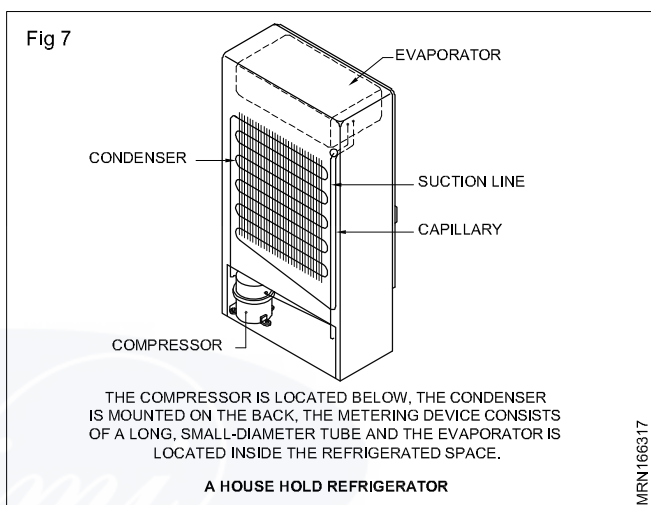
2 Forced draft

Static type evaporator usually have Aluminium plate type coil and have no fins, can be shaped in to a variety of

physical shapes as used in conventional refrigerator. Refer (Fig 6).



Forced draft Finned tube evaporators are usually forced draft. This type of evaporator are used in frost free refrigerator Refer (Fig 7).



Types of Condenser

1 Static type

- External type
- Body condenser

2 Finned tube - Forced draft

Static Type: (External type) This type of condensers are used in conventional refrigerator. Other model Body condensers are used in frost free refrigerator.

Finned tube Forced draft: This type condensers are used in air conditioner. Air is forced by means of fan motor.

Essential for Internal cleaning of evaporator coil and condenser coil in refrigerator

In refrigerator, single feeding capillary tube sizing 0.030" or 0.031" used as a expansion device. Since I.D. of the capillary tube is too small, the refrigeration system should be contamination free. While replacing new compressor against burn out compressor in the system, the total system should be free from contamination. Due to burnt out of Previous compressor carbon particles spread every where in the system. This may cause to chock the passage of refrigerant in the capillary tube so internal cleaning of condenser coil and evaporator coil are very important in refrigeration system.

Defects in conventional type refrigerator - “More Cooling” - “Improper setting of Controls”

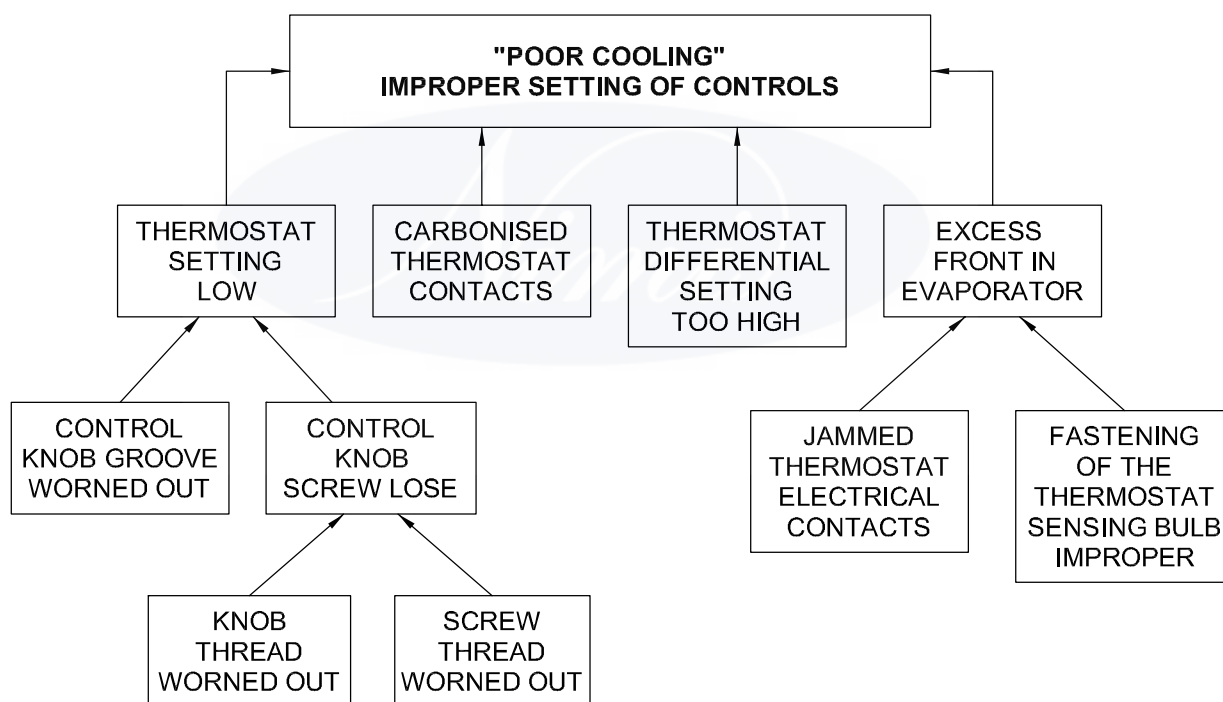
Objectives: At the end of this lesson you shall be able to

- analyse the causes for the complaint “More cooling” - “Improper setting of controls” with the help of Problem Tree (PT)
- analyse the causes for the defect leading to the complaint with the help of Trouble Shoot Chart (TSC)
- analyse the sequence for repairs using Service Flow Sequence (SFS).

Symptom: “More Cooling”

The improper setting of controls in Conventional Type Refrigerator results in more cooling in the refrigerator. Possible causes for the complaint “More cooling” is illustrated in Problem Tree given below. Refer Trouble Shoot Chart (TSC) and Service Flow Sequence (SFC) given in exercise no. 1.4.64A for possible reasons for defects and for the suggested remedial measures.

PROBLEM TREE



Defects in conventional type refrigerator - “Poor Cooling” - “Gas shortage”

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

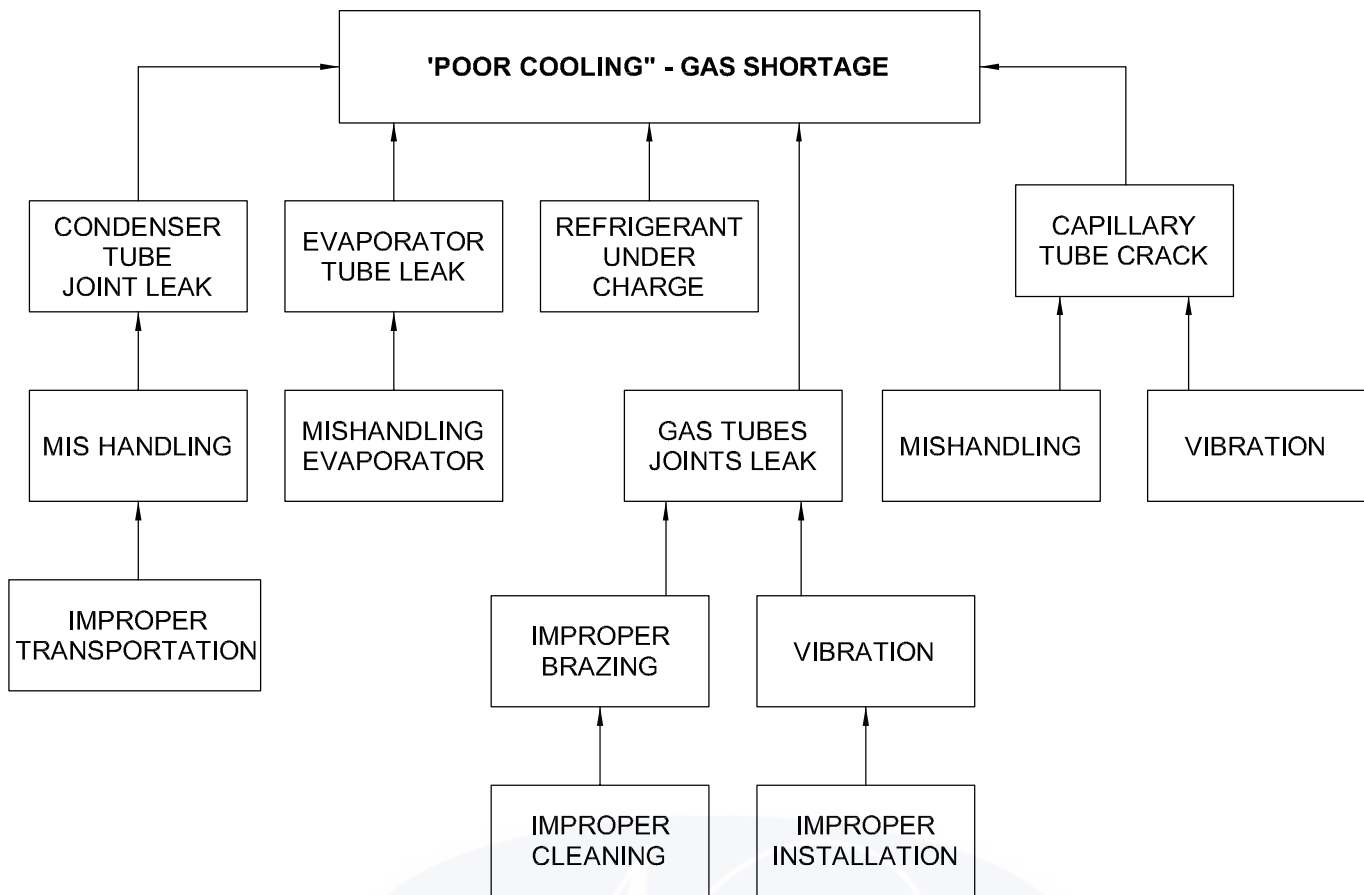
- analyse the causes for the complaint “Poor cooling” - Gas leak with the help of Problem Tree (PT).
- analyse the causes for the defect leading to the complaint with the help of Trouble Shoot Chart (TSC)
- analyse the sequence for repairs using for Service Flow Sequence (SFS).

Symptom: “Poor cooling”

The improper handling, brazing of the gas tube joints of the conventional type refrigerator results in poor cooling due to gas leak in the refrigerator.

Possible causes for the complaint “Poor cooling” is illustrated in Problem Tree given below. Refer trouble shooting chart (TSC) and Service Flow Sequence (SFS) given in exercise no. 1.4.64A for possible reasons for defects and the remedial measures.

PROBLEM TREE



Defects in conventional type refrigerator - “No cooling” - “Short cycling in Compressor”

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

- analyse the causes for the complaint “No cooling” - High leak back in compressor with the help of problem Tree (PT).
- analyse the cause(s) for the defect leading to the complaint with the help of Trouble Shooting Chart (TSC).
- analyse the sequence for repairs using for Service Flow Sequence (SFS).

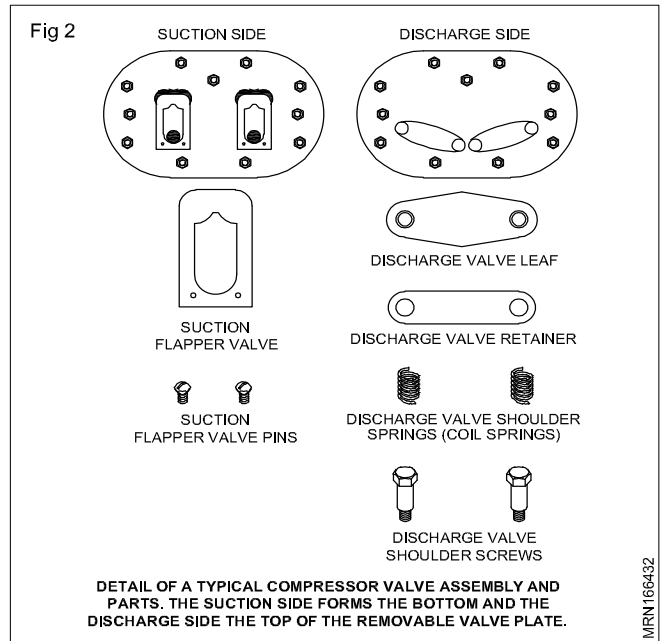
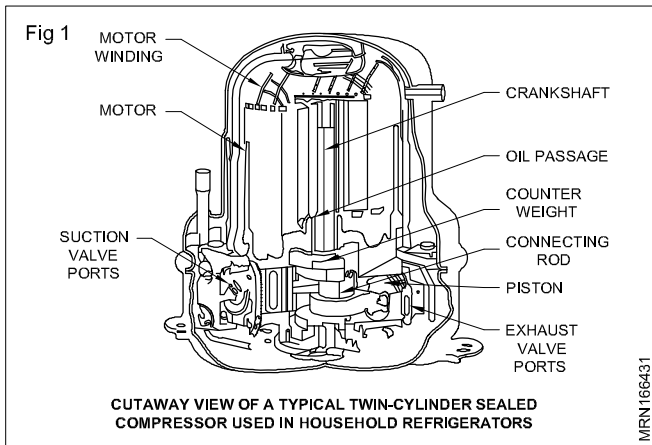
Symptom: “No cooling”

In high leak back in compressor in conventional type refrigerator results “No cooling” in the Refrigerator. Possible causes for the complaint “No cooling” is illustrated in Problem Tree given below.

