REFRIGERATION AND AIR CONDITIONING TECHNICIAN

NSQF LEVEL - 4

1st Year

TRADE THEORY

SECTOR : CAPITAL GOODS AND MANUFACTURING

(As per revised syllabus July 2022 - 1200Hrs)

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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Sector : **Capital Goods and Manufacturing**

Duration : **2 Years**

Trade : **Refrigeration and Air Conditioning Technician - 1st year - Trade Theory NSQF Level - 4 (Revised 2022)**

Developed & Published by

National Instructional Media Institute
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First Edition : September 2022 Copies : 1000

Rs.370/-

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 Trade Theory NSQF Level - 4 (Revised 2022) in Capital Goods & Manufacturing Sector** under annual pattern. The NSQF Level - 4 (Revised 2022) Trade Theory will help the trainees to get an international equivalency standard where their skill proficiency and competency will be duly recognized across the globe and this will also increase the scope of recognition of prior learning. NSQF Level - 4 (Revised 2022) trainees will also get the opportunities to promote life long learning and skill development. I have no doubt that with NSQF Level - 4 (Revised 2022) the trainers and trainees of ITIs, and all stakeholders will derive maximum benefits from these IMPs and that NIMI's effort will go a long way in improving the quality of Vocational training in the country.

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

Jai Hind

Addl.Secretary / Director General (Training)
Ministry of Skill Development & Entrepreneurship,
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New Delhi - 110 001

PREFACE

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

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

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

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

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

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

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

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

Chennai - 600 032 **EXECUTIVE DIRECTOR**

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 NSQF (Level - 4) (Revised 2022)** 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 Trade Theory NSQF Level - 4 (Revised 2022) in Capital Goods & Manufacturing . The contents are sequenced according to the practical exercise contained in NSQF LEVEL - 4 (Revised 2022) 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 perceptional capabilities for performing the skills.

Module 1 - Fitting

Module 2 - Sheet Metal

Module 3 - Electrical

Module 4 - Electronics

Module 5 - Welding

Module 6 - Basic refrigeration

Module 7 - Refrigerator (Direct tool)

Module 8 - Frost free refrigerator

Module 9 - Refrigerator (Inverter technology)

Module 10 - Compressor and motor

Module 11 - Condenser

Module 12 - Drier & Expansion Valve

Module 13 - Evaporator

Module 14 - Refrigerant

Module 15 - Thermal Insulation

Module 16 - Window Air Conditioner

Module 17 - Split A/C

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 - 4 (Revised 2022) 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	Ref.Ex.No
1	Identify trade related hazards and safety procedures following safety precautions.	1.1.01 - 1.1.04
2	Produce fitting jobs as per drawing (Range of operations, marking, sawing, filing, drilling)	1.1.05 - 1.1.06
3	Produce sheet metal components (range of operation marking, metal cutting, bending, riveting and soldering etc.)	1.2.07 - 1.2.10
4	Identify electrical safety. Join different wire, measure power, currents, volts and earth resistance etc. Connect single phase motors.	1.3.11 - 1.3.13
5	Identify the electronic components and their colour code i.e tranisistor, capacitor, diode, amplifier, I.C and able to work soldering.	1.4.14 - 1.4.20
6	Perform gas welding, brazing, soldering observing related safety	1.5.21 - 1.5.27
7	Identify RAC tools and equipment and recognize different parts of RAC system perform copper tube cutting, flaring, swaging, brazing	1.6.28 - 1.6.38
8	Test mechanical & electrical components. Perform leak test, vacuuming, gas charging, wiring in refrigerator	1.7.39 - 1.7.42
9	Identify electrical and mechanical components of a refrigerator	1.7.43 - 1.7.44
10	Test compressor motor terminal, start compressor with relay & without relay, technique of flushing, leak testing, replacing capillary & filter drier, evacuation & gas charging.	1.7.45 - 1.7.50
11	Check components frost free refrigerator (electrical mechanical), wiring of frost free freeze & air distribution in refrigerator sector. Leak detection, evacuators & gas charging	1.8.51 - 1.9.57
12	Dismantle, repair and assemble hermetic, fixed and varibale speed compressor, and test performance	1.10.58 - 1.10.60
13	Identify the terminals of sealed compressor and their wiring and measure current volts, watts and use of DOL starter with different types of motors	1.10.61 - 1.10.64
14	Perform selection of hermetic compressor for different appliances, starting methods, testing controls & safety cut out used in sealed compressor	1.10.65 - 1.10.67
15	Identify the components of control system of inverter AC and wiring of control	1.10.68 - 1.10.69
16	Perform servicing & de scaling of condenser (internals 7 externals) used in different appliances. perform fitting & adjustment of drier, filter & refrigerant controls used in different refrigeration system	1.11.70 - 1.12.74
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18	Carry out recovery and recycling of refrigerant used, alternative of CFC, HFC recover, transfer & handing of gas cylinders	1.14.77 - 1.14.80
19	Retrofit CFC/HFC machine with ozone friendly refrigerant with understanding of the compatibility	1.14.81 - 1.14.82
20	Pack thermal insulation and prevent cooling leakage	1.15.83 - 1.15.84
21	Install window AC, test electrical & electronics components & fault diagnosis remedial measures	1.16.85 - 1.16.88
22	Perform servicing of electrical & electronic control, test, installation, wiring, fault finding & remedial measures of different split AC	1.17.89 - 1.17.98

QR CODE

Ex.No. 1.1.02

Ex.No. 1.1.03

Ex.No. 1.1.04

Ex.No. 1.1.05

Ex.No. 1.2.07-10

Ex.No. 1.3.11-13

Ex.No. 1.5.21-27

Ex.No. 1.6.28-38

Ex.No. 1.7.39-50

Ex.No. 1.8.51-55

Ex.No. 1.10.58

Ex.No. 1.13.75&76

Ex.No. 1.16.85-88

Ex.No. 1.17.89-97

SYLLABUS

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) With Indicative Hours	Professional Knowledge (Trade Theory)
Professional Skill 25 Hrs.; Professional Knowledge 04 Hrs.	Identify trade related hazards and safety procedures following safety precautions.	1. Identify workshop & machineries. (10 hrs.) 2. Demonstrate Safety precautions and First aid. (05 hrs.) 3. Demonstrate firefighting (05 hrs.) 4. Demonstrate working at height using PPE's and identify the hazards and take personal safety precautions. (5 hrs.)	Introduction to trade and related industries.General safety precautions and first aids, firefighting equipment and electrical safety.History of Refrigeration and Air conditioning.Grooming of technicians.(04hrs..)
Professional Skill 25Hrs.; Professional Knowledge 5 Hrs.	Produce fitting jobs as per drawing (Range of operations, marking, sawing, filing, drilling.)	5. Identify general tools, instruments & equipment. Care and maintenance of tool, instruments and equipment. (10 hrs.) 6. Perform measuring, marking, punching, hacksawing and flat filing,to make a job as per drawing. (15 hrs.)	**Fitting** Different types of Fitting hand tools,- their use. Function, construction, working and Specification. Machineries and equipment used in fittings like drilling machine and grinding machine. (05 hrs)
Professional Skill 25 Hrs.; Professional Knowledge 04 Hrs.	Produce Sheet metal components (range of operation marking, metal cutting, bending, riveting and soldering etc.)	7. Perform Sheet Cutting by straight snip as per drawing. (07 hrs.) 8. Perform Sheet Cutting by bent snip as per drawing. (07 hrs.) 9. Bend, fold and join metal sheets in different process. (06 hrs.) 10. Join sheet metal by using rivet set and snap. (05 hrs.)	**Sheet Metal** Function,construction, working, use, and application, specification of Sheet metal tools, instruments and equipment. Care and maintenance of tools. Rivet & riveting- their types and use. (04 hrs..)
Professional Skill 35 Hrs.; Professional Knowledge 06 Hrs.	Identify electrical safety. Join different wire, measure power, currents, volts and earth resistance etc. Connect single phase motors.	11 Demonstrate electricalsafety precautions and first aid. (05 hrs.) 12 Identify, use and maintain electrical tools. (05 hrs.) 13. Measure current, voltage, resistance ,power, energy using analog and digital meter through a single phase circuit. (25 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.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. (06 hrs..)

Professional Skill 47 Hrs.; Professional Knowledge 10 Hrs.	Identify the electronic components and their colour code i.e. transistor, capacitor, diode, amplifier, I.C and able to work soldering.	14. Identify basic electronic components, tools & instrument. (08 hrs.) 15. Colour coding of resistors. (05 hrs.) 16. Use voltmeter, ammeter and multimeter. (8 hrs.) 17. Practice soldering & de-soldering. (8 hrs.)	**Electronics** Introduction to Electronics. Basic Principles of semiconductors, Principles and application of Diodes. Solder – its composition and paste.(05 hrs..)
		18. Identify transistors, resistors, capacitors, diodes, S.C.R., U.J.T., amplifier andI.C. (08hrs.) 19. Construct and test full wave rectifier using diodes. (05hrs.) 20. Construct and test a bridge rectifier. (05hrs.)	Rectification, Zener diode as voltage regulator – transistors parameters- diodes, ICs. (05 hrs..)
Professional Skill 39 Hrs.; Professional Knowledge 7 Hrs.	Perform gas welding, brazing, soldering Observing related safety.	21. Identify gas welding equipment & accessories. (05 hrs.) 22. Demonstrate safety precaution in handling of Oxy-acetylene cylinders, regulators etc. (04 hrs.) 23. Setting up of AIR-LPG, O2- LPG and O2-C2H2 using can type portable flame set. (04 hrs.) 24. Oxy-acetylene gas welding, brazing and cutting on thin sheet metal. (7hrs.) 25. Demonstrate Care & Safety of welding tools and equipment. Back fire arrester. (03 hrs.) 26. Set Oxy-acetylene plant, use two stage regulator, adjustment of flame, gas pressure – O2 and DA. (07 hrs.) 27. Perform brazing between Cu to Cu and Cu to MS, Cu to aluminum pipes. (9 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.Difference between soldering and Brazing in terms of temperatures, filler materials, joint strengths and application. Use of Oxy Acetylene, Oxy LPG, Air LPG and two stage regulators for brazing/soldering. Description of back fire arrester. (7 hrs..)
Professional Skill 100Hrs.; Professional Knowledge 15Hrs.	Identify RAC tools and equipment and recognize different parts of RAC system. Perform copper tube cutting, flaring, swaging, brazing.	**Basic Refrigeration** 28. Identify & use of general hand tools, instruments & equipment used in refrigeration work. (12hrs.) 29. Identify & use of special tools, instruments & equipment used in refrigeration work.(13hrs.) 30. Identify various refrigeration equipment and components of vapour compression system like compressor, condenser, expansion device and evaporator.	**Basic Refrigeration** Basic principle of refrigeration, working, use, specifications of refrigeration tools, instruments and equipment. Fundamentals of Refrigeration and its units.Thermodynamics law.(05hrs..) Science related to refrigeration, work, power, energy, force, Heat and Temperature, Differenttemperature scales, Thermometers, Units of

		Identify and Check vapour absorption refrigeration cycle (VARC) (12 hrs.) 31. Unroll, cut and bend soft copper tubes. (04 hrs.) 32. Swage and make a brazed joint on copper tubing. (10 hrs.) 33. Make flare joints and test them with flare fittings. (10 hrs.) 34. Pinch off copper tubing. (04 hrs.) 35. Use lock ring tool and various fittings of lock ring for servicing of appliances. (10 hrs.). 36. Brazing of Cu to Cu, Cu to steel, Cu to brass using AIR LPG suitable in RAC machine. (07 hrs.) 37. Brazing of Cu to Cu, Cu to steel, Cu to brass using Oxy-LPG. (07 hrs.) 38. Brazing of Cu to Cu, Cu to steel, Cu to brass using Oxy-Acetylene. (11 hrs.)	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.(7hrs..) Construction and working ofV.C Cycle, fundamental operations, sub cooling and super heating.(03 hrs..)
Professional Skill 49 Hrs.; Professional Knowledge 10 Hrs.	Test mechanical & electrical components. Perform leak test, vacuuming, gas charging, wiring in refrigerator.	39. Identify electrical and mechanical components of refrigerator direct cool and frost free. (05 hrs.) 40. Check and replace electrical components of refrigerators. (14 hrs.) 41. Leak test, evacuation, gas charging in a refrigerator. (15 hrs.) 42. Wiring circuit of refrigerator. (15 hrs.)	**Refrigerator (Direct cool & Frost free)** Function, construction, working of single door direct cool refrigerator, frost free refrigerator, specifications, trouble shooting. Heat Insulation materials. Care and maintenance of refrigerators. (10 hrs.)
Professional Skill 16Hrs.; Professional Knowledge 03 Hrs.	Identify electrical and mechanical components of a refrigerator.	43. Installation of refrigerator. (8 hrs.) 44. Check, Find Fault and test the electrical and other system components of refrigerator. (8 hrs.)	**Refrigerator (Direct cool & Frost free)** Study the electrical components of refrigerator. Study the mechanical components of refrigerator and their types. (03 hrs..)
Professional Skill 30 Hrs.; Professional Knowledge 07 Hrs.	Test compressor motor terminal, start compressor with relay & without relay, technique of flushing, leak testing, replacing	45. Testing of compressor. (05 hrs.) 46. Identification of motor terminals. (05 hrs.) 47. Start the compressor with and without relay. (05 hrs.)	Importance of flushing in evaporator and condenser, use of dry nitrogen for flushing, necessity of replacing capillary and drier. Evacuation, leak