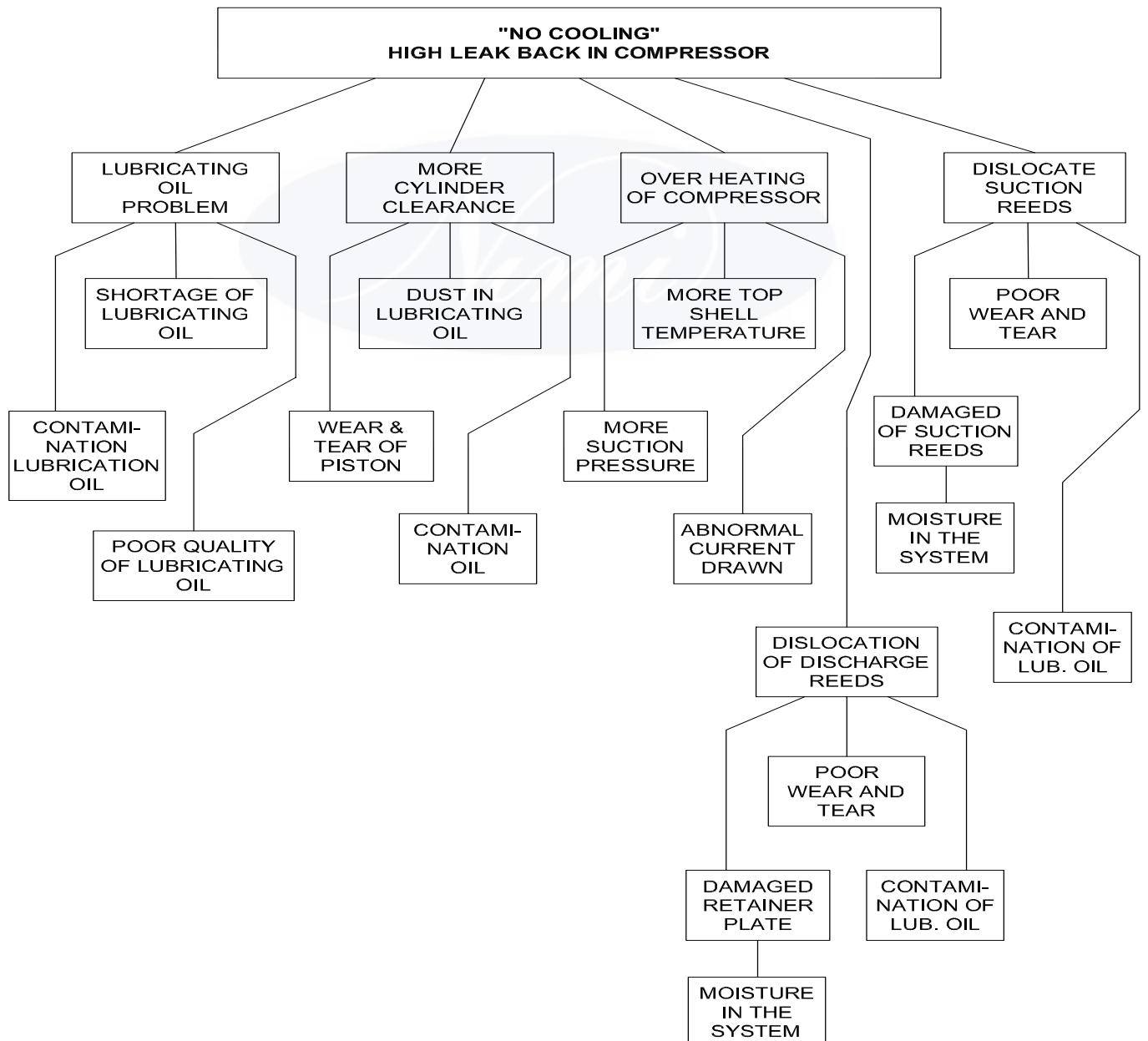
Refer Trouble Shooting Chart (TSC) and Service Flow Sequence (SFS) given in Exercise 1.4.42 for possible reasons for defects and further suggested remedial measures.

In a conventional type refrigerator before undertaking repair work the refrigerant to be released from the system. For releasing refrigerant slowly cut charge line using tube cutter and release refrigerant slowly. Disconnect discharge line, suction line from compressor using gas torch, also remove compressor base bolts. Remove and shift compressor from conventional type refrigerator for analysing and repairing. (Fig 1)

Cut open the hermetic sealed compressor with the help of hacksaw frame, check all mechanical parts inside the defective compressor. Remove contamination lubricating oil. Remove the winding core from the compressor. Remove mechanical parts like piston, head plate, suction and discharge valve plates, inspect and replace worn out parts. (Fig 2) For replacing discharge valve plate remove discharge reeds, coil spring, retainer plate and then remove discharge reeds. Replace new reeds, retainer plate, coil spring and tighten the shoulder screws. All mechanical parts cleaned with trichloroethylene, reassembled all mechanical parts and winding core. Plug the electrical wire socket at inside terminals. Top doom welded with using arc welding. After repairing the compressor, assemble in refrigerator. Braze all joints with the help of gas torch. Test leak and put in vacuum. After perfect vacuuming, charge refrigerant and test refrigerator performance.



PROBLEM TREE



Defects in conventional type refrigerator - “More Cooling” - “Improper setting of Controls”

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

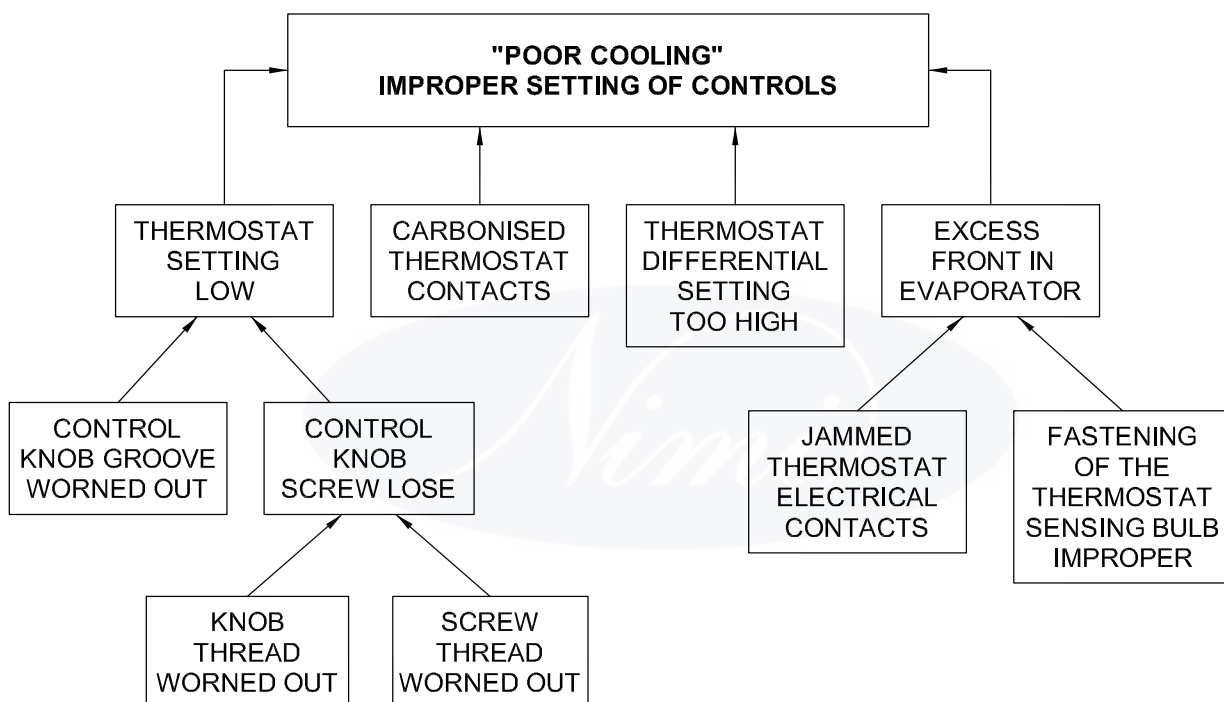
- analyse the causes for the complaint “More cooling” - “Improper setting of controls” with the help of Problem Tree (PT)
- analyse the causes for the defect leading to the complaint with the help of Trouble Shoot Chart (TSC)
- analyse the sequence for repairs using Service Flow Sequence (SFS).

Symptom: “More Cooling”

The improper setting of controls in Conventional Type Refrigerator results in more cooling in the refrigerator. Possible causes for the complaint “More cooling” is illustrated in Problem Tree given below.

Refer Trouble Shoot Chart (TSC) and Service Flow Sequence (SFS) given in exercise no.1.4.38 for possible reasons for defects and for the suggested remedial measures.

PROBLEM TREE



Defects in Frost free Refrigerator - “excess frost” - Malfunctioning of Bimetal thermo, Defrost heater and timer switch.

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

- analyse the causes for the complaint “excess frost” - Malfunctioning of bimetal thermo, defrost heater and timer switch
- analyse the causes for the defect leading to the complaint through Trouble shooting Chart (TSC).
- analyse the sequence for repair using the Service Flow Sequence (SFS).

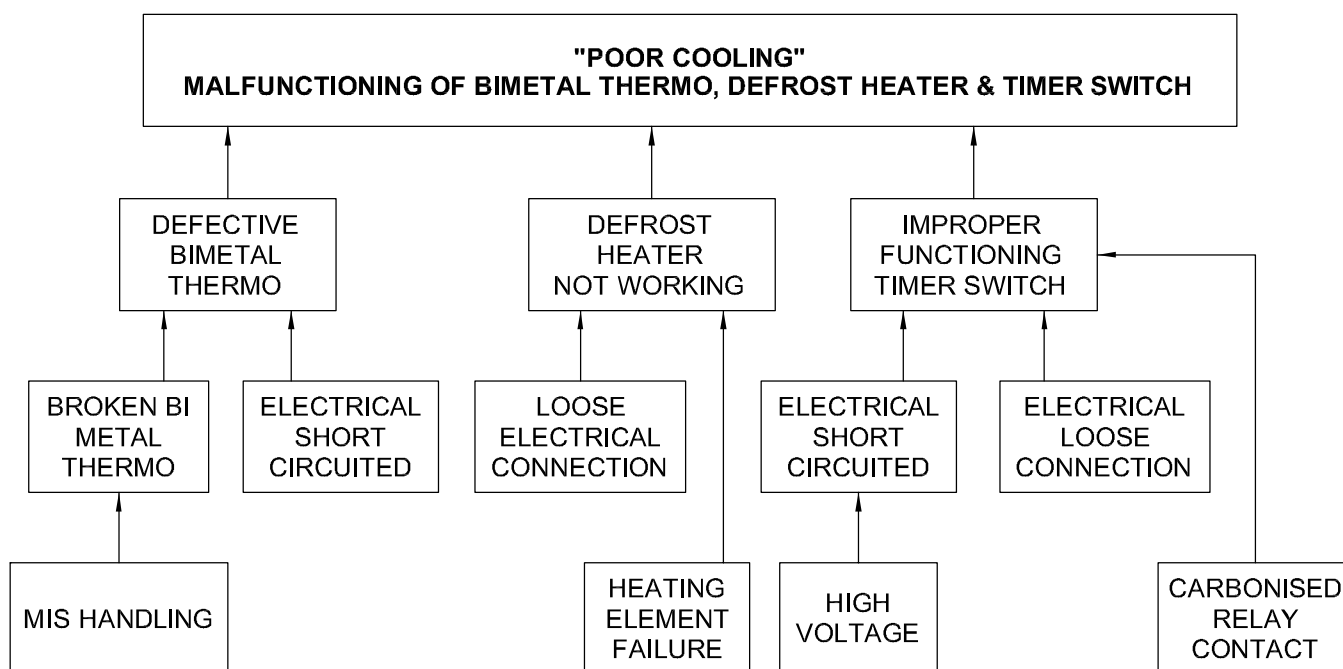
Symptom: “Excess frost”

The malfunctioning of bimetal thermo, defrost heater and timer switch in frost free refrigerator results in “excess cooling” in the refrigerator.

Possible causes for the complaint “excess frost” is illustrated in Problem Tree (PT).

Refer Trouble Shooting Chart (TSC) and Service flow sequence (SFS) given in Exercise 1.4.41 for possible reasons for defects and for suggested remedial measures.

PROBLEM TREE



Replace thermal insulation material of refrigerator cabinet

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

- describe insulating materials
- state the property of insulation materials
- list the types of insulating materials
- explain the heat exchanger in refrigerator
- care and maintenance of refrigerator.

Insulating materials : Heat will flow from high temperature to low temperature. Heat flow by radiation, conduction and convection method through the wall, door, ceiling and glass door to the refrigerated space.

The material which restricts such heat flow is called insulating materials.

Properties of insulating materials

- 1 It is low conductivity
- 2 Resistance to fire
- 3 Less moisture absorption
- 4 Good rigidity
- 5 Odourless
- 6 Vapour permeability
- 7 Light in weight
- 8 Easy of handling
- 9 Low cost

Types of insulating materials

- Fibre glass, this insulation is most common insulation used.
- Mineral wool, glass wool are actually refers to several different types of insulation.
- Cork, Thermocole sheets also was used as insulation.
- In some applications cellulose insulation materials are used. Most eco friendly.
- Poly Urethane Foam (PUF) insulation is widely used for refrigerators.
- Polystyrene (Styro foam) insulation also used in certain cases.

Heat exchanger : While removing insulating material you can find the heat exchanger. It is a device used to transfer heat suction line capillary tube is soldered together to act as heat exchange. Due to heat exchange the efficiency of refrigeration cycle be increased.

Winding and pumping of hermetic compressor

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

- **explain the winding in hermetic compressor.**
- **describe about compressor pumping.**
- **explain system processing.**

When a compressor does not run, it is most likely because of one of the following problem.

- the compressor motor is burnt out
- the compressor is mechanically struck
- there is no voltage to the compressor

In order to check compressor motor windings, disconnect all wiring from the three compressor terminals. Using a multimeter measure the resistance between each two pairs. If the power source is three phase, all three readings on the compressor windings should be equal.

If the compressor operates on single phase power, there should be one resistance reading that equals the sum of the other two. Most resistance readings will fall within the range of 1 to 20 ohms. A compressor with a failed motor will often have one or more of the reading equal to zero (winding is shorted) or infinite resistance (winding is open).

The compressor winding can also be grounded to the casing. For this mark the resistance between each terminal and the casing. So make sure the probe on the casing is touching bare metal. You may scrape away some paint. This resistance reading should be infinity. If there is any movement at all on the meter, there is some continuity to ground and the compressor motor should be considered unserviceable.

If the compressor motor windings are not shorted, not open and not grounded then electrically the motor is all right.

Check pumping pressure in hermetic compressor

Volumetric efficiency of a compressor is the actual volume of refrigerant gas pumped divided by the calculated volume

If the head pressure increases the amount pumped per stroke will decrease. This is because the compressed vapour in the clearance space will expand on the intake stroke and freon vapour cannot move into the cylinder until the pressure in the cylinder is lower than the pressure in the suction line. The higher the compressed pressure the greater the compressed vapour in the clearance space will expand.

Secondly if the low side pressure decreases it is more difficult for vapour to fill the cylinder and the amount pumped per stroke will decrease.

Thirdly if the clearance pocket is enlarged the amount pumped per stroke will decrease. The clearance space is the space left in the cylinder when the piston is at the end of its pumping stroke T.D.C. Tap dead centre.

The efficiency of a compressor also depends on the size of the valve openings. If the intake valve reduces the flow of low side vapour into the cylinder the cylinder will not be filled and the efficiency of the compressor will be lowered. If the exhaust valve stick or if the line from the compressor to the condenser is pinched, this extra pressure in the cylinder will cut down the compressor's pumping efficiency.

System performance of refrigerator

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

- COP of refrigerator system
- explain the factors affecting system performance
- describe the need of a voltage stabilizer.

Coefficient of performance

The coefficient of performance (C.O.P) is the ratio of heat extracted in the refrigerator for the work done on the refrigerant. It is also known as theoretical coefficient of performance.

Theoretical

$$\text{COP} = \frac{q}{w}$$

where

Q = Amount of heat extracted in the refrigerator (or the amount of refrigeration produced or the capacity of a refrigerator)

W = Amount of work done.

System performance: The performance of the system will be affected by many reasons, but due to installation wise also the performance may affect sometimes.

- The heat load to evaporator increases when the door is not closing tightly, thus reduced/ less cooling may occur or quick frost formation on coil may occur if the unit located at coastal cities/areas

- Poor condensation may cause reduced refrigerating effect thus reduced cooling/less cooling may occur.
- Less cooling may occur due to frequent tripping of compressor as it draws high current.
- Less cooling may also occur due to short of gas in the system.

Need of a voltage stabilizer: Voltage stabilizer is supplying constant voltage to the appliance and it also prevents the compressor drawing high current during power get off and gets on immediately. The stabilizers should be provided correct capacity and with time delay arrangement (3 mins).

- You can set the thermostat at medium cool position, in no load condition, note the time it takes to cut-out.
- If it is frost-free with forced air circulation, check when the opening of the door the evaporator fan stops.
- See how long it takes to form cube ice and note it.

Air cooled condenser of domestic refrigerators

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

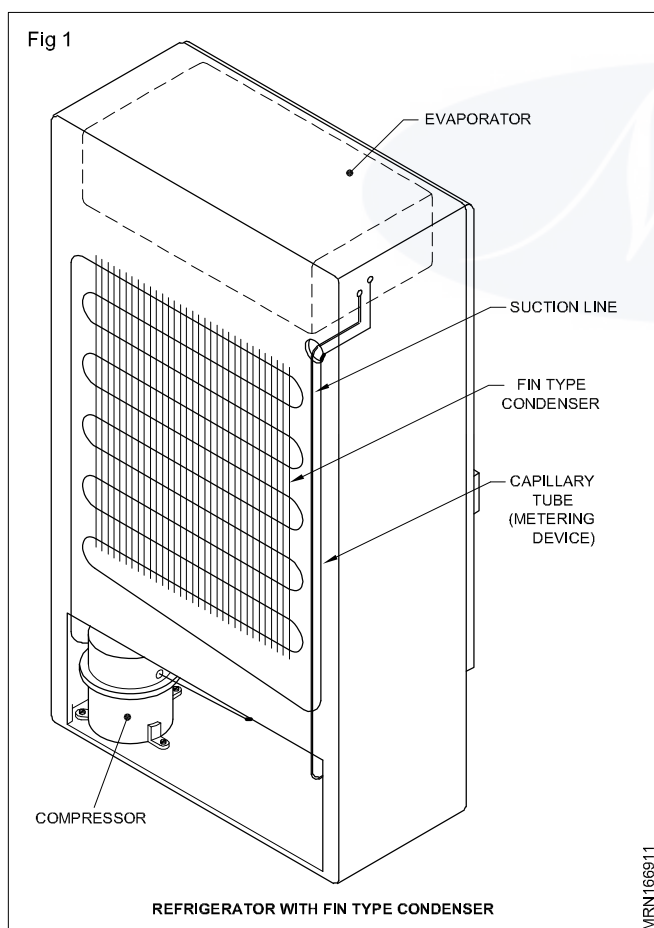
- construction of air cooled condenser of the fridge
- types of condensers used in household refrigerators
- body condenser in modern fridges.

Construction: Industry technicians refer the low side of the refrigeration system, means the metering device and the evaporator. High side means the compressor and condenser. The compressor and condenser mounted together is called condensing unit.

In household refrigerator the compressor is located below and the condenser is mounted on the back. The metering device consists of a long small diameter tube called capillary tube and the evaporator is located inside the refrigerated space.

Types: Normally there are two types of air cooled condensers used in fridges. One is fin type and the other is plate type.

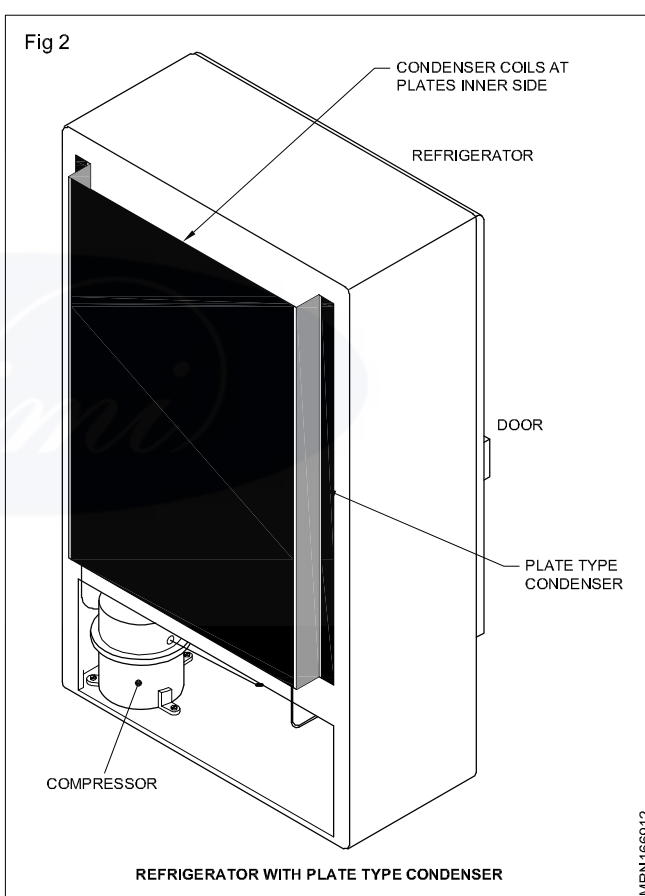
For fin type refer (Fig 1).



Fin type: In this type the fins are provided vertical on a frame. The fins are like a thin rod (2 mm dia) evenly welded in proper interval to the frame. The condenser coils will be clamped and soldered to the fins. The frame is fit at the back wall of the fridge, tighten the screws.

The natural air passes through the fins (distributed) and the condenser coils get cool. The pollution of air, the condenser fins will get a coating of fine dust. These dust over the condensing tubes will affect the heat transfer efficiency of the condenser. That can be cleaned periodically.

Plate type: In this type the condenser tubes are soldered to a metal plate and the plate will be fixed at the back of the fridge- tighten by the corner screws. (Fig 2)



The condensation takes place by natural air ventilation. Condenser tubes give up heat to the plate by conductivity and the plate surface is cooled by natural air velocity. So always it's advised to keep distance minimum 15 cm from the wall to fridge backside for free air circulation.

The condenser tubes are fixed inner side of the plate and if dust covers the tubes or plates can be cleaned with weak soap solution to increase the condensers performance.

In most of the fridges when it needs major repairs, the selection of the unit (condensing unit & the evaporator) can be removed from backside and the total cabinet can be separated.

Modern fridge: Now in modern fridges improved technology, they are using Poly Urethane Foam (PUF) as insulation inside the fridge instead of glass wool.

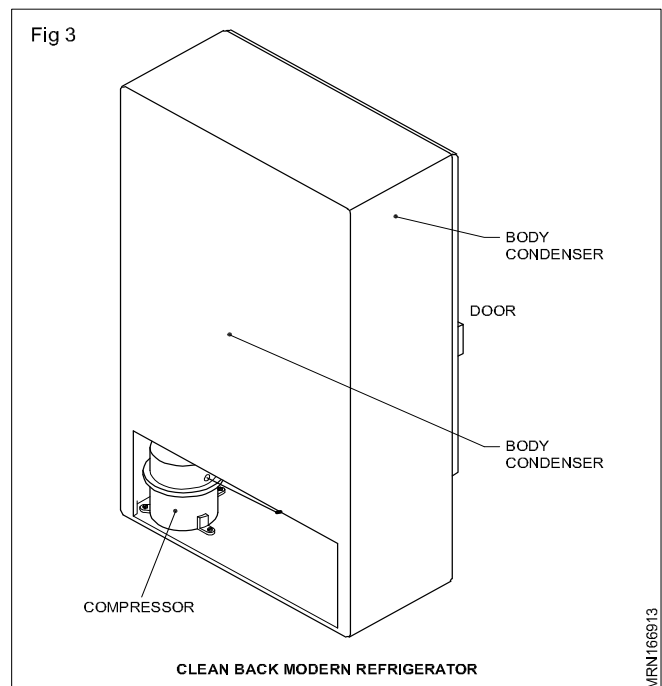
Here the condensing coil is fixed in both inside walls of the fridges sides, between the cabinet side walls and the PUF insulation.

The heat of the condenser coils transmitted to the plates of the cabinets sides and it is cooled by natural air circulation. (Fig 3)

At the back of the fridge will be clean back. These types of condensers are called body condensers.

While the fridge is running the side walls of the cabinet will be warmer than surrounding air temperature, since it conducts the heat of the condenser.

Because the condenser has no possibility of contact with contaminated air, there is no need for any external service.



Internal service of the Conventional Refrigerator's system components

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

- explain the necessity of cleaning and flushing in the system
- list the disadvantages due to presence of moisture in the system
- explain different possibilities of contaminants entering into the system
- describe the restricting of contaminants entering into the system.

It is common knowledge that moisture, air, non condensable gases and foreign materials are biggest enemies of the any refrigeration system to lead bad effect in the system such as failure of compressor, system choke, capacity reduction, waste of manpower, increase in repair cost, bad name from customer, employer.

Bad effects of moisture in the system: The moisture present in refrigeration system can turn into 'ice' at low temperature area or points of refrigeration system. The outlet of capillary tube in a refrigerator or expansion valve orifice in a low temperature. Commercial plants are always at low temperature less than 0°C in the moisture. If present in the system will condense and freeze at this point. This restrict or completely blocks the flow of liquid refrigerant to the evaporator there by affecting system performance.

Further even a much smaller quantity of moisture in combination with freon can form hydrochloric and hydrofluoric acids. These acids particularly hydrofluoric acid are very active and highly corrosive. They attack various parts of the refrigeration system like compressor winding, valve reeds and seats.

Presence of moisture in the compressor oil leads to contaminated and sludge is formed, losing its lubricating properties and thus affecting the life of the bearing and journals. The chemical reaction due to the acids and moisture gets accelerated. The rate of chemical reaction is doubled in every 8°C increase in temperature.

Once the valve read and seat get damaged or pitted the compressor efficiency gets impaired.

The presence of air and non condensable increase head pressure of the system. As the head pressure goes higher, the compressor motor draws more current and reduce the system capacity.

The above points, it is clear that, the presence of moisture, air and non condensable should be removed from the refrigeration system to the maximum possible extent. Hence before a system can be charged with refrigerant it should be thoroughly evacuated and dehydrated by drawing a high vacuum. If this is not done in the initial stage itself, we will never get a clean system.

Possibility of moisture, air and non condensable and foreign materials enter in the refrigeration system.

- leak testing process of refrigeration component
- moisture existence by improper vacuumization
- poor quality of refrigerant
- poor brazing

During the system reprocessing, we are using nitrogen for leak testing, flushing. Dry nitrogen itself contains more moisture. This has to be removed by vacuumising the system. Before gas charging contamination (carbon particle) present at the time of failure of compressor (bournout) Foreign particle present at the time of brazing.

How to minimize the presence of moisture air and non condensable gas and foreign materials in the refrigeration systems.

- proper internal cleaning with CTC
- Good quality brazing and use good quality of filling materials(welding rod)
- Drawing high vacuum with quality vacuum pump

- Use quality refrigerant

- Charge required quantity of refrigerant by volume method or by weight.

Because of failure (burnout) of compressor carbon particle spread everywhere in the system. This way system contaminated with carbon particle.

Contamination in condenser and evaporator of frost free refrigerator

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

- **effect of moisture in the system**
- **bad effects of non-condensable vapour and foreign materials in the refrigerator system**
- **need of deep vacuum to avoid malfunction of system.**

Effect of moisture in the system: The moisture in the system can turn to ice at low temperature area or in refrigeration systems. As the outlet of capillary tube in a refrigerator or a expansion valve orifice in a low temperature commercial plant are always at low temperature less than 0°C. The moisture if present in the system will condense and freeze at this point. This restricts or completely block flow of liquid refrigerant to the evaporator thereby effecting system performance.

A tenth of a drop of water in refrigerator system completely block the orifice of the capillary tube. Further even a smaller quantity of moisture in combination with freon, hydrolyse to form hydrochloric or hydrofluoric acids. These acids particularly hydrofluoric are very active and highly corrosive.

Further they attack various parts of refrigeration system like compressor winding, valve reeds and seats. And presence of moisture in the compressor oil leads to contamination, to form mixture of exceedingly time globus which leads and reduce oils lubricating properties, thereby affecting the life of bearings.

The chemical reaction due to moisture of acids get accelerated. The rate of chemical reaction doubles in every 18°F increase in discharge temperature. The decomposition of metallic surface can cause corrosive 'Sludge' which can clog time orifice of the filters.

Bad effects of non condensable vapour and foreign materials in the refrigerator system.

Possibility of non condensable vapor and foreign materials entering the system

- Flushing with dry nitrogen to different refrigerator component without using dry nitrogen of purity of 3 PPM.
- During leak test process of the system
- Poor quality of refrigerant
- Poor brazing

During system processing for leak test and flushing we use commercial grade dry nitrogen which itself have high moisture. This can only be removed by high vacuum to the system before gas charging. So to avoid this, use only dry nitrogen with purity ppm for flushing.

The presence of air and non condensables increase the head pressure of the system. As the head pressure goes high, the compressor motor draws more current and reduce the system capacity. Charging good quality refrigerant and first grade (without using recycled or reclaimed refrigerant), will overcome problems like efficiency of refrigerant used its compatibility to mix well with refrigerant oil and overall the refrigerant to be 100% pure in its chemical structure and free from trace of moisture.

Poor brazing is the cause of foreign particles blockage in capillary in refrigerator expansion valve in commercial refrigeration system. Therefore while brazing capillary, good joint is to be made (Refer Ex.247 removal and replacement of capillary in hermetic system). The above points is clear that the presence of moisture, foreign particles, non condensable vapour should be removed from the system to the maximum extent possible. Hence before a system is charged with refrigerant it should be thoroughly evacuated, flushed with dry nitrogen for clearing contaminants and dehydration by drawing high vacuum. If this is not done in the initial stage, we will not get clean system.

Need of deep vacuum to avoid malfunction of the system:

Method adopted normally to remove moisture, we convert water content to steam (vapour) and draws it out. This is accomplished by lowering internal pressure, by understanding the relationship of atmospheric pressure and boiling point of water. As we know water boils at 100°C (212°F) at sea level that is 14.7 psi / 1.033 Kg/cm². If the atmospheric pressure falls, so as the boiling point of water. We further create and low internal pressure of 20mm of Hg inside the refrigeration system by using vacuum pump, we decrease boiling point of water to around 22°C (72°F). And further to change state from water to vapour energy is required (better called as latent heat) which is attained drawn by the external heat source (surrounding pipe work) and this vapourisation of moisture will drop inside system temperature.

But to thoroughly dehydrate and pull out other non condensable gas we need deep vacuum which can draw as much of moisture vapour and non condensable by attaining 100 microns by using 2 stage rotary vacuum pump.

Temperature in		Pressure in		
°F	°C	Inches of	Microns	psig
212	100	29.92	759968	14.696
158	70	9.20	233680	4.519
72	22.2	0.80	20320	0.393
32	0.00	0.18	4572	0.088
	0.100		2540 (0.254 cm) (2.54 mm)	
		0.039	1000 (0.100 cm) (1.00 mm)	

Contamination in a hermetically sealed systems

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

- describe contaminants
- list the contaminants
- evaluate the causes of contaminants
- state the effect of contaminants
- explain the control methods.

Introduction: Contamination in a hermetically sealed systems will face many problems resulting reduced cooling or cooling effect. In other words, contamination in a system is indicates pollution in refrigerant and compressor oil which affects severely on the performance of the system.

Contaminant: The material/substance which is behind contamination is called as 'contaminant' or in brief everything is a contaminant except refrigerant and compressor oil in a hermetically seated system.

Contaminants	Effects
1 Unwanted chemicals (brazing flux, processing liquids)	Chemical breakdown of compressor oil
2 Minute metal particles	Wear and tear of moving parts
3 Non condensable gases (air, nitrogen etc.)	High discharge pressure & temperature
4 Moisture	Capillary chock/block
5 Dust/dirt	Reduced refrigerating effect

What are contaminants? Contaminants will be in different forms/sizes into system e.g. dusts, dirt, minute metal particles, chemicals like brazing flux, processing oils, air nitrogen and moisture etc.