	capillary & filter drier, evacuation &gas charging.(NOS: Not available)	48. Test performance of direct start refrigerator. (05 hrs.) 49. Cleaning and flushing of evaporator and condenser with dry nitrogen. (05 hrs.) 50. Replacement of capillary tube and drier. (05 hrs.)	testing, gas charging method in refrigerator, (07 hrs..)
Professional Skill 42 Hrs.' Professional Knowledge 10 Hrs.	Check components of frost-free refrigerator (electrical/ mechanical), wiring of frost-free freeze & air distribution in refrigerator sector. Leak detection, evacuators & gas charging.	51. Tracing electrical circuit of Frost-Free refrigerator. (10 hrs.) 52. Checking, fault finding and testing of electrical accessories like thermostat, timer, defrost heaters, bi-metal, air louvers etc. and other system components. (10 hrs.) 53. Checking air distribution system. (03 hrs.) 54. Servicing of refrigerator. (07hrs.) 55. 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.5hrs..)
		56. Identify three and four door no frost refrigerator. (07 hrs.) 57. Testing components of three/ four door refrigerator. (03 hrs.)	**Refrigerator (Inverter Technology)**Study the construction and its working of two and three door frost free refrigerator with inverter technology Care and maintenance. (05 hrs..)
Professional Skill 39 Hrs.; Professional Knowledge 10 Hrs.	Dismantle, repair and assemble hermetic, fixed and variable speed compressor, and testperformance.	58. Identify different types of compressor. (09 hrs.)	**Compressor** Function, construction, working, application of hermetic compressor,(Fixed speed and variable speed compressor)like Reciprocating, rotary, scroll and inverter type.(5Hrs..)
		59. Dismantle /assembling reciprocating/rotary compressor. (15 hrs.) 60. Identify different parts of dismantled compressor. (15 hrs.)	Study the construction & working of reciprocating, rotary, scroll, wobble & swash plate compressor. wet compression, oil, properties, lubrication methods. (05 hrs..)
Professional Skill 50 Hrs.; Professional Knowledge 8 Hrs.	Identify the terminals of sealed compressor and their wiring and measure current, volts, watts and use of DOL starter with different types of motors.	61. Identify terminal sequence of hermetic compressor motor by using digital multimeter and measure starting current and running current by using ammeter and AVO meter. (12 hrs.)	AC motors and their types. Advantages of AC motor over DC motor. Split phase induction motors, working principle and construction.Starting winding and running winding.Starting current and running current. Study the shaded pole motor, RSIR, CSIR, CSR and PSC motors.(6 Hrs..)

		62. Identification of terminal sequence of CSIR motor by using digital multimeter and measure starting current and running current by using Ammeter and AVO meter. (13 hrs.)	
		63. Start CSR motor and measure starting current and running current. (07 hrs.) 64. Start shaded pole motor and measure starting current (18 hrs.)	Centrifugal switch and its function. Common faults, causes and remedies in motors. (02 hrs..)
Professional Skill 25 Hrs.; Professional Knowledge 4 Hrs.	Perform selection of Hermetic compressor for different appliances, starting methods, testing controls & safety cut out used in sealed compressor.	65. Test open, short, continuity and earth of a hermetic compressor. (04 hrs.) 66. Start the compressor motor by RSIR, CSIR, PSC & CSR method by using different type relay, capacitors, OLP's, etc. (10 hrs.) 67. Check and Test different type relay, Capacitors, OLP's, find out faults and rectification (11 hrs.)	**Motors** Function of Starting relay, Capacitors, OLP's.(04 hrs..)
Professional Skill 16Hrs.; Professional Knowledge 04 Hrs.	Identify theComponents of control system of Inverter AC and wiring of control system.	68. Check control circuit of variable speed air conditioners (Inverter ACs). (08 hrs.) 69. Identify components of control system of Inverter ACs including printed circuit board (PCB) NTC,PTC e.g. Power PCB, Filter PCB, Heat sink reactor. (08 hrs.)	Working principle of inverter technology, advantages of variable speed technology over fixed speed. Working principle of control system for inverter Air Conditioners (ACs). (04 hrs..)
Professional Skill 46 Hrs.; Professional Knowledge 10 Hrs.	Perform servicing & de scaling of condenser (internals &externals) used in different appliances.Perform Fitting & adjustment of drier, filter & refrigerant controls used in different refrigeration system.	70. Familiarize with different types of condensers used in refrigerators, Bottle coolers, visible coolers, deep freezers, Window and Split AC. (10 hrs.) 71. Clean, flush, service and leak test different type of air-cooled condensers, micro channel condensers. Remove dust from fins in air cooled condenser, micro channel condensers. (10 hrs.) 72. Identify different items necessary for de-scaling like diluted Hcl, Pump & motor, hose, etc. (07 hrs.)	**Condenser** Function of condenser, types, Construction of air-cooled condenser. Effect of chocked condenser. Advantages, de scaling of air-cooled condenser, application, and advantages. Liquid receiver, pump down, application, types, function and working. **Drier** Function of drier, types, application and its advantage. Description of desiccants.

		73. Identify drier and capillary tube used in different cooling machines. (09 hrs.) 74. Replace drier and capillary tube at the time of gas charging according to manufacturer's direction. (10 hrs.)	**Expansion Valve** Expansion valve used in domestic refrigeration and air conditioning systems. Capillaries, Automatic and Thermostatic Ex. Valves, and electronic expansion valves.(10 hrs..)
Professional Skill 16 Hrs.; Professional Knowledge 05 Hrs.	Perform servicing of different evaporator used in different appliances.	75. Identify and service different types of evaporators like plate and tube type, Fin andtube type, etc. fitted in refrigerators, Bottle coolers, water cooler, Window and split AC. (08 hrs.) 76. Perform leak test, flush to remove oil by dry nitrogen in evaporator. (08 hrs.)	**Evaporator** Working principle, Function, types of evaporators used in refrigerator, water coolers, bottle coolers, window and split A.C, Super heating in evaporators, Function of accumulator and types. Methods of defrosting. (05 hrs..)
Professional Skill 30 Hrs.; Professional Knowledge 06 Hrs.	Carry out Recovery and Recycling of Refrigerant used, alternative of CFC, HFC re-cover, transfer & handing of gas cylinders.	77. Identify and explain different colour code of different type refrigerant cylinder like HCFCs (HCFC-22, HCFC-123). HFCs (HFC-134a, HFC-32, R- 410A, R-407C and R-404A) and low-Global Warming Potential (GWP) refrigerants like ammonia, R-290, HFC- 32, blends of HFCs (R-410A, R-404A, R-407C etc.) and hydro Fluor olefins (HFOs: HFO-1234yf, HFO-1234ze, HFO-1233zd, HFO-1336mz), blends of HFCs and HFOs. (10 hrs.) 78. Recover refrigerant from a faulty machine. (07 hrs.) 79. Transfer refrigerant from one cylinder to another using ice. (04 hrs.) 80. Measure pressure andtemperature of refrigerants including HCFC-22, ammonia, R-290, HFC-32, HFC-134a, R-404A, R-407Cand R-410A, HFOs. Identify flammability and toxicity of A3 and A2L of refrigerants. (09 hrs.)	**Refrigerant** Classification of refrigerants, nomenclature of refrigerants including chemical name and formulas, hydro chloro fluorocarbons (HCFCs), hydro fluorocarbons (HFCs) and hydro fluoroolefins (HFOs), blends of HFCs and blends of HFCs/HFOs. Climatic impact of refrigerants: Stratospheric ozone depletion, global warming, mechanism of ozone depletion; the Montreal Protocol phase-out schedule of ozone depleting refrigerants (HCFCs) and high global warming refrigerants (HFCs). Brief introduction of Ozone Depleting Substances (Regulation and Control) Rules, 2000 and its amendments. Introduction of properties of refrigerants; environment related properties: Ozone Depleting Potential (ODP), GWP; ODP and GWP of various refrigerants, thermo chemical properties: flammability and toxicity of refrigerants, lower flammability limit (LFL) and upper flammability limit of A3 and A2L refrigerants. Thermo physical properties: pressure temperature of different refrigerants.(06 hrs..)

Professional Skill 22 Hrs.; Professional Knowledge 07 Hrs.	Retrofit CFC/HFC machine with ozone friendly refrigerant with understanding of the compatibility.	81. Demonstrate safe handling of refrigeration cylinders. (10 hrs.) 82. Recover CFC by recovery pump and cylinder on CFC filled domestic refrigerator. (12 hrs.)	Safe handling of flammable refrigerants. Refrigerant leak detection methods, evacuation and charging of refrigerant, temperature glides of refrigerant blends, procedure of charging of refrigerant blends especially the zeotropic lends,hydrocarbon blends, HFC blends (R-404A, R-407C,R-410A) and blends of HFCHFO. **Retrofitting** Changes of components & practices while retrofitting CFC appliances with HC Refrigerants. Properties of HCs(07 hrs..)
Professional Skill 13 Hrs.; Professional Knowledge 02 Hrs.	Pack thermal insulation and prevent cooling leakage.	83. Identify different insulating materials.(polyurethane rigid foam and polystyrene). (03 hrs.) 84. Fill with insulation material like PUF and glass wool. (10hrs.)	**Thermal Insulation** Function,types,thermodynamic properties of heat insulation materials used in refrigeration and Air Conditioning systems. (02 hrs..)
Professional Skill 50 Hrs.; Professional Knowledge 7 Hrs.	Install window AC, test Electrical & electronics components & Fault diagnosis & remedial measures.	85. Acquainting with mechanical and electrical components (electrical components like selector switch, thermostat switch, relay, starting capacitor, running capacitor, overload protector, remote and PCB control, etc.) used in window air- conditioner. (15 hrs.) 86. Troubleshooting, installation, tracing wiring circuit. (5 hrs..) 87. Leak testing, evacuation and gas charging, Show discharge pressure and suction pressure during running time. (15 hrs.) 88. Hands on practice on installation of window AC following step by step procedure. (15 hrs.)	**Window Air Conditioner** Study the constructionand working principle of window AC and its components; electrical controls and wiring. Installation, troubleshooting and servicing. (7 Hrs)
Professional Skill 100 Hrs.; Professional Knowledge 18Hrs.	Perform servicing of electrical& electronic control, test, Installation, wiring, fault finding & remedial measures of different split AC.	**Split AC (wall/floor/Cassette)** 89. Identify various components of split AC like wall mounted, floor and ceiling mounted, duct able and multi split AC. (04hrs.) 90. Identify electrical circuits of wall mounted split AC. (04hrs.)	**Split AC (wall/floor/Cassette)** Construction and working principle, troubleshooting & care and maintenance. Selection of location of indoor and outdoor units.

		91. Test different components and fault finding. (03 hrs.) 92. Leak testing of the system, evacuation and gas charging. (03hrs.) 93. Trouble shooting in split AC. (06hrs.)	**Split AC (Wall Mounted)** Construction and working principle, types, trouble shooting. Description of electrical components used in split A.C. Study the wiring circuit.
		94. Install IDU and ODU of wall mounted split AC. (16hrs.) 95. Install IDU of floor, Ceiling / Cassette mounted Split AC. (16hrs.)	**SPLIT A.C (floor, Ceiling / Cassette mounted Split A.C)** Construction and working principle, types, trouble shooting. Description of electrical components used in split A.C. Study the wiring circuit.
		96. Install IDU and Duct of Ductable split AC. (16hrs.)	**SPLIT A.C (Ducted**) Study of the Duct able split AC, its Construction and working principle, types, trouble shooting.Description of electrical components used in split A.C. Study the wiring circuit.
		97. Servicing of Multi Split AC. (16hrs.)	**MULTI SPLIT A.C** Study the construction and working, various components, electrical circuits, testing components, fault detection
		98. Identify the parts of Inverter Split AC. (16hrs.)	**INVERTER SPLIT A.C.** Study of construction and working principle of inverter AC and its components, electrical circuit and controls, installation, servicing, trouble shooting, fault detection, leak testing and gas charging.Concept of Indian Seasonal Energy Efficiency Ratio ISEER). Energy Efficiency leveling oninverter AC.(18 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, out policy and economy is based on the method of peace itself. W 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 out country needed huge number of well doing SKILLED CRAFMENS' so, in the year 1950 Govt. of India started the CRAFTMEN 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 (DGE&T) 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 Craftsmen 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 form 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 there by to gain confidence.

Mechanic refrigeration & air conditioning

Mechanic

A person who has through 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 is 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.

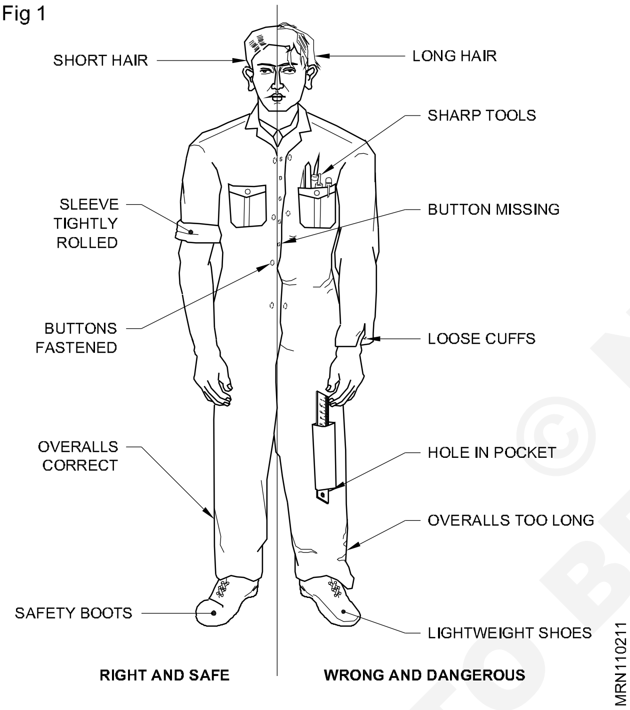
Due to tremendous growth in technology, by 1990 all areas of refrigeration and air conditioning were using microprocessor control systems. The purpose of this system is to increase reliability and efficiency of the heating and cooling units. By 1990, the automobile air conditioner became as standard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

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)

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)

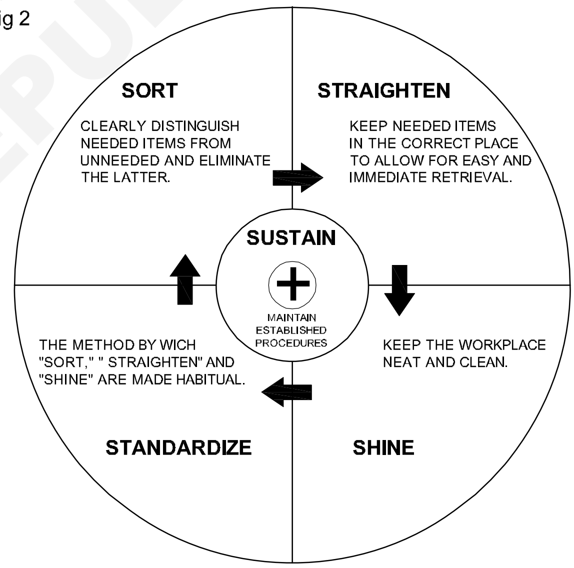
5 Shitsuke (SUSTAIN).

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

Fig 2



5S WHEEL

MRN110212

Basic safety - First aid treatment - Artificial respiration

Objectives: At the end of this lesson you shall be able to
- **explain how to rescue a person who is in contact with a live wire**
- **brief how to give first aid treatment for a victim.**

Rescue operation

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 victim is still in contact with the supply - break the contact either by switching off or by removing the plug or pulling the cable free.

If not, stand on some insulating material such as dry wood, rubber or plastic or newspaper and then pull his shirt sleeves. However, you have to insulate yourself and break the contact by pushing or pulling the person free. (Fig 1 & 2)

Fig 1

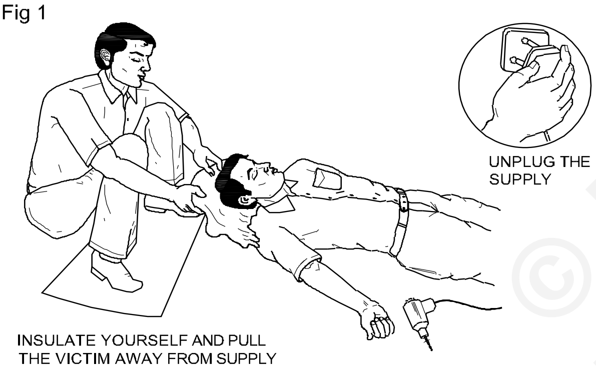


Fig 2

In any case avoid direct contact with the victim. Wrap your hands in dry material if rubber gloves are not available.

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

If the victim is at a height, efforts must be taken to prevent him from falling or to make him fall safe.

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 (Fig 3) 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 in the recover position. Send for help. (Fig 4)

Fig 4

> **Do not give an unconscious person anything to eat or drink.**
>
> **Do not leave an unconscious person unattended.**

If the casualty is not breathing - **Act at once to resuscitate the victim** - do not waste time.

Artificial respiration methods already dealth in practical exercise 1.1.03 in detail and refer practical book.

Basic first-aid treatment

First aid is defined as the immediate care and support given to an acutely injured or ill person, primarily to save life, prevent further deterioration or injury, plan to shift the victim to safer place, provide best possible comfort and finally help them to reach the medical centre/ hospital through all available means. It is an immediate life-saving procedure using all resources available within reach.

Imparting knowledge and skill through institutional teaching at younger age group in schools, colleges, entry point at industry level is now given much importance. Inculcating such habits at early age, helps to build good healthcare habits among people.

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

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

- **Preserve life:** If the patient was breathing, a first aider would normally then place them in the recovery position, with the patient leant over on their side, which also has the effect of clearing the tongue from the pharynx. It also avoids a common cause of death in unconscious patients, which is choking on regurgitated stomach contents.

  The airway can also become blocked through a foreign object becoming lodged in the pharynx or larynx, commonly called choking. The first aider will be taught to deal with this through a combination of 'back slaps' and 'abdominal thrusts'. Once the airway has been opened, the first aider would assess to see if the patient is breathing.

- **Prevent further harm:** Also sometimes called prevent the condition from worsening, or danger of further injury, this covers both external factors, such as moving a patient away from any cause of harm, and applying first aid techniques to prevent worsening of the condition, such as applying pressure to stop a bleed becoming dangerous.

- **Promote recovery:** First aid also involves trying to start the recovery process from the illness or injury, and in some cases might involve completing a treatment, such as in the case of applying a plaster to a small wound.

Hazard identification

One of the essential elements of the health and safety management system is hazard identification. it is the foundation for developing safe work procedures, establishing prevention programs and making other precautions to eliminate or control the hazards.

A hazard is any source of potential damage, harm or adverse effects on something or someone. Risk is the chance that a hazard will cause harm. Hazard identification process involves identifying both existing and potential workplace hazards, assessing the risk, determining and implementing the controls, and reviewing hazards.

Employers have the legal responsibility to identify and control, to the best of their ability, workplace hazards in order to protect workers. Likewise workers have the right to know about the hazards of the job and how to protect themselves, and the responsibility to follow company rules that outline the hazard control processes. It is the responsibility of all workers to understand what a hazard is, what the risk is, how the hazards can affect people, property and the environment and how to prevent injury or illness from that hazard.

When to identify hazards?

There are formal hazard assessments involving all workers before commencing work. Documentation from this should be reviewed as conditions change. There are informal hazard assessments that are ongoing and often undocumented, which consists of continuously scanning surroundings to be aware of condition changes.

It is an on-going process. You can identify hazards:

1 During design and implementation
   - Designing new process
   - Purchasing and installing machinery

2 Before tasks are done
   - Using new equipment or processes.
   - Each shift in hazardous environments

3 During work
   - Be aware of changes, abnormal conditions, or sudden emissions

4 After incidents
   - Near misses or minor events
   - Injuries

Occupational health and safety

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

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/ or rendered services.

Types of occupational health hazards

1 Physical Hazards
2 Chemical Hazards
3 Biological Hazards
4 Physiological
5 Psychological
6 Mechanical
7 Electrical
8 Ergonomic

Safety practice - fire extinguishers

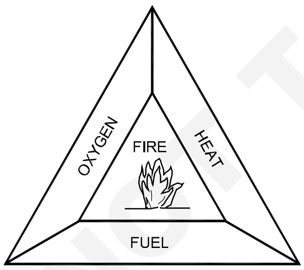
Objectives: At the end of this lesson you shall be able to
- **state the effects of a fire breakout**
- **state the conditions required for combustion relevant to fire prevention**
- **state the general precautionary measures to be taken for fire prevention**
- **distinguish different types of fire extinguishers**
- **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)

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.

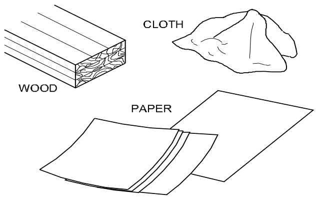
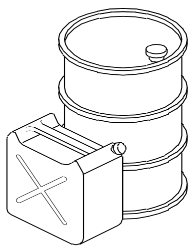
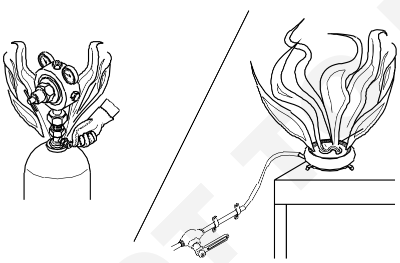
- Class A Fire
- Class B Fire
- Class C Fire
- Class D Fire

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.

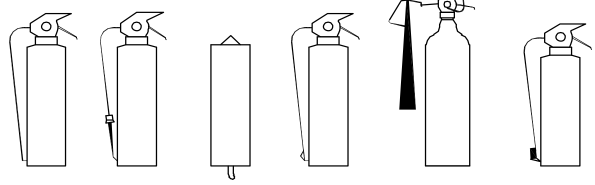
Fuel		Extinguishing
CLASS 'A' Fire	Wood, paper, cloth etc. Solid materials. 	Most effective i.e. cooling with water. Jets of water should be sprayed on the base of the fire and then gradually upwards.
CLASS 'B' Fire	Flammable liquids & liquefiable solids 	Should be smothered. The aim is to cover the 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 CO_2 may be used on this type of fire.
CLASS 'C' Fire	Gas and liquefied gas 	Extreme caution is necessary in dealing with liquefied 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 off control fire.

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

Fig 6

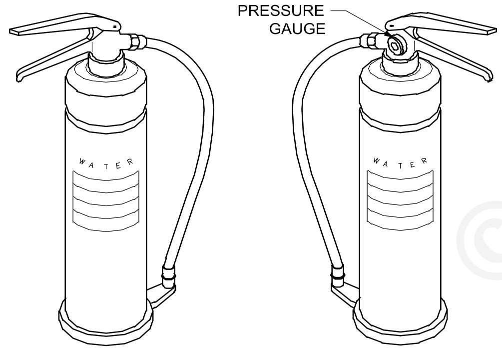


Water-filled extinguishers

There are two methods of operation. (Fig 7)

- Gas cartridge type
- Stored pressure type

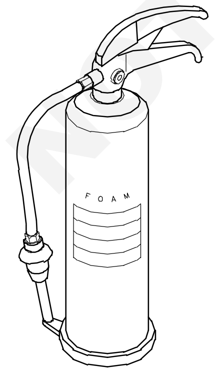
Fig 7



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

Foam extinguishers (Fig 8)

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:

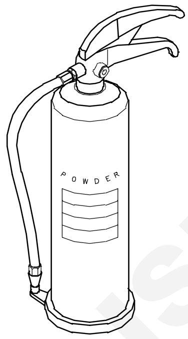
- flammable liquid fires
- running liquid fires

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.

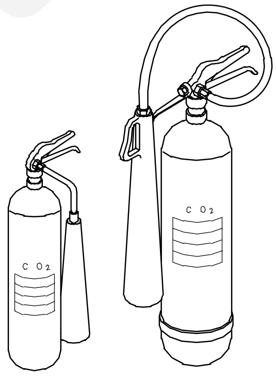
Fig 9



Carbon dioxide (CO_2)

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

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.

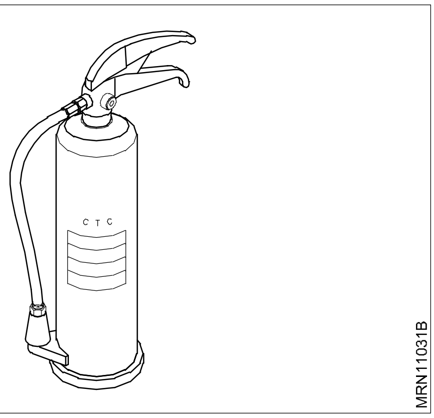
Halon extinguishers (Fig 11)

Theses extinguishers may be filled with carbon tetrachloride and bromochlorodifluoro methene (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



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.