Causes of contaminants: The contaminants caused by the following

- Poor brazing and cleaning
- Improper flushing and drying
- Inadequate vacuum level
- Insufficient dehydration

Effects of contaminants (Fig 1): The contaminants may result 'no cooling/poor cooling' with the following symptoms

- Wear and tear of moving parts of compressor
- Capillary chock/block
- Chemical breakdown of refrigerant (compressor) oil
- Removal of motor insulation
- High discharge pressure and temperature
- High compressor winding temperature

Control of contaminants: It must be necessary / useful to control the contaminants with the following aspects.

- 1 Prevent the entry of solid particles into the system during manufacturing of components.
It is to be done by effective cleaning of components with carbon tetra chloride liquid or tri chloroethylene
- 2 Prevent the entry of chemical compounds/ liquid particles during assembling of components.
This can be achieved by complete flushing of components with dry nitrogen or dry air
- 3 Prevent the entry of non condensable gases like air, moisture, nitrogen etc during pressure leak testing of components.
To avoid this kind of problems an effective evacuation process to be established by using 2 stage vacuum pump.
- 4 Prevent the entry of moisture/ air during vacuumising or after vacuumising process.
This can be achieved by complete dehydration (removal of moisture by heating the components with heating kit (Infra red lamp type) of individual components during vacuumising/ after vacuumising process.

Capillary tube in the hermetic type compressor in refrigerators

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

- explain where are capillary tubes used
- explain the function of capillary tube
- explain the handling of capillary tube
- explain the advantages of capillary tube
- explain the servicing procedure of capillary tubes.

Where are capillary tubes used: The capillary tube is the most commonly used metering device on small refrigeration and air conditioning system. It is used on virtually all domestic refrigerators and window air conditioners.

Function of capillary tube: The capillary tube has to perform the following functions

- To meter the amount of refrigerant admitted to the evaporator. There must be sufficient to pick up and the heat working to be removed but not so much that the evaporator is filled with liquid.
- To regulate the pressure of the refrigerant and thus help maintain the evaporator at its designed temperature.

The capillary tube consists of a long small diameter copper tube. As the liquid from the condenser is pushed through such a small passage, the friction between the refrigerant and the tube causes a pressure drop. When this pressure drop causes flashing of the liquid to occur, the additional space occupied by the flash gas causes the pressure drop to increase rapidly.

Handling of capillary tube: The capillary tube is commonly much longer than the distance from the condenser to evaporator, the excess length accommodated by rolling the capillary tube into a coil, extreme care must be taken not to knik the capillary tube.

This may be avoided by using any solid cylindrical shape as a form to wrap the capillary around a tin can to be used.

Advantages of capillary tube: The advantage of a capillary tube as a metering device is inexpensive and has no moving parts. Because it cannot change in order to match the different amounts of refrigerant that may be flowing through the system however, its use is restricted to those systems that have a relatively constant load.

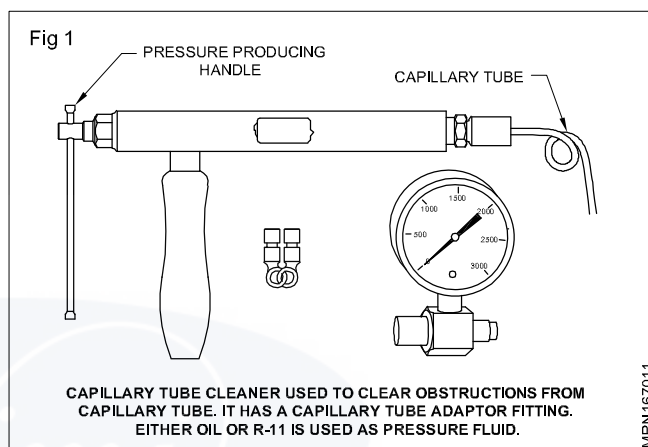
Servicing procedure of capillary tube: Debraze the capillary joints along with the filter dryer.

It is sometimes possible to repair capillary tube by cleaning it. Procedure is as follows:

Disconnect the capillary tube at both ends. Fill the capillary tube cleaner with fresh refrigeration oil or R11.

Attach the capillary tube cleaner to the outlet end of the tube.

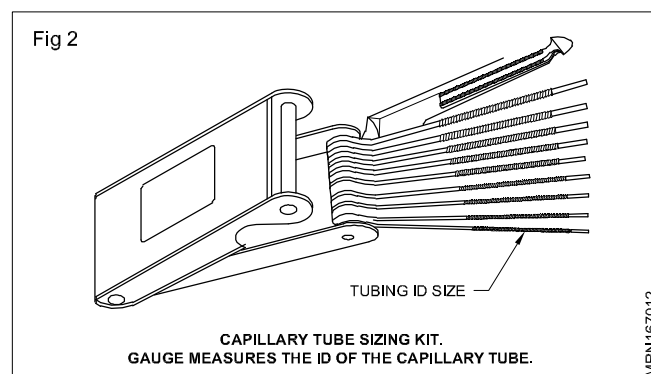
Build up pressure on the tube by tightening pressure producing handle to force the wax or dirt out as in (Fig 1).



After the capillary tube has been cleaned continue to flush out the tube thoroughly. Use either R11 or the Refrigerant which the system is charged.

Install a new filter dryer and braze the flushed capillary to the system.

If the blockage is due to wax, the compressor oil is to be replaced with fresh refrigeration oil. Don't use any antifreeze. (Fig 2).



Dehydrators (Filter drier)

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

- explain when to replace a dehydrator (filter drier)
- explain the purpose of dehydrator (filter drier)
- explain why it is called a dehydrator (filter drier)
- explain what is desiccants.

When to replace a dehydrator (filter drier)

- A (filter drier) dehydrator should be replaced when a new motor compressor is installed, if the filter is clogged.

Purpose of dehydrator (filter drier): Dehydrators (filter drier) serves a dual purpose, first they act to strain out any particles that may be in the system.

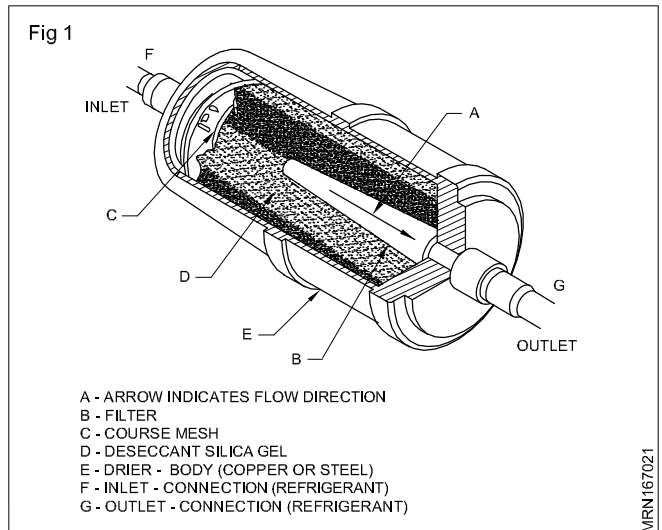
Most commonly, these particles might be oxidation that has formed on the inside of brazed tubing which breaks loose during operation of the system.

The second function of a dehydrator (filter drier) is to dry the refrigerant that does not mean that it removes liquid but that it absorbs and holds water that may have not been properly removed when the system was put together.

Dehydrator (filter drier): The opening through which the liquid passes in the capillary tube is generally very small and can easily become blocked. Preventing a liquid flow, the filter drier consists of a very fine filter designed to trap small particles or dirt which would cause blockage at the capillary. The filter element is followed by a desiccant (drying agent) which has a high capacity for absorbing water which would otherwise freeze at and block the capillary.

Dehydrator (filter drier) consists of the following. (Fig 1)

- A – arrow mark -indicates the flow
- B – filter element - to catch strain the particles and dirt
- C – course filter - not to allow desiccant to travel
- D – desiccant- drying agent silica gel



E – drier body - made of copper or steel holds the internal

F – inlet connection flare or brazed - refrigerant

G – outlet connection flare or brazed - refrigerant

A Freon 22 filter dryer must be three to five times larger as those needed for Freon 12.

Desiccants:

Desiccants are drying agents used in dehydrators (filter-drier) In freon group gases silicajal was used as drying agent molecular sieves, activated alumina are the other desicauts are used in refrigeration field according to the different refrigerats. There are highly absorption of moisture.

Gauge service manifold for Hermetic systems

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

- **describe all gauges and service connections to a Hermetic system.**

It is good practice to make all gauges and service connections to a hermetic system through a gauge service manifold. Most domestic refrigerators and freezers with hermetic systems do not provide a gauge opening, therefore special attaching devices must be used to make it possible to use the gauge manifold.

Low side could be connected to the charging line.

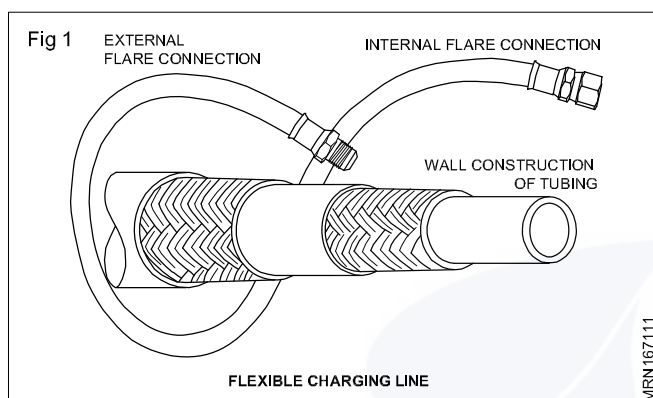
High side could be connected to a separate line connected to the condenser outlet.

Valve positions for various operations: (Ref. Practical Ex.1.4.71 shows various uses and valve positions of a gauge manifold. Separate gauges and hand valves can be used with the special service valves mounted on. Hermetic system however to purge a system check pressure or to evacuate and to charge the system would mean removing these devices and using others for each operation.

A gauge manifold with two gauges, two hand valves and three separate lengths of flexible refrigeration tubing enables the service technician to perform these operations more easily.

The three flexible hoses are equipped with 6 mm flare fittings pressure tight which could be tightened by fingers alone. (Fig 1) shows a flexible hose. Also the construction.

There gauge manifold are arranged for one suction and one discharge gauge. Either three or four flared connection for the lines from the vacuum pump, refrigerant cylinder and appliance are to be tested.



Leak testing, evacuation of gas charging in refrigerator

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

- leak testing, evacuation of gas charging in refrigerator
-

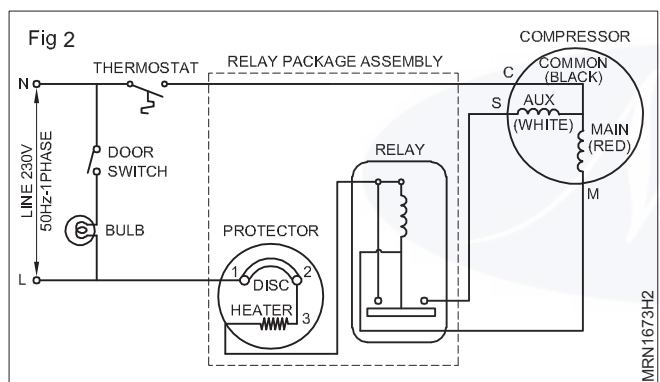
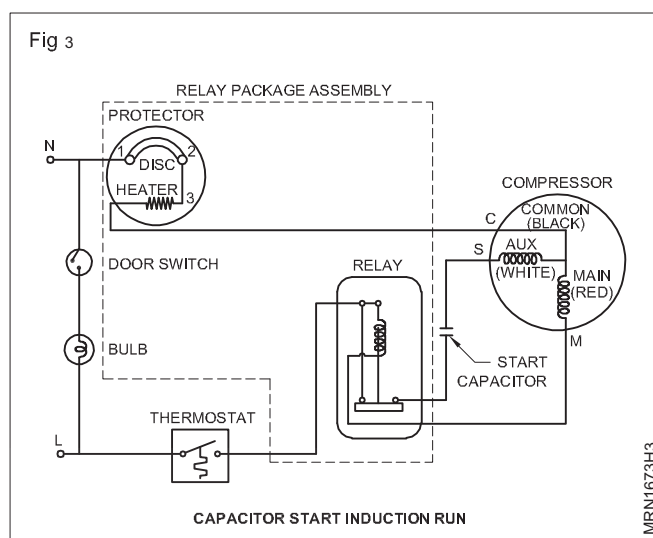
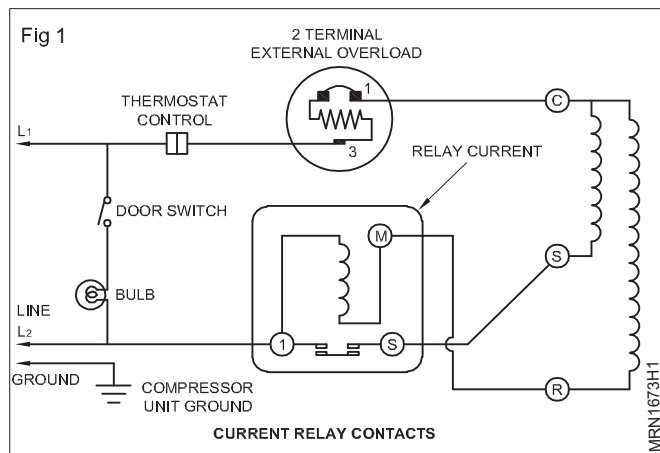
Refer exercise 1.5.56



Electrical wiring of refrigerator

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

- electrical wiring of refrigerator

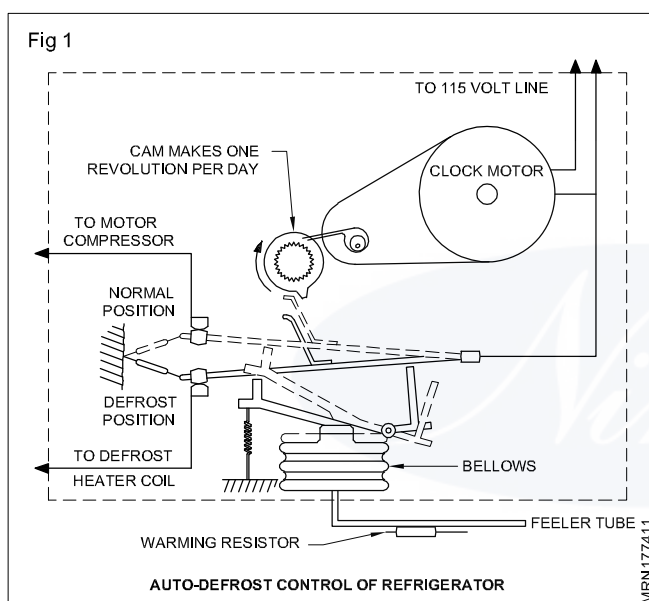


Defrost, temperature controls and electrical circuit of frost free refrigerators

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

- explain the electrical defrost system
- explain hot gas defrost system
- explain defrost controls - thermostat, timer and heater
- explain to control different temperatures by damper adjustment.