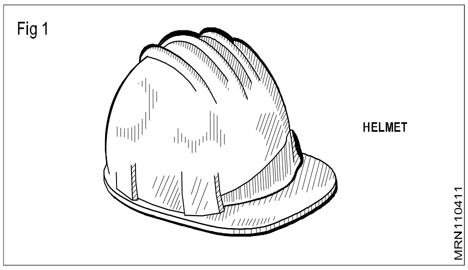
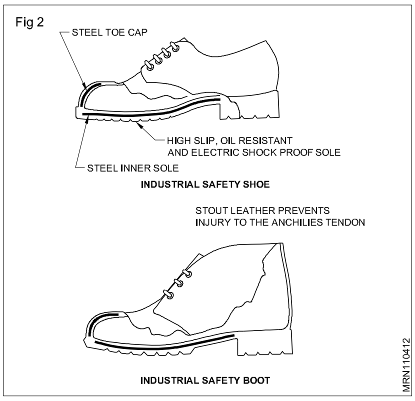
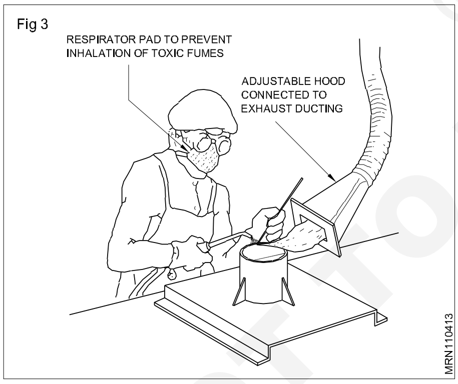
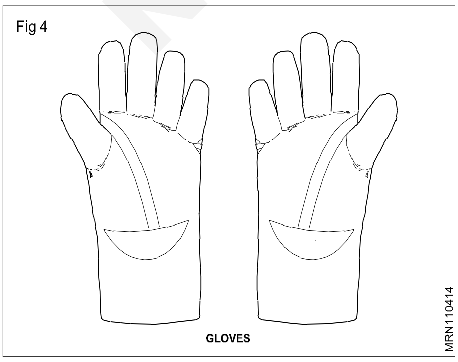
Quality of PPE's

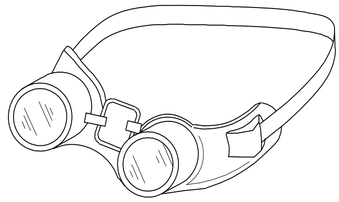
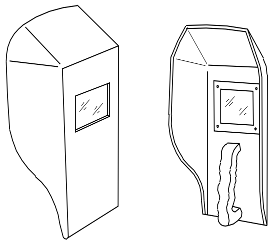
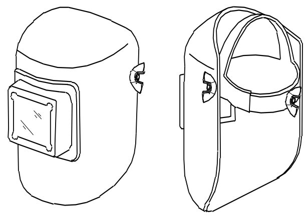
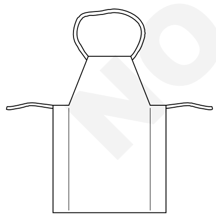
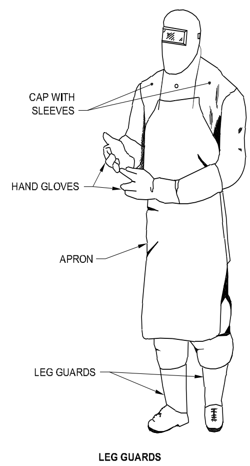
PPE must meet the following criteria with regard to its quality-provide absolute full protection against possible hazard and PPE's be so designed and manufactured out of materials that it can withstand the hazards against which it is intended to be used.

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 	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  Ear protection (Fig 7) 	1. Spark generated during Welding, grinding 2. Welding spatter striking 3. Face protection from UV rays 1. High noise level	Face shield Head shield with or without ear muff Helmets with welders Screen for welders Ear plug
Body protection (Fig 8, & Fig 9) Fig 8 	1. Hot particles Fig 9 	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

Different types of Hand tools - specification

Objectives: At the end of this lesson you shall be able to
- **list the tools necessary for a wireman**
- **specify the tools and state the use of each tool**
- **explain the care and maintenance of wireman hand tools.**

It is important that the wireman 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.

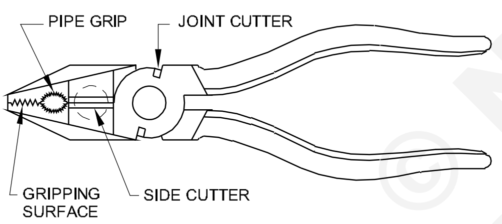
Listed below are the most commonly used tools by wireman.

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.

Fig 1



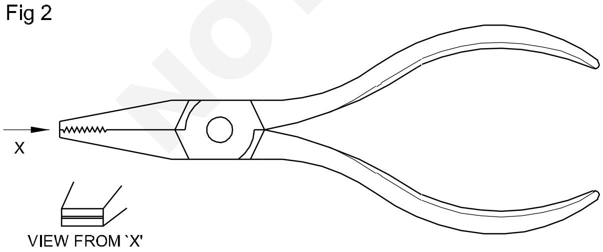
COMBINATION SIDE CUTTING PLIERS
(ENGINEER'S PLIERS, COMBINATION PLIERS)

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.

Fig 2



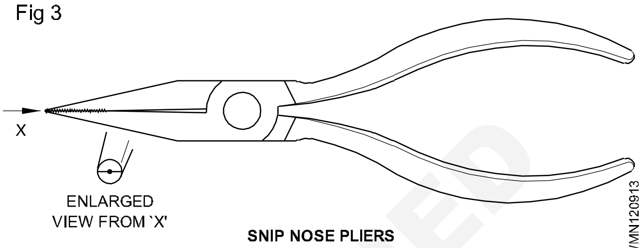
FLAT NOSE PLIERS

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.

Fig 3



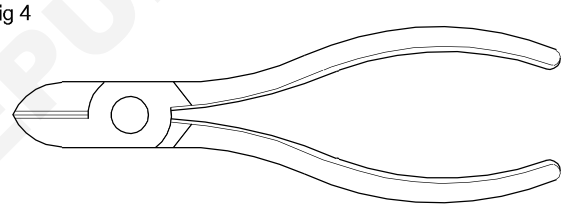
SNIP NOSE PLIERS

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).

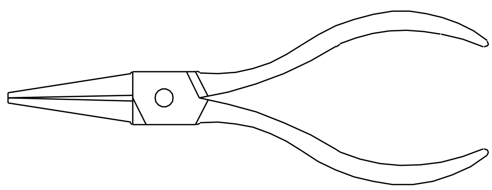
Fig 4



DIAGONAL CUTTING PLIERS/NIPPER

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

Fig 5



ROUND NOSE PLIERS

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.
- 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 correctly fit the grooves of the screw to have maximum efficiency and to avoid damage to the screw heads.

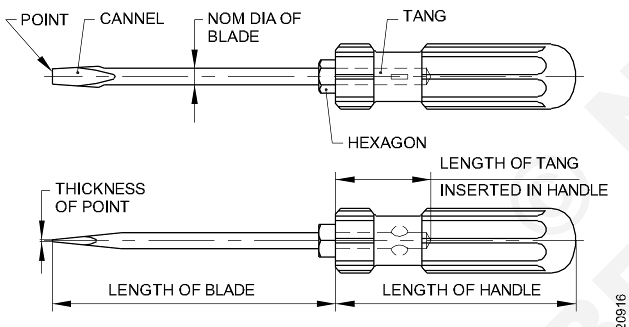
As the length of the screw driver is proportional to the turning force, for small work choose a suitable small sized screwdriver and vice versa.

Star-head screw driver: 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.

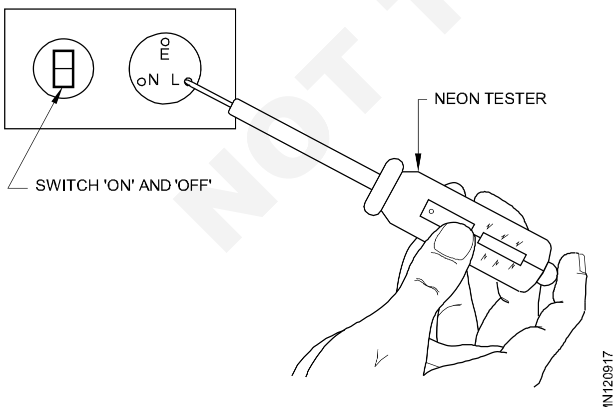
Fig 6



NOMENCLATURE FOR SCREWDRIVERS

7 Neon tester BIS 5579 - 1985 (Fig 7)

Fig 7



NEON TESTER

It is specified with its working voltage range 100 to 250 volts but rated to 500 V.

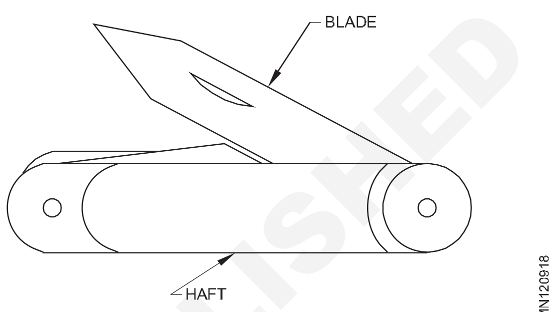
It consists of a glass tube filled with neon gas, and electrodes at the ends. To limit the current within 300 micro-amps at the maximum voltage, a high value resistance is connected in series with one of the electrodes. It may have a tip like a probe or screwdriver at one end. The presence of supply 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.

8 Electrician's knife (Double blade) (Fig 8)

Fig 8



ELECTRICIAN'S KNIFE

The size of the knife is specified by its largest blade length eg. 50 mm, 75 mm.

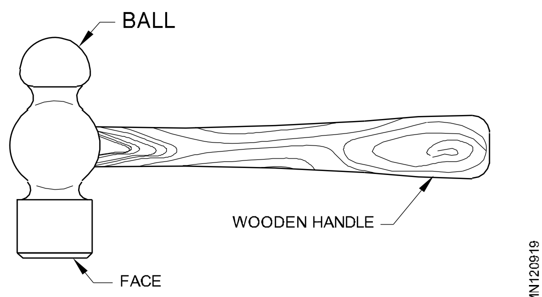
It is used for skinning the insulation of cables and cleaning the wire surface. One of the blades which is sharp is used for skinning the cable and the rough edged blade is used for cleaning the surface of the wires.

Care and maintenance

- Do not use the knife for cutting wires.
- Fold the knife blade when not in use.

9 Hammer ball pein (Fig 9)

Fig 9



BALL PEIN HAMMER

The size of the hammer is expressed in weight of the metal head. Eg.125 gms, 250 gms etc.

The hammer is made out of special steel and the striking face is tempered. Used for nailing, straightening, and bending work. The handle is made of hard wood.

Care and maintenance

- The face of the hammer must be free from oil, grease and mushrooms.

10 Try-square (Engineer's square) (Fig 10) BIS 2103

This is specified by its blade length.

Eg. 50 mm x 35 mm

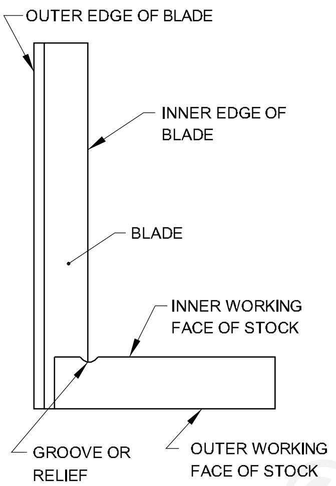
100 mm x 70 mm

150 mm x 100 mm etc.

There are two types; one is the beveled edge with stock and the other is the flat edge without stock. It is used to check whether the object is plane, perpendicular and at right angle. Two straight blades set at right angles to each other constitute the try-square. The steel blade is riveted to the stock. The stock is made of cast iron. The stock should be set against the edge of the job.

Do not use it as a hammer.

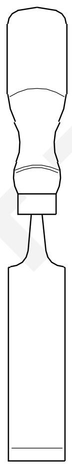
Fig 10



TRY-SQUARE

11 Firmer chisel (Fig 11)

Fig 11



FIRMER CHISEL

It has a wooden handle and a cast steel blade of 150 mm length. Its size is measured according to the width of the blade eg. 6 mm, 12 mm, 18 mm, 25 mm. It is used for chipping, scraping and grooving in wood.

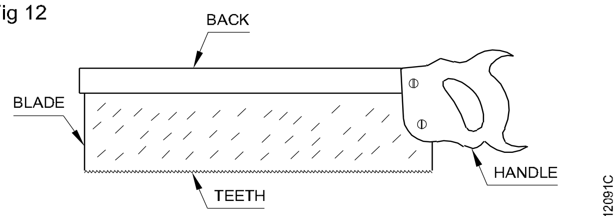
Care and maintenance

- Use mallet for chiseling.
- Grind on a water stone and sharpen on an oilstone.

12 Tenon-saw (Fig 12) BIS 5123, BIS 5130, BIS 5031

Generally the length of a tenon-saw will be 250 or 300 mm. and has 8 to 12 teeth per 25.4 mm and the blade width is 10 cm. It is used for cutting thin, wooden accessories like wooden batten, casing capping, boards and round blocks.

Fig 12



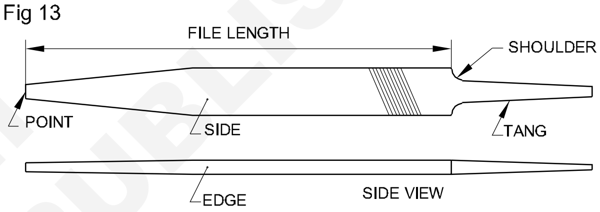
TENON-SAW

Care and maintenance

- Keep free from rust.
- Apply grease when not in use.

13 Files (Fig 13) BIS 1931

Fig 13



FILE

These are specified by their nominal length.

Eg.150 mm, 200 mm, 250 mm 300 mm etc.

These files have different numbers of teeth designed to cut only in the forward stroke. They are available in different lengths and sections (Eg. flat, half round, round, square, triangular), grades like rough, bastard second cut and smooth and cuts like single and double cut.

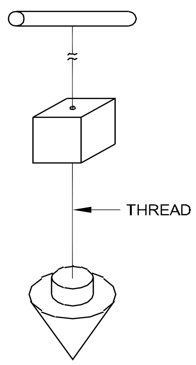
These files are used to remove fine chips of material from metals. The body of the file is made of cast steel and hardened except the tang.

Care and maintenance

- Do not use the file without the handle.

14 Plumb bob (Fig 14)

Fig 14



PLUMB BOB

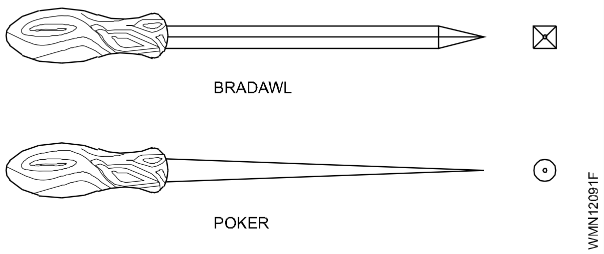
It has a pointed tip with a centre hole at the top for attaching a string as shown in Fig 15. It is used for checking the vertical alignment of the wall.

Care and maintenance

- String to be changed in a period of time intervals.

15 Bradawl square pointed (or poker) (Fig 15) BIS 10375 - 1982

Fig 15



It is specified by its length and diameter eg. 150 mm x 6 mm.

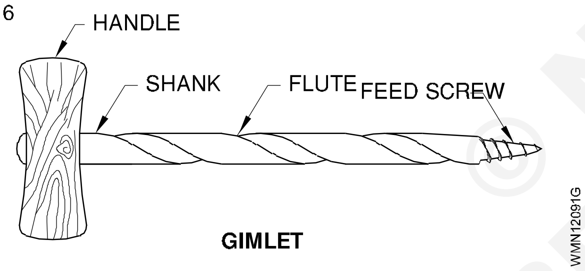
It is a long sharp tool used for making pilot holes on wooden articles to fix screws.

Care and maintenance

- Do not use it on metals for making holes.

16 Gimlet (Fig 16)

Fig 16



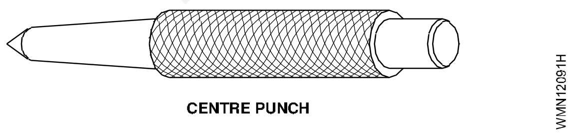
It is used for boring small holes on wooden articles. It has a wooden handle and a boring screwed edge. The size of it depends upon its diameter. Eg. 3 mm, 4 mm, 5 mm, 6 mm.

Care and maintenance

- Do not use it without the handle.
- Keep it straight while making holes, otherwise the screwed portion can get damaged.

17 Centre punch (Fig 17) BIS 7177

Fig 17



The size is given by its length and diameter of the body.

Eg. 100 mm x 8 mm. The angle of the tip of the centre punch is 90°.

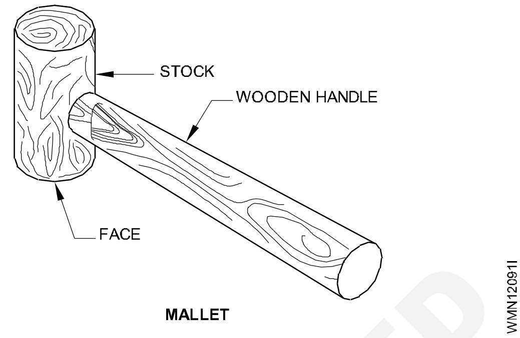
It is used for marking and punching the center of pilot holes on metals. It is made of tool steel and the ends are hardened and tempered.

Care and maintenance

- Keep the tip sharp and at a proper angle.
- Avoid mushroom heads.

18 Mallet (Fig 18)

Fig 18



The mallet is specified by the diameter of the head or by the weight.

eg. 50 mm x 150 mm

75 mm x 150 mm or 500gms, 1 Kg.

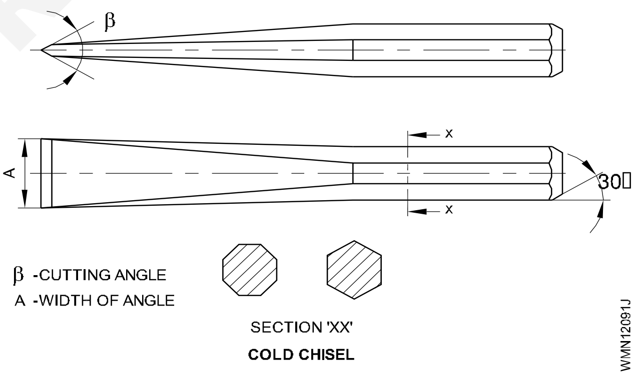
It is made out of hard wood or nylon. It is used for driving the firmer chisel, and for straightening and bending of thin metallic sheets. Also it is used in motor assembly for coil winding alignment.

Care and maintenance

- Do not use it for fixing nails.

19 Flat cold chisel (Fig 19) BIS 402

Fig 19



Its size is given by the nominal width and length.

ie. 14 mm x 100 mm

15 mm x 150 mm

20 mm x 150 mm

The body shape of a cold chisel may be round or hexagon.

The cold chisel is made out of high carbon steel. Its cutting edge angle varies from 35° to 45°. The cutting edge of the chisel is hardened and tempered. This chisel is used for making holes on wall etc.

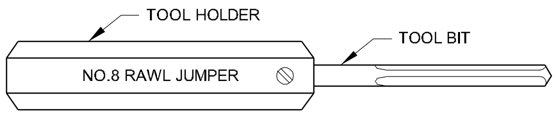
Care and maintenance

- The edge of a chisel must be maintained as per the required angle.

- While grinding a chisel apply a coolant frequently so that its temper may not be lost.

20 Rawl plug tool and bit (Fig 20)

Fig 20



RAWL PLUG TOOL

WMN12091K

Its size depends upon the number. As the number increases, the thickness of the bit as well as the plug also increases. Eg. Nos.8, 10, 12, 14 etc.

A rawl plug tool has two parts, namely the tool bit and tool holder. The tool bit is made of tool steel and the holder is made of mild steel. It is used for making holes in bricks, concrete wall and ceiling. Rawl plugs are inserted in them to fix accessories.

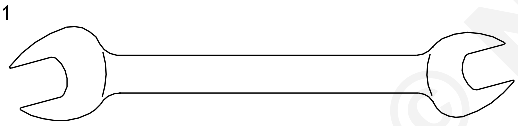
Care and maintenance

- Slightly rotate the holder after each hammering stroke.
- Hold the tool straight.
- Keep its head free from mushrooms.

21 Spanner: double ended (Fig 21) BIS 2028

The size of a spanner is indicated so as to fit on the nuts. They are available in many sizes and shapes.

Fig 21



DOUBLE ENDED OPEN JAW SPANNER

WMN12091L

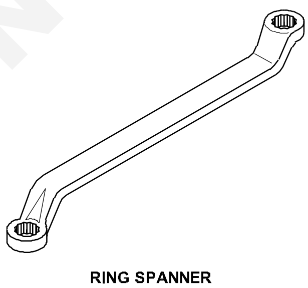
The sizes, indicated in double-ended spanners are the distance between two jaws of a side.

10-11 mm	12-13 mm	14-15 mm
16-17 mm	18-19 mm	20-22 mm
21-23 mm		

For loosening and tightening of nuts and bolts, these are used. It is made out of cast steel. They are available in many sizes and may have single or double ends.

22 Ring spanner set (Fig 22) BIS 2029

Fig 22



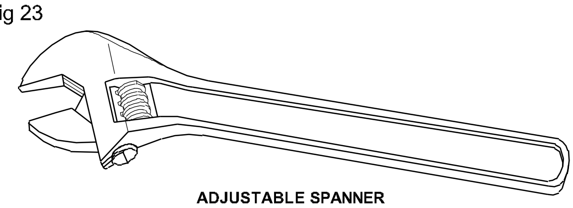
RING SPANNER

WMN12091M

The ring spanner is used in places where the space is restricted and where high leverage is required.

23 Single ended open jaw adjustable spanner (Fig 23) BIS 6149

Fig 23



ADJUSTABLE SPANNER

WMN12091N

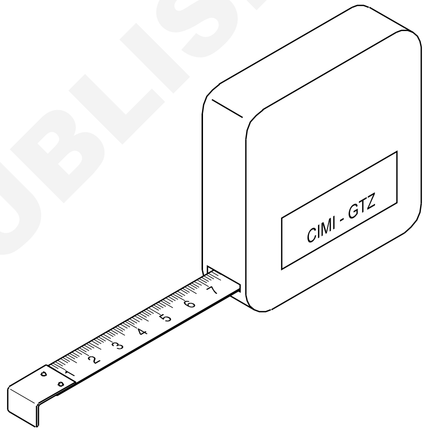
It saves time and working. The movable jaw is made adjustable by operating a screw. It is known as a monkey wrench also. Available in 150,200,250mm etc.

Care and maintenance

- Use correct size spanner suitable to the size of nut and bolt.
- Prevent the grease and oil traces on its jaws.

24 Measuring steel tape (Fig 24)

Fig 24



MEASURING STEEL TAPE

WMN12091O

The size will be the maximum length it can measure. Eg. Blade 12 mm wide 2 metres long.

The measuring tape is made of thin steel blade, bearing dimensions on it.

It is used for measuring the dimension of the wiring installation and general measurements.

Care and maintenance

- Handle with great care as carelessness may spoil the graduation.

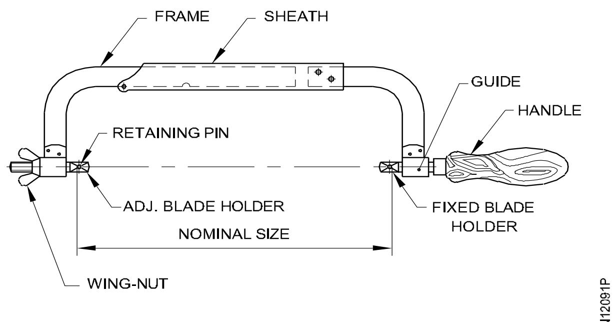
25 Hacksaw (Fig 25) BIS 5169-1986 for frames BIS 2594 - 1977 for blades

It is made out of sturdy nickel plated steel frame. The frame can be adjusted for 250 mm to 300 mm blades. It should be fixed on the frame with its teeth pointing away from the handle in order to do the cutting in forward stroke. It is mainly used for cutting metals.

Care and maintenance

- The blade should be properly tightened.
- Use a coolant while cutting.
- Lift the saw slightly on the return stroke.

Fig 25



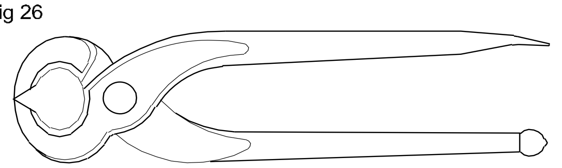
NOMENCLATURE FOR HACKSAW FRAME

26 Pincers (Fig 26) BIS 4195

The size is given by its length. Eg. 100 mm, 150 mm, 200 mm.

It is used for extracting nails from the wood.

Fig 26



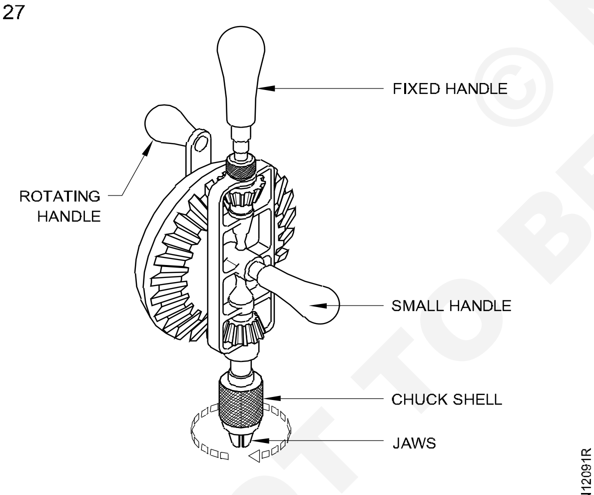
PINCERS

Care and maintenance

- Do not use it as a hammer.

27 Hand drill (Fig 27)

Fig 27



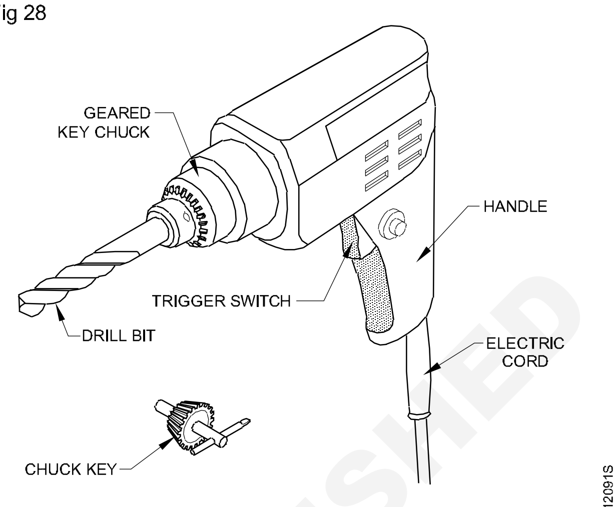
HAND DRILL

The size is given by the twist drill bits which can be fitted in. Eg. 6 mm, 0-12 mm capacity.

A hand drill machine is used for making holes in thin metal sheets or wooden articles.

28 Portable Electric drilling machine (Fig 28)

Fig 28



ELECTRIC DRILLING MACHINE

When power is available, a power drilling machine is a more convenient and accurate tool for drilling holes on wooden and metal articles.