Electrical de-frost system: Most of the frost free refrigerators have a standard temperature section and a frozen foods section in the cabinet. These dual purpose cabinets need a special series of motor controls. The controls must give correct temperature in both sections and the controls must provide completely automatic defrost.



One type of control is shown (Fig 1).

The timer turns off the compressor and freezer cabinets fan. At the time it energize the electrical heater on the evaporator coil and the heater on the drain through.

Heater melts the frosting ice and the water drain down, through the tube collects on the tub kept on the compressor. This water get evaporated by the heat of the compressor while the unit is running.

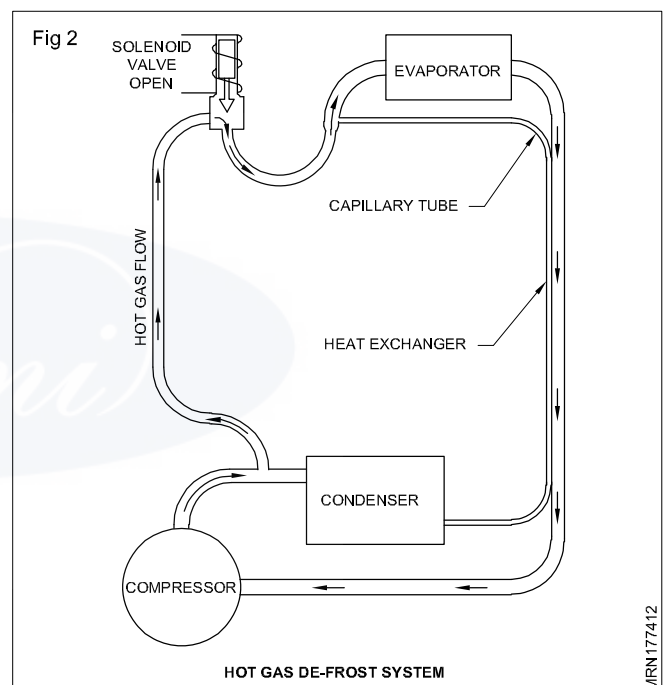
When the temperature at the bimetal thermo disc reaches approx. to 10°C the coil heater turned off. Coil will be completely defrost by this time, around 10 min will be the defrosting time.

Suppose the bimetal disc fails to cut the heater, the timer switch when it closes 15 min 'off cycle', it will cut off the heater (18°C approx.)

The drain heater stays on approximately 5 min after the coil heater has been shut off by the thermo disc and it cut off by the timer switch. This is to ensure the complete melted water to drain.

Soon as the timer switch engage the compressor start immediately to bring the coil temperature down to required cooling. The evaporator fan will run 5 min later by time delay, since to prevent the circulation of warm moist air.

Hot gas defrost system: The hot gas method of defrosting uses a solenoid to open and close the bypass from the compressor discharge to the evaporator. The operation of solenoid and the cycle is shown (Ref. Fig 2) when the



solenoid valve open, the hot gas flows to evaporator and melts the frosting ice and returned to compressor.

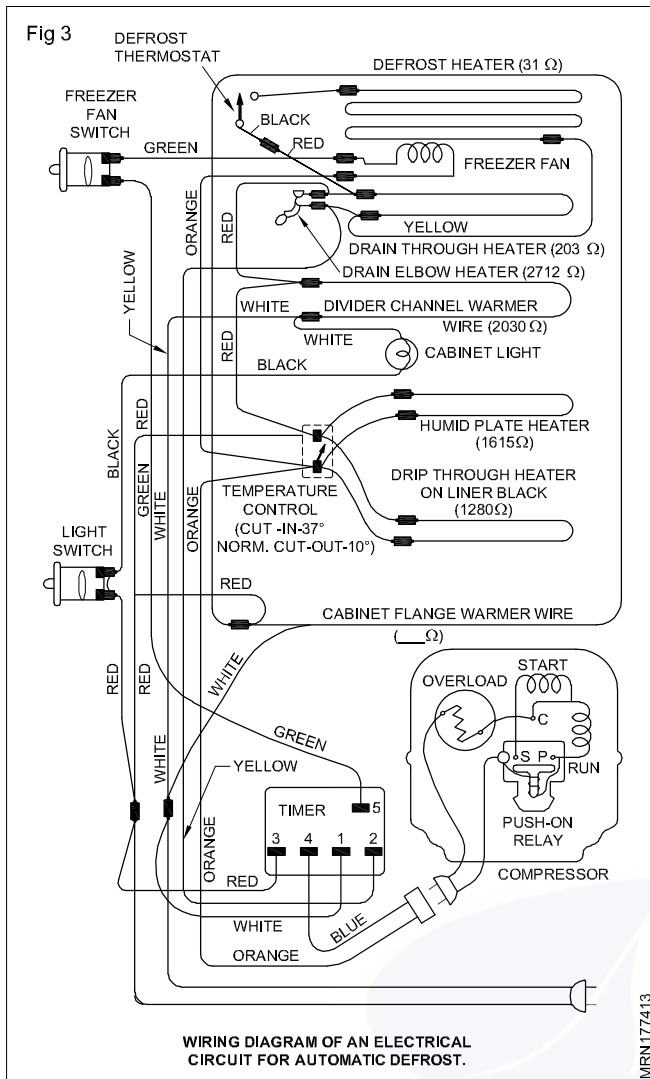
After defrost time is over the solenoid valve close, the hot gas bypass line which goes to evaporator will shut and normal cycle put into operation for the refrigerator.

In this type defrost time also the compressor will run continuously only the discharge vapour is diverted to evaporator other than in normal condition the hot gas will flow to condenser for usual cycle.

Defrost Controls

Thermostat: It is a temperature standard control serving as 'on' and 'off' switches for the compressor according to required temperature maintains in evaporator compartment as well as refrigeration cabin.

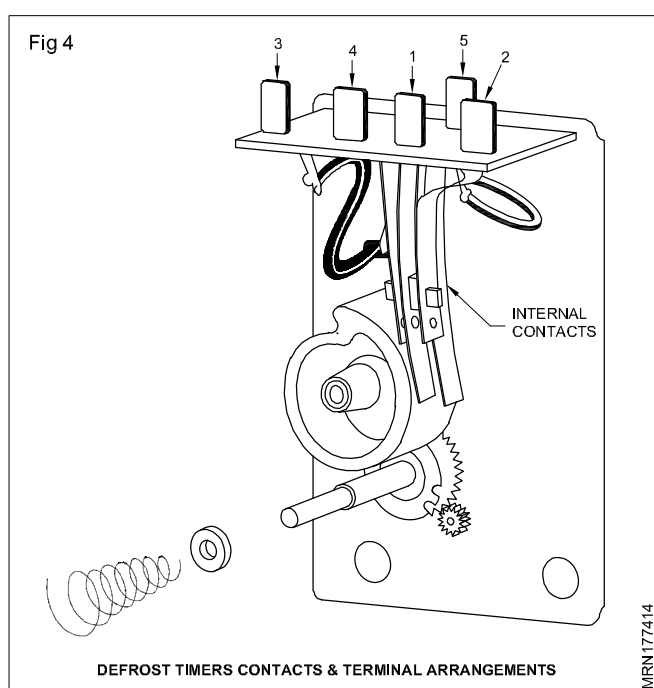
Timer and Heater: The defrost heater energised on cut out periods of the unit only or it may be operated by a



control timer mechanism, starting a defrost cycle once in every 12 hours. (Ref. wiring diagram of an electrical circuit, auto defrost in refrigerator (Fig 3).

The compressor is controlled by the temperature control switch during both the defrost and refrigeration cycle. The defrost control switch be in a defrost position during the thermostat cut off position (when the compressor is 'off').

The defrost cycle will not start until the temperature control switch closes and starts the compressor. The switch arm is moved to the defrost position by an electrical clock. (Ref.



(Fig 4). The switch arm is returned to the normal position by a power element which is responsive to changes in temperature.

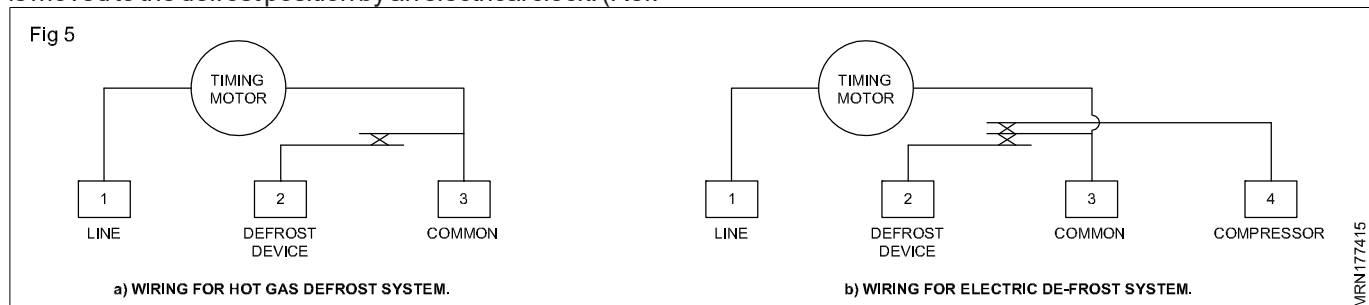
The liner heater operates during the 'off cycle of the compressor and defrost the ice formation. Bimetal defrost thermostat (Ref Fig 6) controls this heater closed at 6°C and open at 10°C during defrost. The timer clock runs only when the unit is running. These controls defrost these evaporators during each 'off position of the operating cycle, either hot gas or electric heating elements are used.

It shuts off the compressor and the evaporator fans and start the electric heater will be 'on' for about 15 min.

Then it shut off the electric heater and starts the compressor.

Evaporator fan starts after compressor has run about 5 min and then the unit returns to normal operation.

The simple wiring diagram of an automatic defrost control (Ref. Fig 5(a)), motor circuit is broken during defrost time.



In hot gas defrost system (Ref Fig 5(b)). The compressor runs continuously in defrost cycle to supply hot gas to the evaporators since the solenoid valve open.

Damper controls : There is a damper control manual

switch is provided in refrigerator cabin that can be adjusted according to the need of food products stored in either freezer or refrigerated compartments.

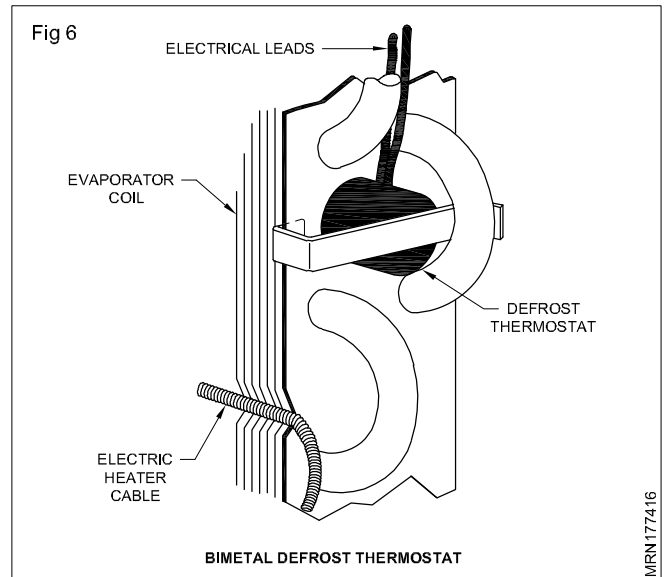
There will be 5 position in that piano type switch as A,B,C,D

Damper control adjustment

Switch position	Air flow in freezer cabin	Air flow in refrigerator cabin
A	20%	80%
B	40%	60%
C	50%	50%
D	60%	40%
E	80%	20%

& E. It controls the open or close of the damper. the air flow open totally 100 % means each position will share 20% of the opening.

According to these arrangement the user can manually adjust the damper for air flow as well as required temperature inside the freezer or refrigerator compartments.



Electrical parts in frost free Refrigerator

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

- explain name all the electrical parts in frost free refrigerator.
- explain function of the electrical parts in frost free refrigerator.
- explain testing frost free refrigerator after fix back all electrical parts.

Electrical parts in frost free refrigerator,

- Compressor
- Relay and overload protector
- Thermostat switch
- Light holder and light switch
- Cooling coil fan motor and fan door switch.
- Timer switch
- Cooling coil defrost heater
- Cabinet coil heater
- Drip tray heater

In 165 litres refrigerator, 1/8 HP compressor is used.

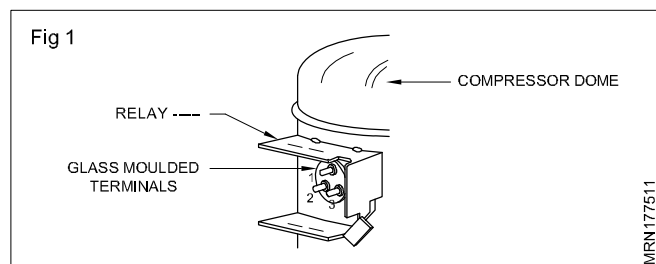
80 to 300 litres refrigerator, 1/6 H.P. compressor is used.

350 litres refrigerator, 1/5 H.P. compressor is used.

Function of compressor: It has got 3 terminals moulded with glass on the compressor body. From this the motor gets supply and start run.

From the Fig 1 given below, the glass mould is used for insulation. The compressor is supplied by 220V and takes 1.5 to 2 Amps.

Relay and overload protector



Relay used in frost free refrigerator has 2 types.

Box type

Push type

Both relays used for starting purpose and takes 1.5 to 2.5 Amps with 220V supply.

The relay is made with bracket housing and consists of copper winding, dropping plunger and spring inside.

Overload protector: It is made of bracket in a round housing with bimetal disc and heater coil as per compressor load of 1/10, 1/8, 1/6, 1/5, 1/4, 1/3 hp capacity. When the compressor is running the current increases. The heater coil gets hot and side of the bimetal disc open the contact

which is going to compressor terminal and stop (protect) compressor from damage.

Cooling coil fan motor

The function of fan motor has got small shaft blower and shaded pole winding. This winding is fully insulated. This insulation totally protect the motor from short circuit and earth fault. This motor is connected to 220V supply. This motor circulates the temperature evenly in the freezer cabin.

This motor is connected through a door switch. When the door is opened, the switch open the contact and disconnect the motor. When the door is closed, the contact will lose the supply and the motor starts, rotate and circulate the cool air.

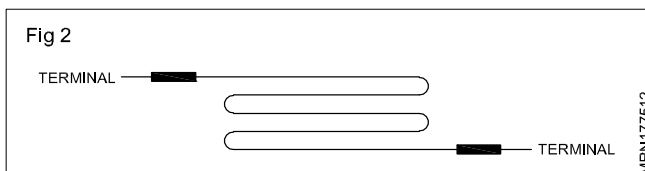
Timer Switch:

It is placed in a small P.V.C.housing. A small motor is attached with teeth wheel.

Timer switch is used to defrost ice in freezer, by controlling the solenoid (or) heater coil connected with freezer coil. Timer switch work on clock mechanism. When timer switch (2,4) get power supply, clock mechanism start work, and switch on the compressor through thermostat switch. When cooling coil get over frost by time of 12 hours, the timer switch cut compressor to run and switch off. Heater coil which attached with cooling coil and start melt ice. After the duration of timer switch (17 minutes), again the timer will switch off the heater (a) solenoid connection and switch on. Compressor motor is connection through thermostat. The cooling coil fan motor is not operated at defrost cycle.

Fan motor connection will cut off by Timer switch.

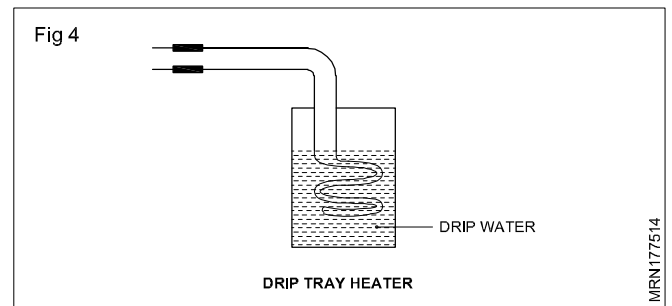
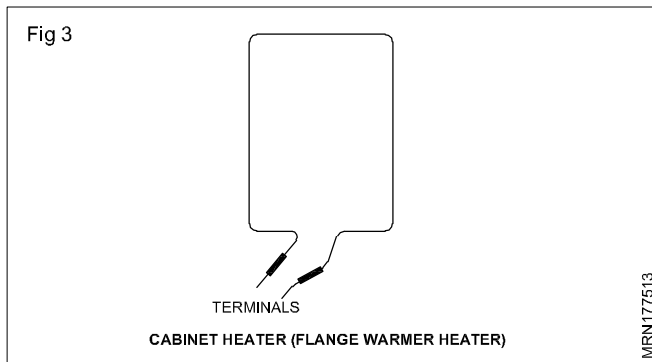
During defrost cycle, the timer switch will cut off the compressor, switch on cooling coil defrost heater for (AP) 17 minutes and melt ice in the cooling coil. Refer (Fig 2).



Cabinet heater and drip tray heater Refer (Figs 3 & 4). Cabinet heater (FLANGE warmer heater).

The heater protects the moisture entering inside the cabinet. This heater work very less watts, less amp.

This heater evaporate the drip water and work with less power.



Frost free refrigerators and side by side refrigerators

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

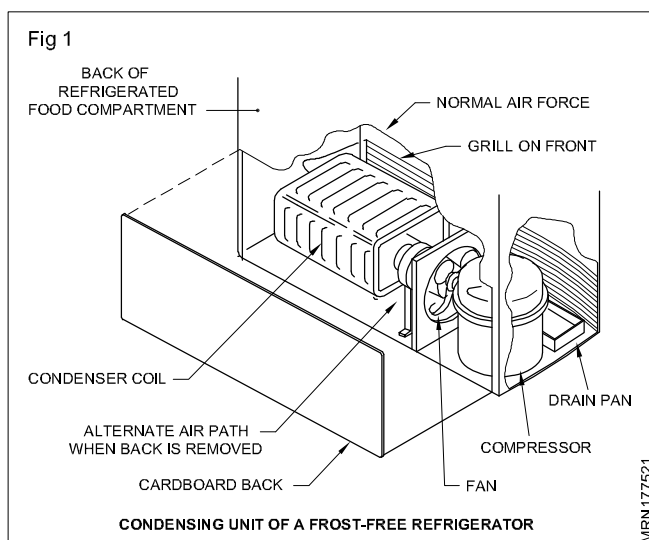
- explain the features of the house hold refrigerators
- explain the construction of the frost free refrigerator
- describe the air flow inside the non frost refrigerator.

Features of the household refrigerators: There are many changes in features of refrigerators designed to create more food storage space within the same inside area of the refrigerated cabin (insulation become thinner with polyurethane material) and convenient to the users like auto defrost system.

In order to save the space to provide excess of refrigerated place useful to the users the condenser is located at the bottom of the food compartment next to the compressor. These condensers are smaller to improve the efficiency, a fan is provided to increase the air flow and heat transfer in higher capacity like side by side refrigeration.

Some condensers coils are fixed on box type plate to fit in the small space. The fan draw the air through the front grill and cool the condenser. (Ref. Fig 1)

The other type is finned tube condensers kept flat at the bottom cooled by natural ventilation in most of the Indian models. In foreign fridges and side by side models the fresh air drawn by the fan through the condensers. (Fig 1)



Evaporators also made smaller by using finned tube or plate type provided with small fan blowing the refrigerated air across the coil through plastic ducts inside the cabin.

These units are provided with auto defrost with electrical heating elements.

The timer activates the heater and stop the compressor and condenser fan, evaporator fan also at defrosting period. The condensate water will drain from the evaporator to the tray on the compressor and get evaporated as in conventional refrigerators.

In some of the other models the alternate methods used for defrosting is to energize a hot gas solenoid valve that supplies hot gas to the evaporator to defrost.

Construction of the frost free refrigerator: The arrangement of the condensing unit is already explained in the features. Usually this models have two door one on top to cover freezer cabin and the down to close the refrigerator cabinet. The light facility will be provided only for the down refrigerator compartment and light switch is operated by the bottom door.

The necessity of defrosting and manual defrosting methods are already known. Still to make more convenient to the users, automatic defrosting is adopted in frost free refrigerators.

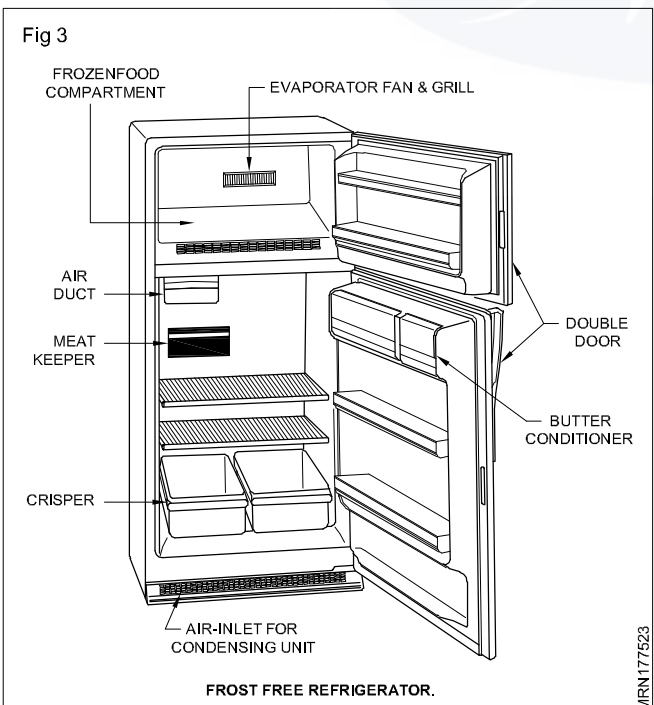
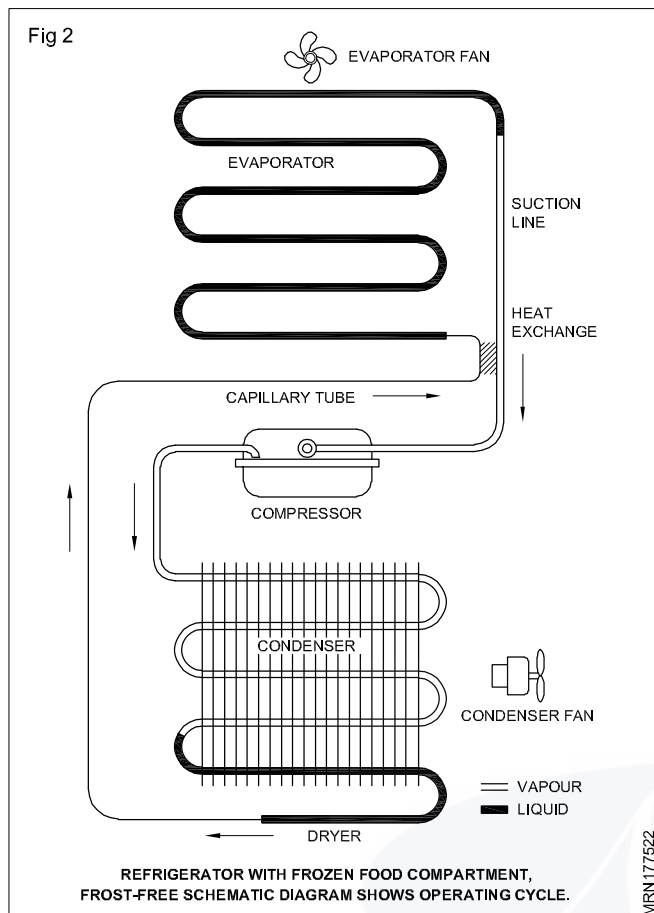
The refrigeration cycle is almost same as conventional refrigerators but the condenser and evaporators are provided with fan and the heating elements helps to defrost faster. Compare to conventional frost free refrigerators takes more current load.

The skeleton or schematic diagram of the frost free refrigerator (Ref. Fig 2) shows the operating cycle of this type.

In these types there are two basic system used for auto defrosting. The hot gas system controls by solenoid valve, use the discharge line hot refrigerant vapour to defrost the evaporator.

The other system uses the electric heater to melt the frosting on the evaporator and keep the outer cabinet warmer and avoid sweating. It has a frozen food compartment and auto defrost. Evaporator in frozen food

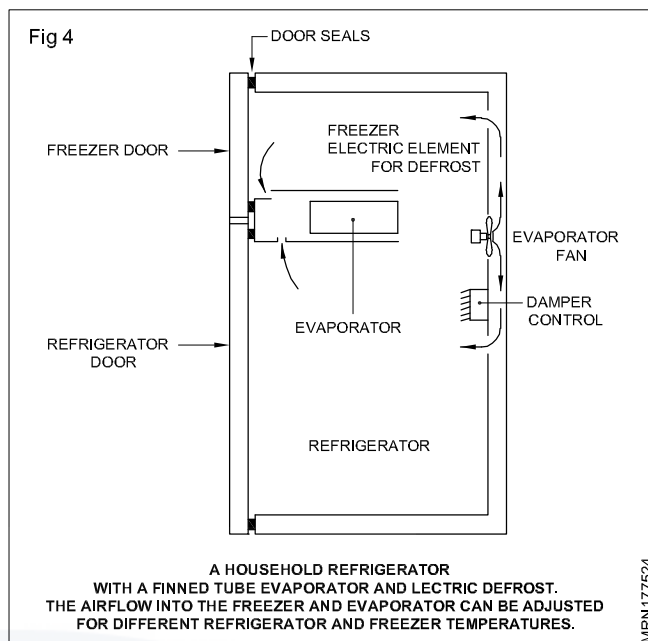
compartment serves as fast freezing shelf. The fresh food cabinet has butter conditioner, fresh meat storage and vegetable crisper. (Fig 3)



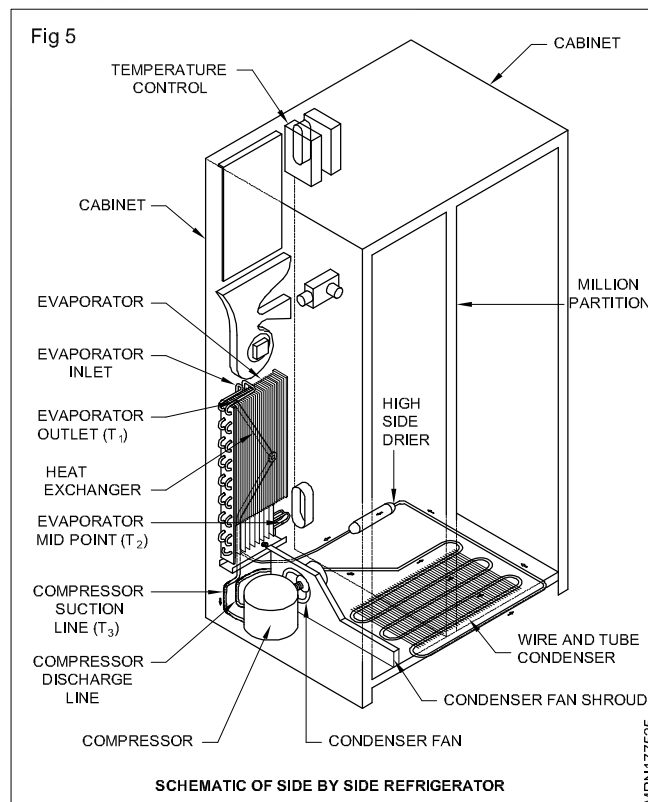
In auto defrost the condensate water collects by the drain tube to the tray which is provided on the compressor and evaporator by the heat of the compressor and condenser temperature while the fridge is in operation.

The evaporator is located at the bottom of the freezer cabinet which separates the freezing compartment from

the fresh food compartment. An electrical resistance heater at the top of the cabinet inside the outer case keeps the outside of the cabinet warm enough so it will not collect condensation and avoid sweating on the surface during damp weather conditions. The evaporator may be plate type or fin type with electrical defrost the air flow into the freezer and evaporator can be adjusted by dampers. (Fig 4)



Side by side refrigerators: The evaporator is behind the frozen food compartment compressor and condenser are in the bottom. Air circulated over the condenser by a fan enters and venting through the bottom grill. A fan on the evaporator circulates very cold air in the freezer compartment. Damper will allow according to the setting, the cold air to flow into the fresh food compartment. (Fig 5)



The fresh food compartment act as a return air duct from the freezing compartment back into the evaporator cabin.

The refrigerator automatically defrosts every 6 hours of compressor running time compare to other frost free models being the capacity is high in side by side, frosting will form fast, so defrosting interval also will be in short period to make as non frost.

The defrost is an electric heater attached to the evaporator

controlled by timer switch. The defrost thermostat opens the heater circuit at approx. 10°C. 30 min after the start of the defrost cycle the timer restores the operation of the compressor and air circulation fan. The defrost thermostat contacts close at reset -7°C.

The various cabinet temperatures are maintained by use of dampers which control flow of cold air into various compartments.

Electrical components of frost free refrigerator

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

- explain the construction and working of defrost timer
- explain the construction and working of Bimetal thermo
- explain the construction and working of defrost heater
- explain the construction and working of overload protector
- explain the construction and working of fan motor.

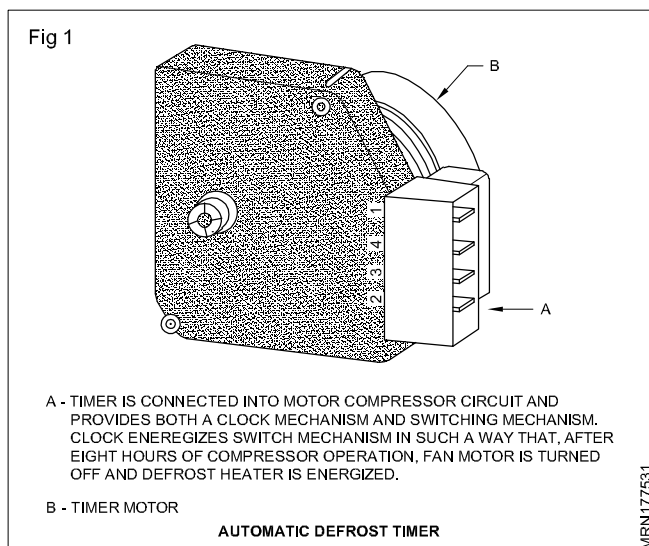
Deforst Timer : Defrost timer is located at the back side of the compressor compartment. It is used to activate the Defrost heater periodically (once in 8 hrs).