Care and maintenance

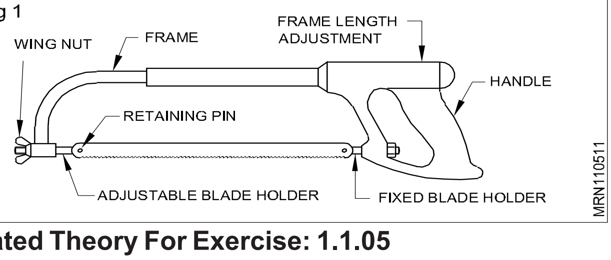
- Lubricate all the moving parts of the machine.
- Fix the drill bit firmly in the jaws.
- Before drilling, mark the job with a centre punch.
- For taking out the drill bit move the chuck in the reverse direction.
- Do not apply excess pressure on small bits.
- In the case of an electric drilling machine it must be properly earthed and the insulation should be sound.

Identify general tools

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.

Fig 1



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.

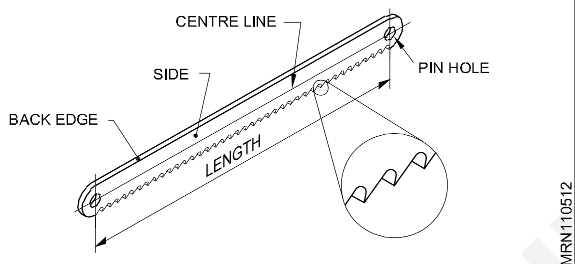
3 Adjustable frame (tubular type)

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)

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

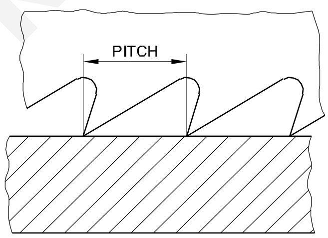
These are hardened to the full length between the pin holes.

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)

Fig 3

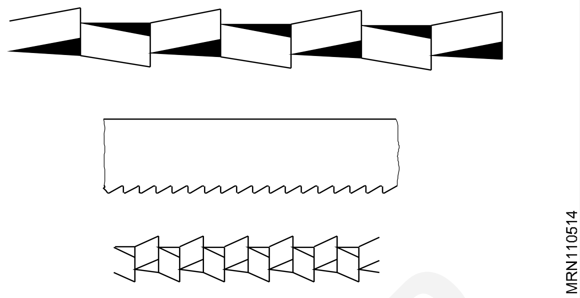


The distance between adjacent teeth is known as the 'pitch' of the blade.

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

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

Fig 4

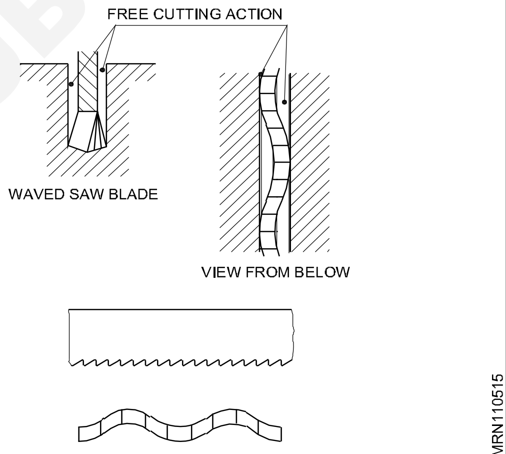


Classification of sets

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



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)

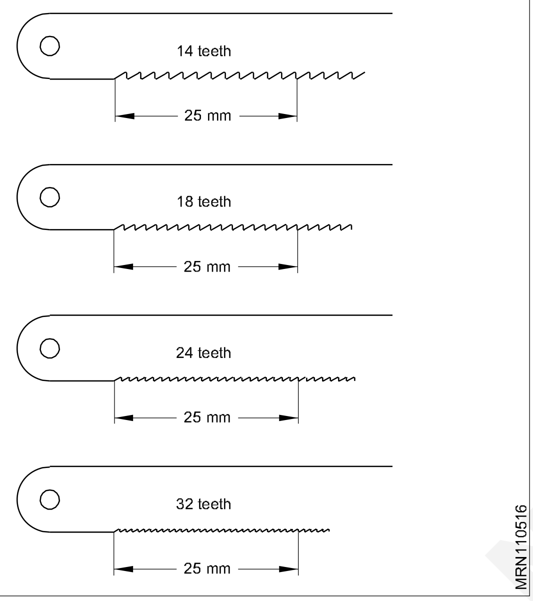
– 14 teeth per 25 mm
– 18 teeth per 25 mm
– 24 teeth per 25 mm
– 32 teeth per 25 mm.

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 turing 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.

Fig 6



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.

Filing surface 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.

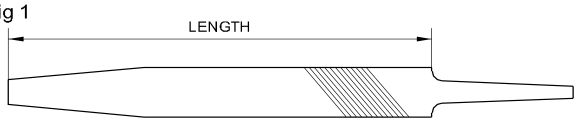
Length is the distance from the tip of a file to the heel.

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)

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.

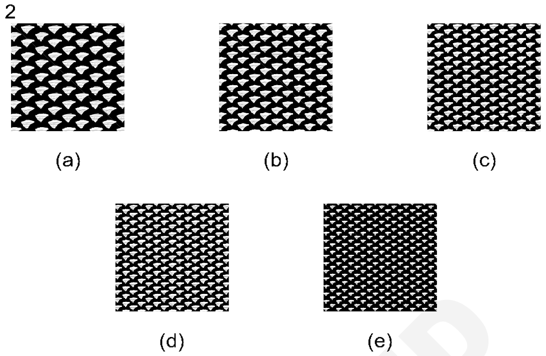
A **bastard file** is used in cases where there is a heavy reduction of material.

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 i**s used to bring to accurate size with a high degree of finish.

Fig 2



GRADES OF FILES

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

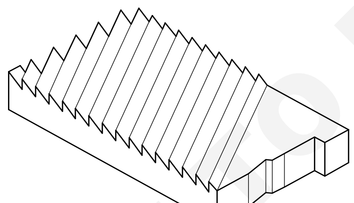
Basically there are four types.

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)

Fig 1

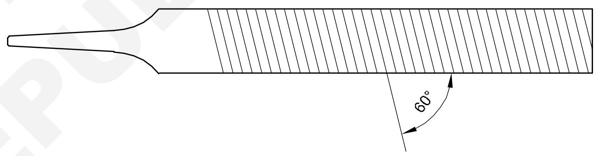


A single cut file has rows of teeth cut in one direction across its face. The teeth are at an angle of 60° to the centre line. It can cut chips as wide as the cut of the file. Files with this cut are useful for filing soft metals like brass, aluminium, bronze and copper. Single cut files do not remove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

Fig 2

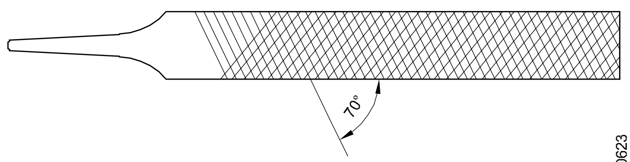


SINGLE CUT FILE

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.

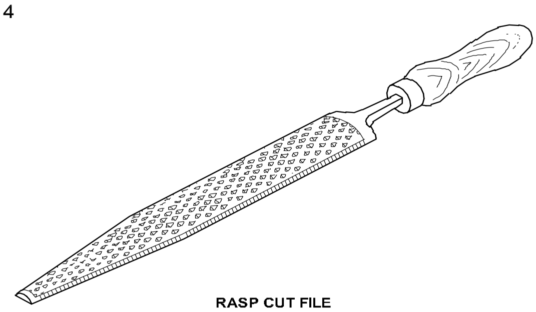
Fig 3



DOUBLE CUT FILE

Curved cut file (Fig 4)

Fig 4



RASP CUT FILE

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

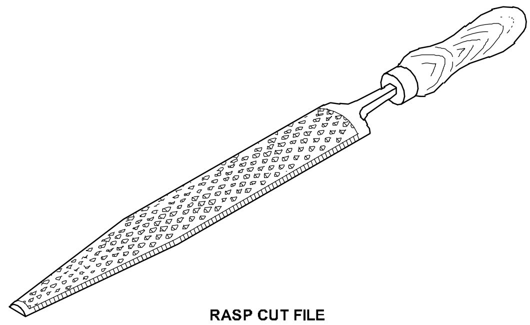
The curved cut files are available only in a flat shape.

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)

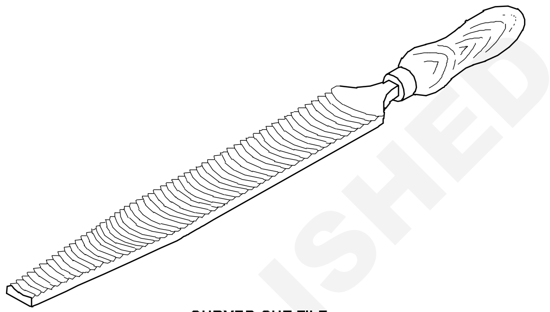
Different sizes of files with the same grade will have varying sizes of teeth. In longer files, the teeth will be coarser.

Fig 4



RASP CUT FILE

Fig 5



CURVED CUT FILE

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.

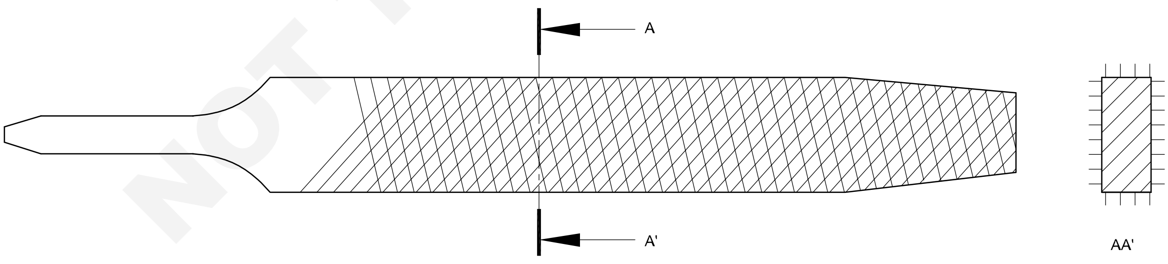
The shape of files is usually specified by their cross- section.

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.

Fig 1

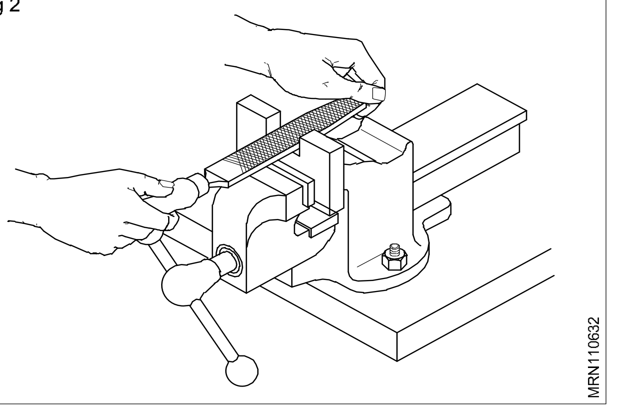


Hand files (Fig 2)

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.

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.

Fig 2



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

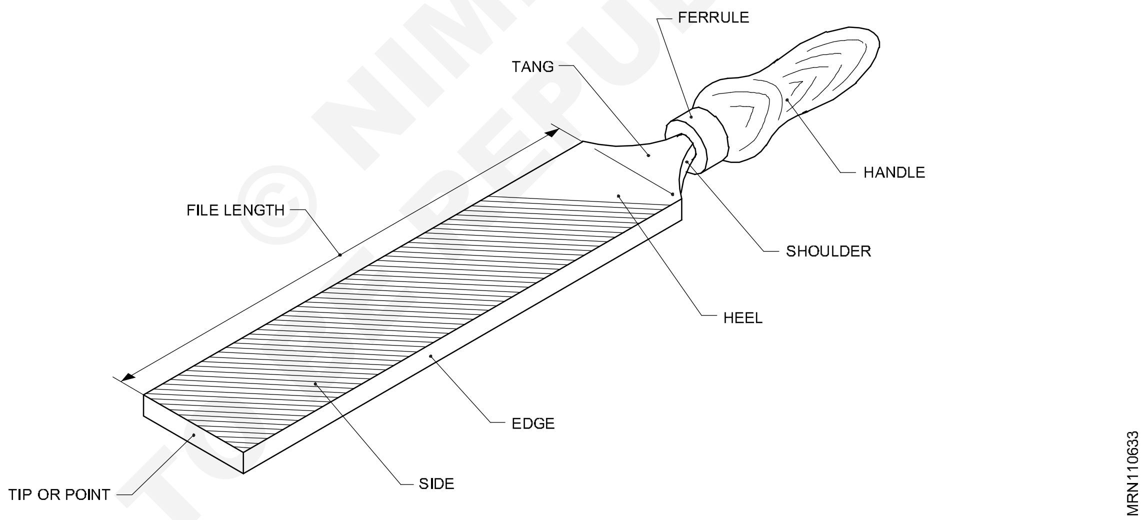
Ferrule

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)

Fig 1

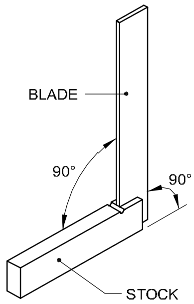


Fig 2

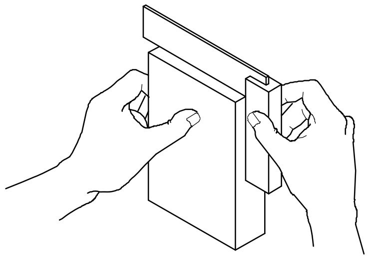


Fig 3

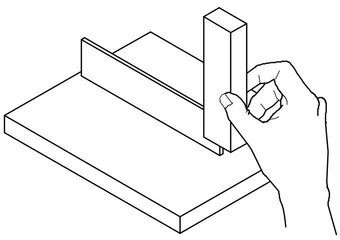
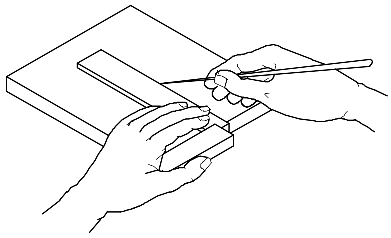


Fig 4

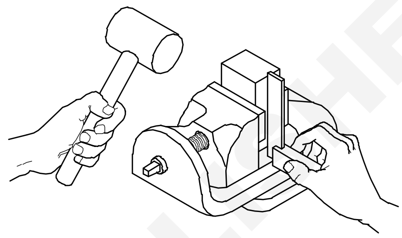


– set work pieces at right angles on work-holding devices. (Fig 5)

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.