Defrost Timer basically has two section

- 1 Motor assembly
- 2 Gear assembly

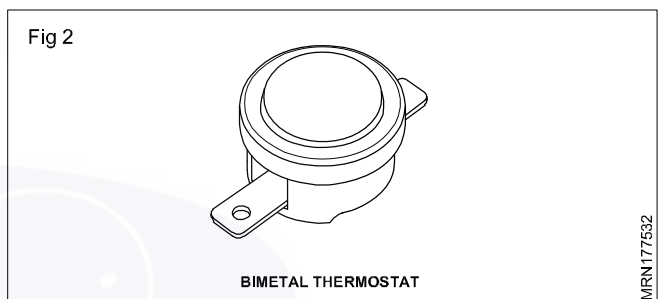
In frost free refrigerator normally 8 hrs. timer is used. When the timer motor is energised, motor rotates at their own speed. With the help of gear assembly, the rpm is reduced to 1 (1 rpm/8 hrs). After 8 hrs., mechanical change over takes place to activate defrost heater. The movement of change over timer is stopped.

After defrosting, the motor come into the circuit, and the change over takes place, bring to its normal position and activitate the compressor in the circuit. Refer (Fig 1).

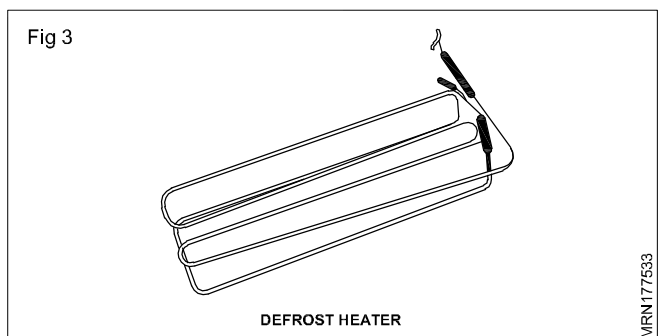


Bimetal Thermo : It is a compact device which has two terminals kept in the vacumized sealed bag for free from dust and water condensation. It is embeded in the evaporator coil outlet and controls the defrost heater timing. Whenever the temperature is negative, the

evaporator contacts are closed and is opened whenever the temperature is above +13°C. Ref. (Fig 2).

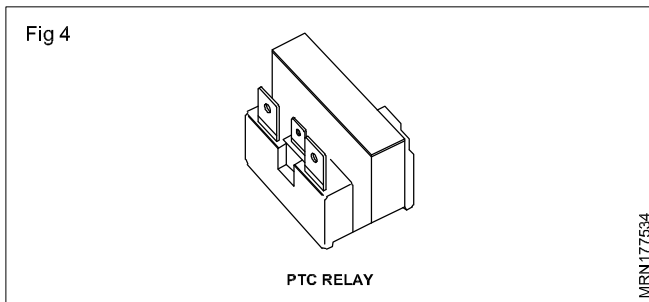


Defrost Heater : It is located below the evaporator coil. During the defrost cycle, compressor is disconnected and heater is energised to melt the accumulation of the ice in the evaporator coil. If frost is not removed, Ice in the evaporator coil act as an insulator, cooling effect will be reduced. Refer (Fig 3).



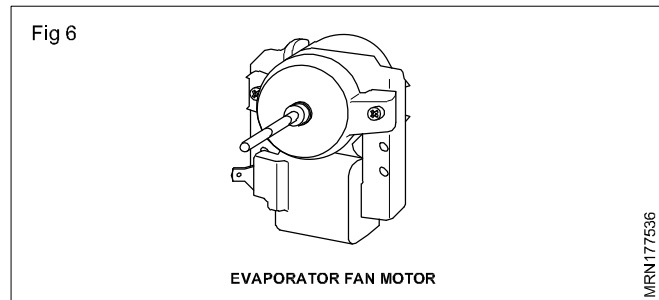
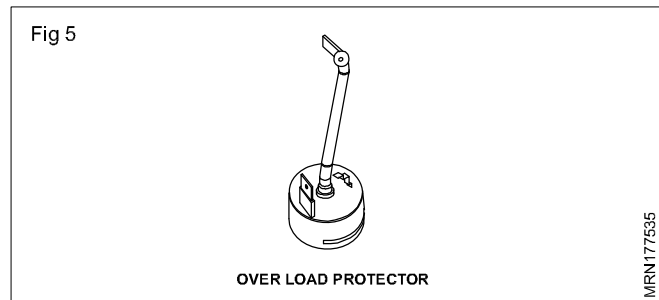
PTC relay : PTCR (Positive Temperature Co-efficient Resistor) Relay is used in FHP compressor with RSIR circuit for starting purpose. Mostly current coil type relay is used for FHP compressor. There are some disadvantage in current coil type relay, hence PTCR is introduced. In PTCR there is no electrical noise and no moving parts inside. Initially there will be a continuity between main to starting terminal approximately 30 Ω. At the time of starting there will be current flow in the starting winding through solid ceramic plate to start the compressor. Once compressor is started, the solid ceramic material gets

heated up and resistance will increase approximately 30000 Ω . There will be no current flow. This way starting winding is disconnected. Refer (Fig 4).



Overload protector : This is located in the compressor terminal box. It has two terminal of bimetal disc inside and senses shell temperature and current. It protect the compressor from abnormal operating condition. OLP will not rectify the condition. It can give only signal something is wrong in the system. (Fig 5).

Fan motor: Used in frost free refrigerator. Force the cold air to the freezer component and refrigerator compressor. According to our requirement air flow can be adjusted with the help of adjustable damper. Refer (Fig 6).



Air Distribution system in frost free refrigerator

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

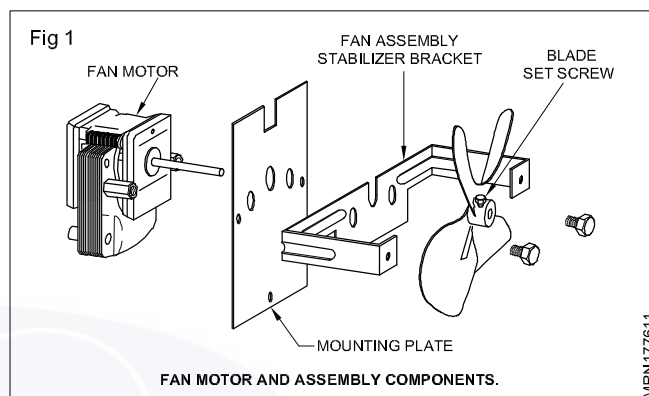
- state the meaning of air distribution system in frost free refrigerator.
- explain the frost free refrigerator air distribution system and boosting the performance of the refrigerator.

- On the running part of the cycle, air is drawn over the evaporator and is forced into the freezing and refrigerator compartment by the use of a motor driven fan (Fig 1)

On the off part of the cycle, these evaporators automatically defrost. The condensation from the evaporator which melts off during the off cycle is carried to an evaporating pan or collecting surface directly over the compressor evaporates this moisture and it is returned to the room's temperature. There is no any visible frost accumulation in this type of frost control.

- All air contains some moisture, when air comes in contacts with an evaporator surface which is below the freezing temperature, the moisture will condense and form ice on the evaporator in the conventional manual defrost refrigerator. The frozen food cannot be preserved for long period.
- In frost free refrigerator, a motor driven fan forces the air

over the evaporator surface through various ducts. This provides the necessary temperature to the compartments. There by cool air is circulated in the entire refrigerator cabinet. The food kept without packing can be preserved for several weeks. The fresh vegetables and other crisp product does not become stale in one week.



System performance in frost free refrigerator

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

- explain frost free refrigerator.

In frost free refrigerator frost forms when water vapour hits the cold coils. The water vapour condenses - turn to liquid water. Think of the water beading upon a glass of iced on a summer day - that is an example of water vapour in the air condensing. The same thing happens on the ice - cold freezer coils except that when the water condenses on to the coils it immediately freezes.

In a frost free refrigerator every six hour (or) so, the timer turns on the heating coil. The heating coil is wrapped, among the freezer coils. The heater melts the ice off coils. When all is melt, the temperature rising above 32°F (0 degree C) and turns off the heater.

Heating coils every six hours takes energy and it also cycles the food in the freezer through temperature changes the food lasts longer protected in the frost free refrigerator.

Repair and service of refrigerator cabinet

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

- state the necessity of servicing cabinet
- servicing of internal civil
- distinguish between primer and painting.

Necessity of servicing and repairing: The bottom side of refrigerator cabinet and door may become rusty when they come in contact with salty water. If this happens the cabinet and door should be repaired after removing of refrigeration system, insulation and all other parts. (Fig 1)

Putty: Putties are very heavy pigmented materials designed for deep filling of damaged sheet metal parts after scraping the excess pigments using emery paper.

Primer paint: A primer is a first coat applied to a surface to provide bond for the surface. Different types of primer paint's are available as per the application.

Emery sheets: Emery sheet generally used contains silicon carbide, water proof. Dry type emery sheets are used for rubbing the surface of the cabinet.

Paints: Paints generally applied on the cabinet for good looking and prevent from rust erosion. Generally two types of paints are available in the market.

- 1 Acrylic paint and synthetic enamel paint

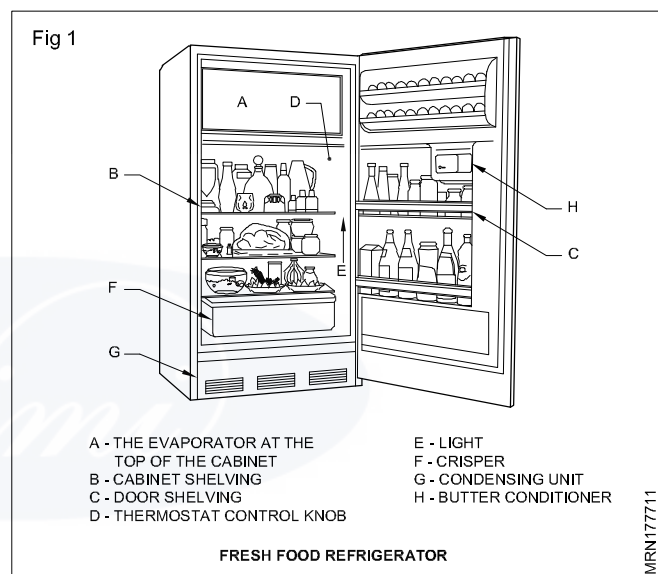
Acrylic paints are generally applied in the refrigeration cabinet due to following reasons

- 1 Fast dry
- 2 Durability and good looking shine to long time and resistance to corrosion.

Types of polishing employed are as follows:

- 1 Clear polish
- 2 Silicon polish and
- 3 Wax polish

Generally wax polishing employed in painted surface of the refrigerator cabinet.



Internal service of the conventional refrigerator's system components

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

- explain the necessity of cleaning and flushing in the system
- list the disadvantages due to presence of moisture in the system
- explain different possibilities of contaminants entering into the system
- describe the restricting of contaminants entering into the system.

It is common knowledge that moisture, air, non condensable gases and foreign materials are biggest enemies of the any refrigeration system to lead bad effect in the system such as failure of compressor, system choke, capacity reduction, waste of manpower, increase in repair cost, bad name from customer, employer.

Bad effects of moisture in the system: The moisture present in refrigeration system can turn into 'ice' at low temperature area or points of refrigeration system. The outlet of capillary tube in a refrigerator or expansion valve orifice in a low temperature. Commercial plants are always at low temperature less than 0°C in the moisture. If present in the system will condense and freeze at this

point. This restrict or completely blocks the flow of liquid refrigerant to the evaporator there by affecting system performance.

Further even a much smaller quantity of moisture in combination with freon can form hydrochloric and hydrofluoric acids. These acids particularly hydrofluoric acid are very active and highly corrosive. They attack various parts of the refrigeration system like compressor winding, valve reeds and seats.

Presence of moisture in the compressor oil leads to contaminated and sludge is formed, losing its lubricating properties and thus affecting the life of the bearing and journals. The chemical reaction due to the acids and

moisture gets accelerated. The rate of chemical reaction is doubled in every 8°C increase in temperature.

Once the valve read and seat get damaged or pitted the compressor efficiency gets impaired.

The presence of air and non condensable increase head pressure of the system. As the head pressure goes higher, the compressor motor draws more current and reduce the system capacity.

The above points, it is clear that, the presence of moisture, air and non condensable should be removed from the refrigeration system to the maximum possible extent. Hence before a system can be charged with refrigerant it should be thoroughly evacuated and dehydrated by drawing a high vacuum. If this is not done in the initial stage itself, we will never get a clean system.

Possibility of moisture, air and non condensable and foreign materials enter in the refrigeration system.

- leak testing process of refrigeration component
- moisture existence by improper vacuumization
- poor quality of refrigerant

- poor brazing

During the system reprocessing, we are using nitrogen for leak testing, flushing. Dry nitrogen itself contains more moisture. This has to be removed by vacuumising the system. Before gas charging contamination (carbon particle) present at the time of failure of compressor (burnout) Foreign particle present at the time of brazing.

How to minimize the presence of moisture air and non condensable gas and foreign materials in the refrigeration systems.

- proper internal cleaning with CTC
- Good quality brazing and use good quality of filling materials(welding rod)
- Drawing high vacuum with quality vacuum pump
- Use quality refrigerant
- Charge required quantity of refrigerant by volume method or by weight.

Because of failure (burnout) of compressor carbon particle spread everywhere in the system. This way system contaminated with carbon particle.



Inverter refrigerator

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

- explain about 2 & 3 door inverter refrigerator.
-

The advent of digital inverter compressors, the energy consumption is even further reduced than a single-speed induction motor compressor, and thus contributes far less in the way of green house gases.

Because of the introduction of new energy efficiency standards, refrigerators made today are much more efficient than previous models they consume the same amount of energy while being three times as large.

The efficiency of older refrigerators can be improved by defrosting (if the unit is manual defrost) and cleaning them regularly, replacing old and worn door seals with new ones, adjusting the thermostat to accommodate the actual contents (a refrigerator needn't be colder than 4°C (39°F) to store drinks and non-perishable items) and also replacing insulation, where applicable. Some sites recommend you clean condenser coils every month or so on units with coils on the rear. It has been proven that this does very little for improving efficiency, however, the unit should be able to "breathe" with adequate spaces around the front, back, sides and above the unit. If the refrigerator uses a fan to keep the condenser cool, then this must be cleaned, at the very least, yearly.

Frost-free refrigerators or freezers use electric fans to cool the appropriate compartment. This could be called a "fan forced" refrigerator, whereas manual defrost units rely on colder air lying at the bottom, versus the warm air at the top to achieve adequate cooling. The air is drawn in through an inlet duct and passed through the evaporator where it is cooled, the air is then circulated throughout the cabinet via a series of ducts and vents. Because the air passing the evaporator is supposedly warm and moist, frost begins to form on the evaporator (especially on a freezer's evaporator). In cheaper and/or older models, a defrost cycle is controlled via a mechanical timer. This timer is set to shut off the compressor and fan and energize a heating element located near or around the evaporator for about 15 to 30 minutes at every 6 to 12 hours. This melts any frost or ice build up and allows the refrigerator to work normally once

more. It is believed that frost free units have a lower tolerance for frost, due to their air-conditioner like evaporator coils. Therefore, if a door is left open accidentally (especially the freezer), the defrost system may not remove all frost, in this case, the freezer (or refrigerator) must be defrosted.