Fig 5



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

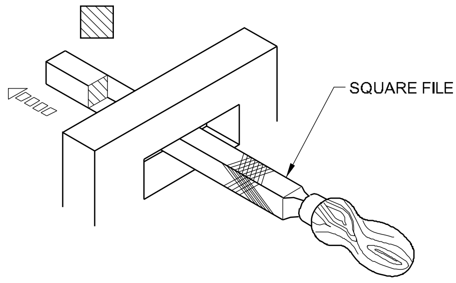
Half round file, Triangular file and Knife-edge file.

(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)

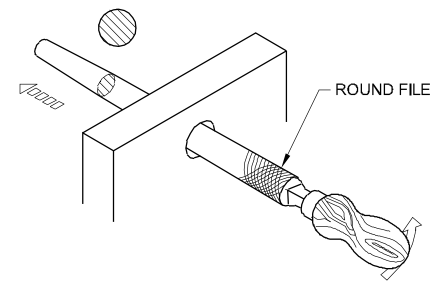
Fig 1



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)

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)

Fig 3

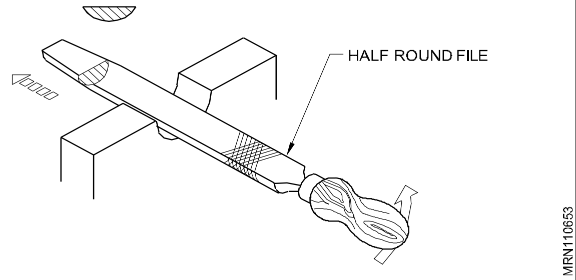
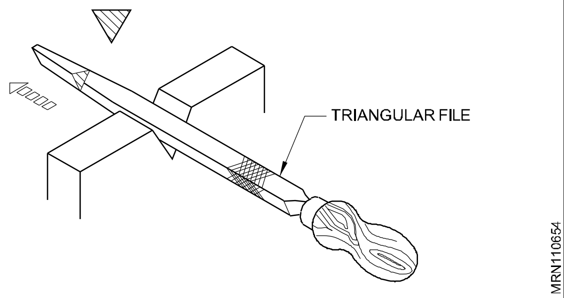


Fig 4



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)

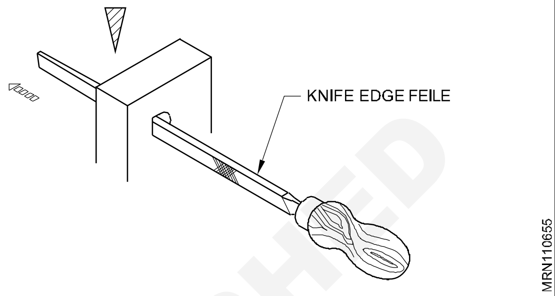
Knife-edge file

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.

Fig 5



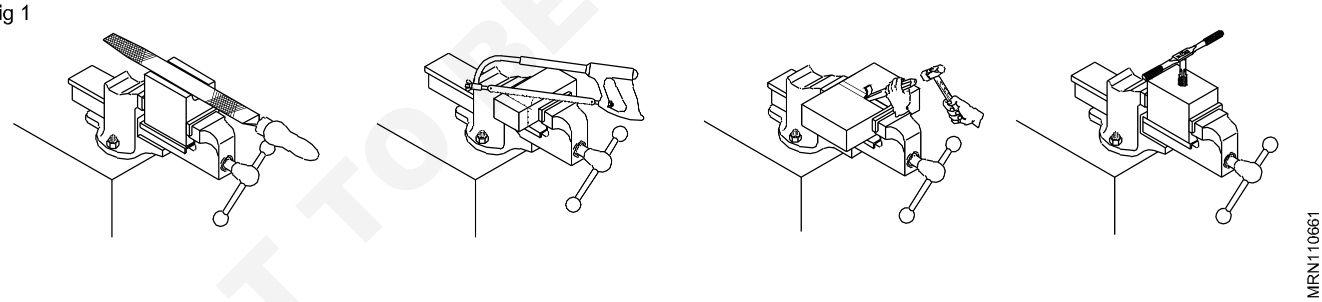
Bench vice

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.

Fig 1



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.

Fig 2

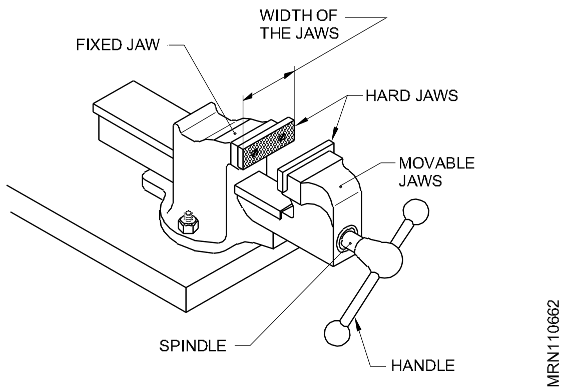
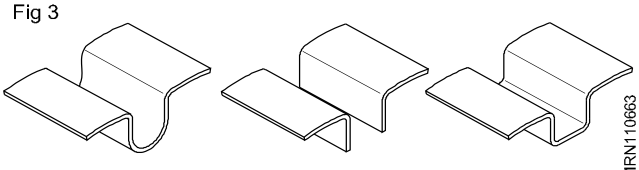


Fig 3



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 1

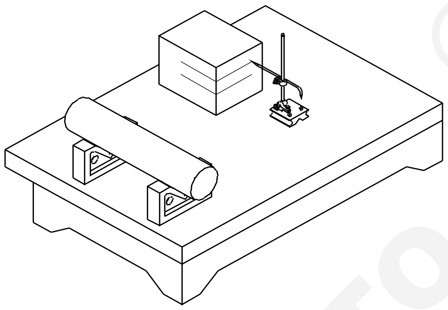
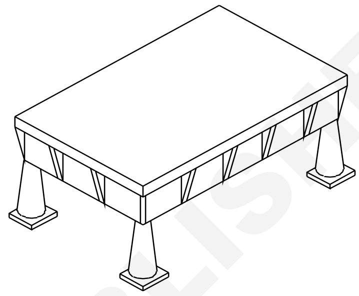


Fig 2



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

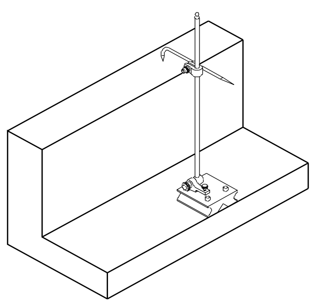
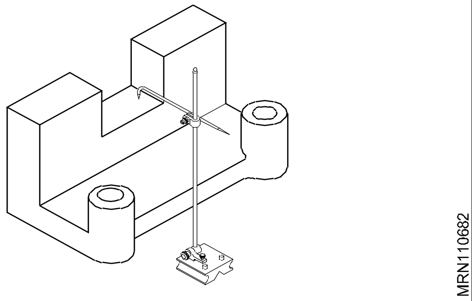
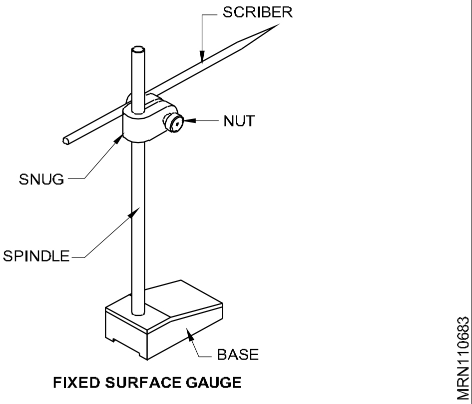


Fig 2



– Fixed (Fig 3)

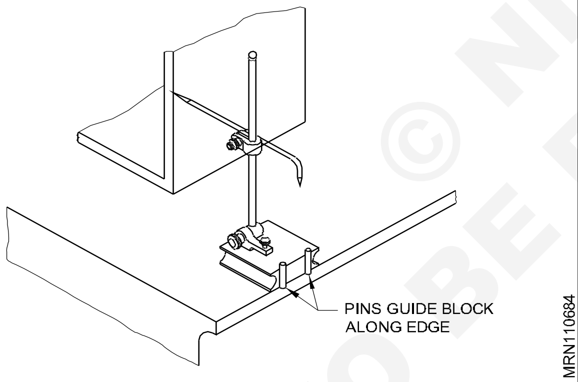
Fig 3



FIXED SURFACE GAUGE

– Universal (Fig 4)

Fig 4



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

Universal surface gauge: This has the following additional features.

– The spindle can be set to any position.

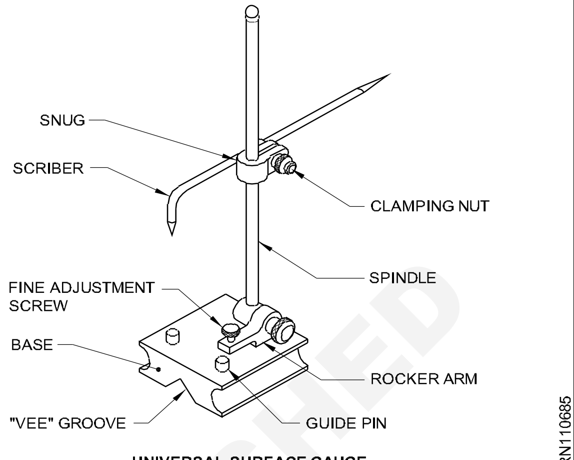
– Fine adjustments can be made quickly.

– Can also be used on cylindrical surfaces.

– 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



UNIVERSAL SURFACE GAUGE

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:

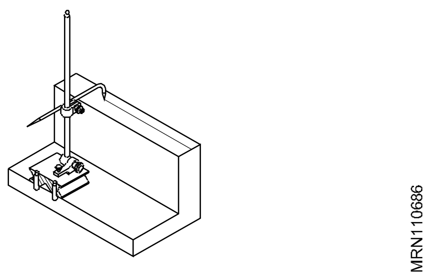
The spindle is attached to the rocker arm.

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



Angle plate

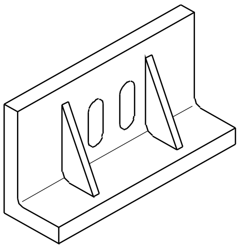
Objectives: At the end of this lesson you shall be able to
- **state the features and functions of angle plates**
- **name the types of angle plates**
- **state the uses of angle plates.**

Angle Plate (Fig 1)

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

An angle plate is made of cast iron or steel and is machined accurately to an angle of 90^0.

Fig 1



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

Fig 2

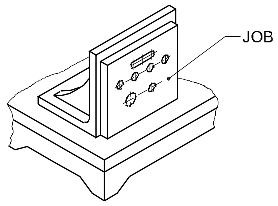
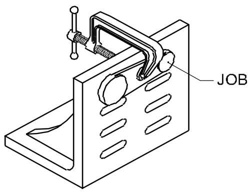
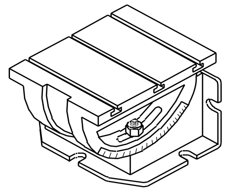


Fig 3



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

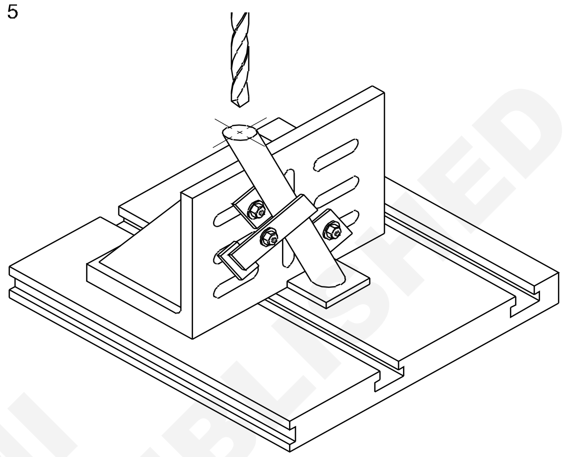
Fig 4



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



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

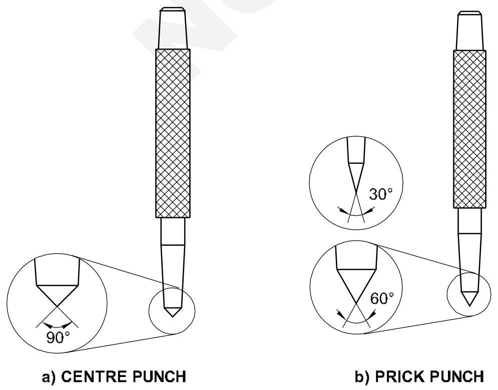
Types of marking punches

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.