If the defrosting systems melts all the ice before the timed defrosting period ends, then a small device (called a defrost limiter) acts like a thermostat and shuts off the heating element to prevent too large a temperature fluctuation, it also prevents hot blasts of air when the system starts again, should it finish defrosting early. On some early frost-free models, the defrost limiter also sends a signal to the defrost timer start the compressor and fan as soon as it shuts off the heating element before the timed defrost cycle ends. When the defrost cycle is completed, the compressor and fan are allowed to cycle back on.

Frost-free refrigerators, including some early frost free refrigerator/freezers that used a cold plate in their refrigerator section instead of airflow from the freezer section, generally don't shut off their refrigerator fans during defrosting. This allows consumers to leave food in the main refrigerator fans during defrosting. This allows consumers to leave food in the main refrigerator fans during defrosting. This allows consumers to leave food in the main refrigerator compartment uncovered, and also helps keep vegetables moist. This method also helps reduce energy consumption, because the refrigerator is above freeze point and can pass the warmer-than-freezing air through the evaporator or cold plate to aid the defrosting cycle.

Modular refrigeration system

Many special stores use flexible refrigeration system. The glass door storage components can be used in numerous combination with the refrigeration units. The refrigeration unit cools up to four storage units. The system has force air circulation, automatic defrost, adjustable temperature control. These kind of units are used in small restaurants.

Inverter refrigerator

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

- explain working of inverter system
- describe the stage of inverter
- explain the working of BLDC motor.

Digital inverter technology

Digital inverter compressor are more advance than the conventional ones. It automatically adjust its speed to meet cooling demand.

The speed of motor can be varied to required RPM by altering the frequency with the help of IGBT (Insulated gate bipolar transistor).

IGBT is a three terminal power semiconductor device noted for high efficiency & part switching it is also used in PWM pulse width modulator three phase drives. The PWM plays an important role in inverter compressor. The AC power supply is in the sinusoidal wave or sine wave, But this wave is altered to square wave including the width and amplitude as shown in Fig 1a & 1b. This change in width varies the frequency from 0 to 120 Hz; The compressor motor speed varies according to change in frequency Fig 2 show the stages of inverter system.

Working of BLDC motor

The main thing with a brushless DC motor is that it has permanent magnet (Insulated of electro magnets) for the poles. A permanent magnet generator a DC magnetic field instead of AC magnetic field that is produced by passing AC current through an electro magnet. This magnetic field interacts with the magnetic field of the stator to generate motion. The current in the stator electromagnet can be varied to change the speed of motion just because motor generate DC magnetic field even the stator has to generate DC magnetic field this happens when the stator coil gets DC.

However the current that comes through our regular electric supply is alternating current (or AC) that is why we need an inverter and an electronic unit that convert AC to DC of varying strength (to change the speed of motor) of make it function properly.

Pulse wave and digital control signals

In computer or digital control applications, a second type of alternating current is used-pulse wave electronics. The signals in these applications are electrical pulses. The control is obtained by the spacing of pulses and the width of the pulses. Most control systems using computers have 5-volt pulses.

If they are used in motor control, the voltage is amplified to the voltage required by the motor.

Inverter

Electrical energy stored in a battery is available as direct current (dc) energy. The voltage supplied by the battery is

a steady voltage. It gradually decreases with time as the charge is drained from the battery. An electric motor powered by a battery must be a dc motor.

DC motors are heavier and more expensive than ac motors. It is often an advantage to change the battery voltage so an ac motor can be used. The device used to do this is called inverter.

This device does the opposite of the rectifier circuits. The rectifier converts ac power to dc power.

Older electrical systems used dc motor connected to an ac generator to do this inverting. Newer solid-state electronic devices do this without any mechanically moving parts. The basic elements used in solid state inverter are:

- A crystal that oscillates at a frequency of the ac power required
- A switching circuit using SCRs to switch dc power on and off.

A simple inverter, using a set of standard diodes, produces a square wave output.

Most motors and controls are designed to operate only with alternating (ac) power, similar to that provided by the power company (EB). These devices will operate with square wave. However, they will not operate as efficiently. Their lifetimes will usually be shorter as they operate less efficiently. Their lifetimes will usually be reduced.

An inverter is usually required in solar electric energy systems. The output of solar cells is dc power.

The air conditioners have fixed speed compressors. They work on fixed RPM since the AC supply has the fixed frequency (ie) 50 cycles/second and the speed of drive motor is function of frequency and the no of motor poles.

In an AC induction motor,

Where, N_s = Synchronous speed of stator field

f = Frequency of power supply

P = Number of stator winding poles.

The rotor speed is less than the stator magnetic field. The difference between these two speeds is considered as slip. If there is no slip, there will be no induced emf, current & torque in rotor.

The speed of an induction motor is directly proportional to the supply frequency. By changing supply frequency smoothly, speed can be increased or decreased precisely and continuously.

If speed control is to be achieved by changing frequency, the supply voltage also has to be changed simultaneously. This is because if frequency (f) is reduced keeping the supply voltage (v) constant, flux is increased which causes increase excitation current and larger losses and thus affects the efficiency of the motor.

On the other hand if the frequency (f) is increased with applied voltage (v) constant, the flux will decrease thereby reducing torque.

VFDs

Therefore, it is important that the frequency (f) and voltage (v) should be changed proportionately. The constant ratio of variable frequency drives (VFDs) work on the principle. This is also called as variable speed drives (VSDs). This drive is applied to vary the flow of refrigerants in Air conditioners by varying the speed compressors.

VFD

This device controls the speed of a “driven equipment” the focus is mainly restricted here to an electronic controller which controls the speed of the induction motors of 1- ϕ & 3- ϕ AC supply.

A VFD consists of a frequency converter that can vary the frequency and voltage of the supply fed to the induction motors that are commonly used squirrel cage type. The advantageous part is the energy savings.

Concept of electronic VFDs

Any electronic VFD system is of three main components

- i An electronic actuator - the controller
- ii A driving electrical machine - motor
- iii A driven machine (Load) - fan, blower, pump compressor, Dampers, and inlet guide vanes & throttle valves etc.

These devices with a stepless control of motor speed can be easily done on new as well as existing installations to make them more energy efficient. The task of a VFD system is to convert the electrical power supplied by the mains into mechanical power with minimum loss.

A optimum technological process is achieved by:

- the drive must be variable in speed
- the driven machine's speed to be adjusted smoothly & steplessly.
- the low loss controller, IGBT (Integrated gate bipolar transistor) based inverter circuit accomplishes the above requirement.

A VFD consists of an I/P rectifier (which converts AC to DC) followed by an inverter (which inverts DC to AC) connected through a DC intermediate voltage link, shown in figures.

Single phase system has the restricted power range.

Driven equipment and load pattern

All driven equipment has a load characteristic (or) a speed and torque relationship. They can be generally classified as:

- Constant torque (CT)
- Variable torque (VT)
- Constant power (or) HP

Constant torque load (CT)

In these loads, the O/P power requirement may vary with speed of operation but the torque does not vary.

Examples: Positive displacement pumps, compressors conveyors etc.,

Variable torque load (VT)

In VT loads, the torque required varies with the speed of operation. Torque varies as the square of speed.

Example: Centrifugal pumps and fans.

VT loads, as the largest potential for energy savings exists for the loading pattern in which as the speed is varied the power requirement changes as the cube of the speed.

Constant HP/power load

Power loads are those for which torque requirement typically change inversely with speed.

Inverter refrigerator

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

- explain anatomy of refrigerator control system
- describe about generation FOC for BLDC in a compressor.

Anatomy of refrigerator control system

There're usually two parts of control existing in a refrigerator, one is for compressor control and the other is for the system control. See Figure 1 The system control part mainly reads the temperatures of the chambers, the environment, and so on to decide the speed of the compressor, the states of the fans and the defrost heater in the fridge based on a control strategy. It also drives a control panel with display and key inputs on it. The system control part outputs a PWM signal with its frequency indicating the command speed, and the compressor control part drives the motor per this command. Typically, a frequency range of 40 Hz ~ 150 Hz corresponds to 1200 RPM ~ 4500 RPM.

The system control and compressor control parts are usually implemented on separate MCUs in current markets. It is common that there's a system control board and a compressor control board together with a HMI module inside a refrigerator. These two parts can be also implemented on one board so as to eliminate a set of AC-DC power circuits.

Background of refrigeration system

A typical refrigeration system is composed of a compressor, a condenser, a metering device and an evaporator. The metering device is often a capillary tube in refrigerator. When the system starts to work, the compressor compresses the low pressure vapor refrigerant from its inlet and generates high pressure high temperature vapor at its outlet. This high pressure high temperature vapor refrigerant flows into the condenser. Because the ambient air is cooler than the condenser, the heat is transferred to the cooler air and the vapor refrigerant becomes a high pressure liquid status. Then this high pressure liquid refrigerant leaves the condenser and flows into the metering device which is a capillary tube. The refrigerant becomes a low pressure and cooler liquid when it reaches to the evaporator. The cooler refrigerant in the evaporator tubes absorbs the heat in the air where the evaporator is placed, and it changes to a low pressure cold vapor when it reaches to the inlet of the compressor. The low pressure vapor refrigerant is sucked into the compressor and the cycle starts over. The high-side pressure (measured at the outlet of the compressor) increases significantly as the refrigerating cycle goes on, and the low-side pressure (measured at the inlet of the compressor) also decreases a little bit.

Some features in refrigerator compressor control

There are some major features in refrigerator compressor control:

- The loading is not constant but changes periodically every mechanical revolution, namely, there's a maximum loading torque and a minimum loading torque in each mechanical revolution due to the reciprocating motion of the piston.
- The residual pressure difference between the inlet and outlet of the compressor can be very large, which makes startup difficult.
- Efficiency is very important to refrigerator. Since the compressor is stopped most of the time, the influence of the control board consumption becomes important.
- There are all kinds of protections.

Startup under high pressure difference

The motor inside the compressor drives a crankshaft, which in turn drives a piston moving in a reciprocating motion. The vapor is compressed in this motion. Since the high-side pressure is much higher than the low-side pressure, there's a significant load torque change in one mechanical revolution. When motor is running at high speed, this periodic load torque change is not a big problem because the load change in a very short period of time won't lead to much speed variation. When the compressor stops after working for a while, the pressure difference between high-side and low-side still exists, and it'll come to zero over time. When there's a large residual pressure difference, the loading can be either large or small at the very moment of startup because the exact rotor and piston position are not known, hence we don't know whether the piston is to move against the pressure or the other way around at this very moment of startup, which makes it rather difficult to start the motor in traditional open-loop start up fashion due to the absence of position sensors. In practical use, when a compressor is stopped, it won't be started immediately even if there's a valid speed command, unless a couple of minutes (usually 5~10 min) have passed by. But even so, when the ambient temperature of a refrigerator is high, the residual pressure difference could be still large, which makes start up really challenging. The startup method mentioned here uses a fast converging flux observer at open-loop startup, which greatly shortens the startup time. This method has been tested and proved to be reliable under production. Typically, the startup can be reliable when the pressure difference is around 0.6 MPa.

Efficiency

The popular working pattern of the refrigerator compressor is still on/off mode even though the control method of the compressor is FOC. The motor only runs at several specified speeds, e.g. 1200 RPM, 2700 RPM, 3400 RPM and 4300 RPM. These speeds are decided based on the efficiency of the compressor, so different compressors may have different optimal running speeds. The system control strategy of the refrigerator affects the temperature stability and the system efficiency. For instance, when the chamber temperature is higher than desired, the compressor should be turned on, but which speed should be used? It really makes a difference on the efficiency when different control strategies are applied. There may be around 50% of the time that the compressor isn't working at all. There are several key factors that affect the system efficiency.

- The cooling efficiency of the compressor itself
- The motor running efficiency
- The control strategy of the whole system
- Since the compressor stops almost half the time, the power consumption of the control boards becomes crucial.

Protections

The protections on compressor control part are various. Most systems include protections of hardware triggered over current, DC bus under voltage, DC bus over voltage, startup fail (stall), open phase detection. Other systems may require additional software triggered over current or over power protection.

Sensorless FOC for BLDC in a compressor

The startup procedure is well designed as four stages, during which startup fail is under detection. A quasi-synchronous reference frame d-q is used before estimated rotor position is used. The four stages are:

- **Alignment**
- **Startup:** speed open-loop startup with predicted position
- **Spin:** speed open-loop spin with estimated position
- **Spin:** speed closed-loop with estimated position.

Alignment

Alignment is to align the rotor to a known position. In this case, a current vector of 1.5 A is placed at the q-axis, and the position of d-axis is located at -90° . So the rotor is actually expected to be pulled on A-axis or a-axis. See Figure 2. The alignment lasts two seconds, and the current rises from 0 to 1.5 A at a ramp of 1.5 A/s.

Startup with predicted position

After alignment, the current vector starts to rotate. The rotating speed increases from 0 to a certain value with a ramp of -200 RPM/s, and the predicted position is an integration of this given predicted speed. The current vector is still placed at the q-axis, and the d-axis rotates inversely

from -90° to 90° . This stage ends as soon as the d-axis reaches 90° . Figure 3 shows the rotation of the current vector in this stage.

Figure 4 shows the real values of the variables in this stage. There are four scopes in figure 4:

- The first one on the very top is the predicted speed.
- The second one lines are predicted position and estimated position
- The third one is the estimated speed
- The last one is a state variable, a value 3 indicates this open-loop startup stage, which is from time point T1 to T2, as enclosed in a shadowed rectangular.

The reference currents of dq frame maintain the same, which means I_d reference is still zero, and the I_q reference is still 1.5 A. Since current loop is much faster than speed loop, the current vector will jump ahead for 90° very quickly, which leaves an angle of 90° between the current vector and the rotor, so a maximum electrical torque is generated. Where I_{D_Req} and I_{Q_Req} are dq current references, and the motor is quickly accelerated from time point T3 on. Figure 6 shows how the current vector jumps to accelerate the motor in vector diagram. The duration of T2~T3 is about 4ms. which means current controller dynamic response is much faster compared with speed response.

Current vector is placed at q-axis which is 90° ahead of rotor flux from time point T3 on. Motor is accelerated under a constant electrical torque (this torque should be designed as large as possible so as to cope with large loading, but also should make compromise with speed over-shoot and copper loss). Once the estimated speed reaches 1000 RPM, speed regulator is enabled, which is the time point of T4 in Figure 6.

Another state observer (based on DQ rotation frame) is enabled from the beginning (T2) of this stage, as shown in Figure 9. The time stamps and the shadowed part in figure 9 share the same meaning of which in figure 6. The startup is deemed as failure if the estimated speed of flux observer doesn't reach 1000 RPM within 0.35 s, the motor will start up again with a current of 2.5 A.

In figure 9, the meanings of the variables are:

- The first scope (the top one) illustrates the estimated speeds during open-loop spin stage: the red one is out of the flux observer, and the green one is from the state observer.
- In the second scope, the blue one is the position generated by flux observer, while the orange one is the position generated by the state observer.
- In the third scope, a counter counts the time when the estimated speed of the flux observer is below 1000 RPM.