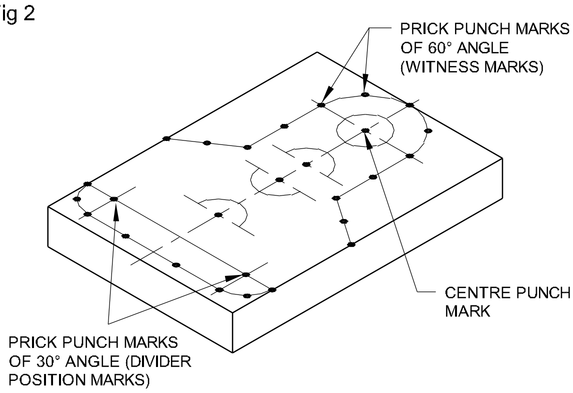
Centre punch: The angle of the point is 90°. The punch mark made by this is wide and not very deep. This punch is used for locating holes. The wide punch mark gives a good seating for starting the drill. (Figs 1a & b)

Fig 1



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 2



Drilling & grinding 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.**

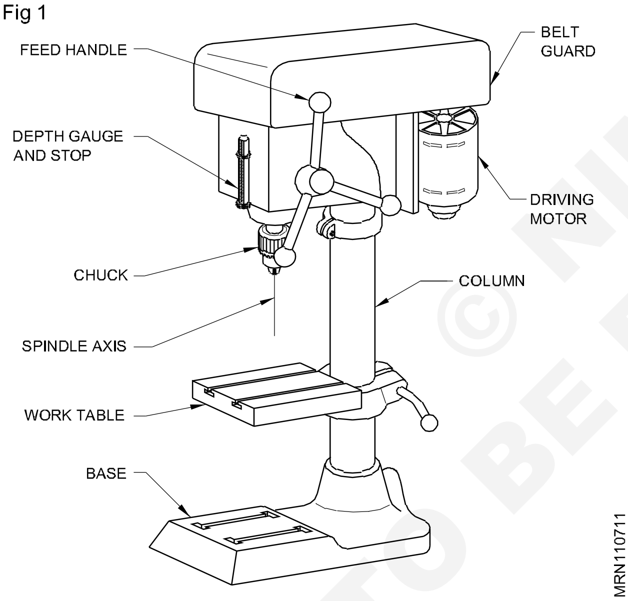
The principal types of drilling machines are the sensitive bench drilling machine the pillar drilling machine the column drilling machine and the radial arm drilling machine. (Radial Drilling Machine).

(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)

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

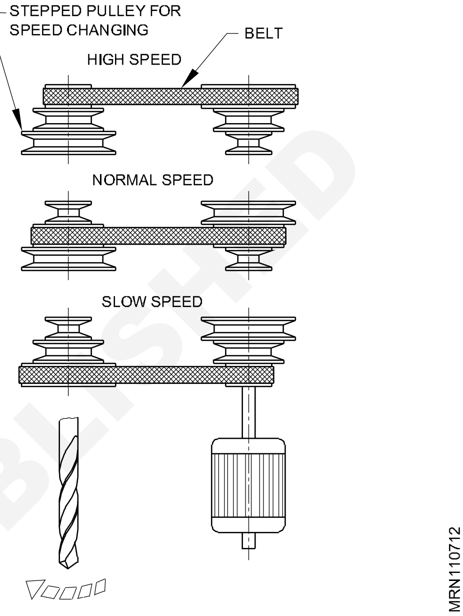
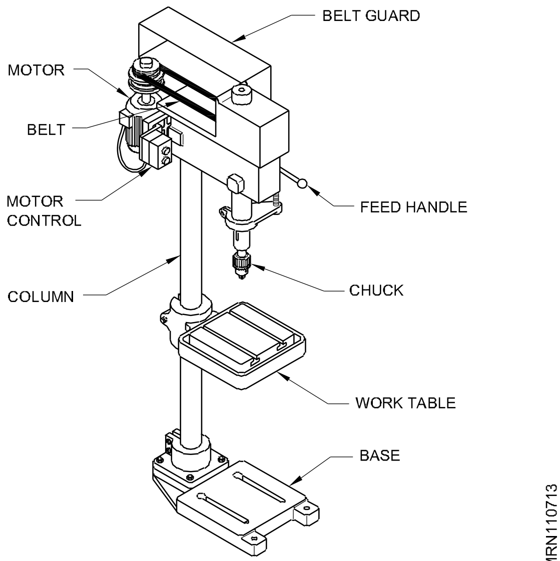


Fig 3



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)

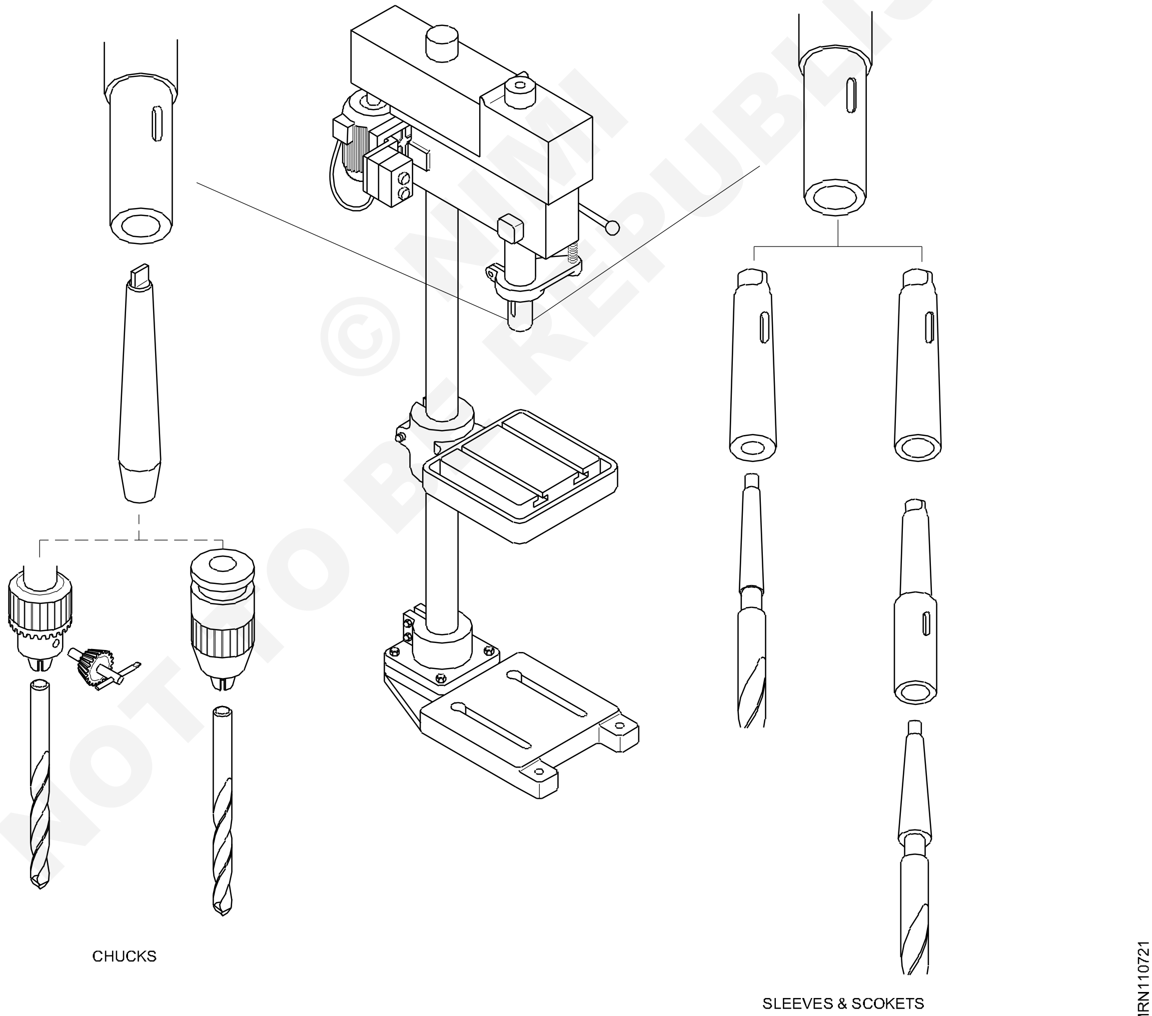
Taper shank drills have a morse taper. Sleeves and sockets are made with the same taper so that the taper shank of the drill, when engaged, will give a good wedging action. Due to this reason morse tapers are called self-holding tapers.

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)

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)

Fig 2

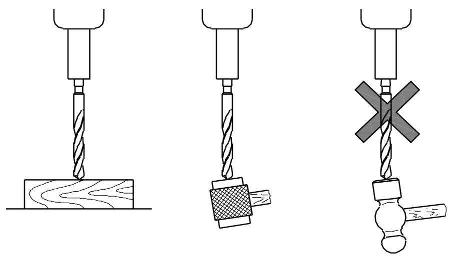


Fig 3

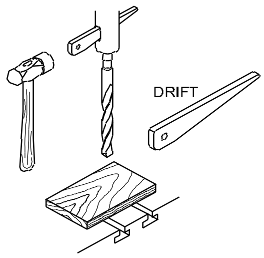
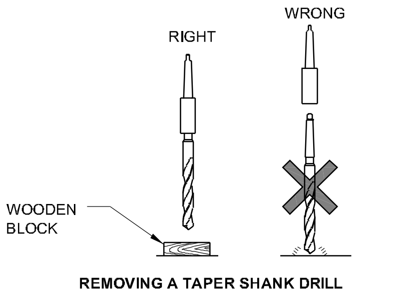


Fig 4



Work-holding devices

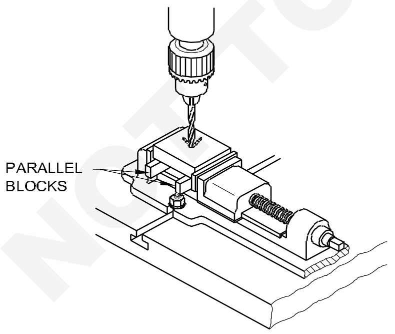
Objectives: At the end of this lesson you shall be able to
- **state the purpose of work-holding devices**
- **name the devices used for holding work**
- **state the precautions to be observed while using work-holding devices.**

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)

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)

Fig 2

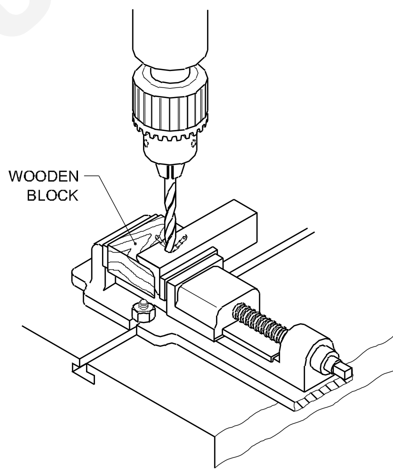
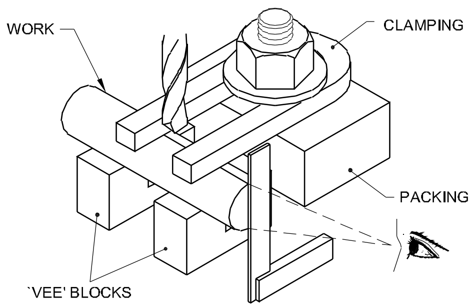


Fig 3



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

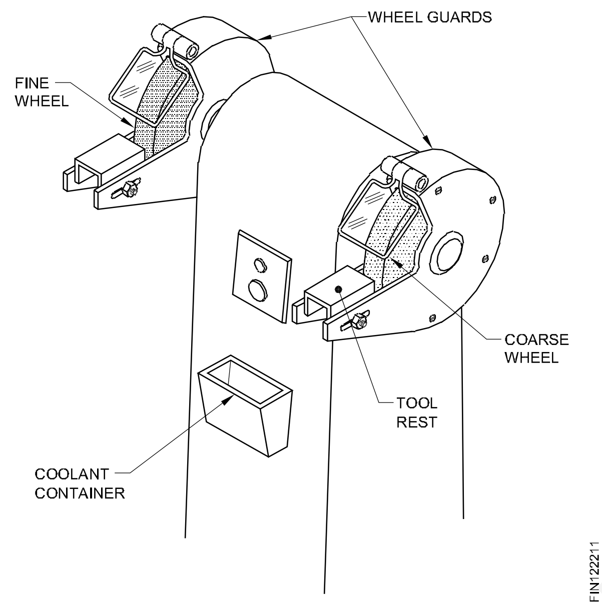
Sharpening of chisels

Objective: At the end of this lesson you shall be able to
- **state the procedure for resharpening the cold chisels on pedestal grinding machines.**

Chisels will become blunt due to use. For efficiency in chipping. the chisels are to be re-sharpened regularly.

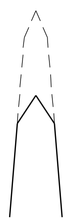
Chisels are sharpened on grinding machines. (Fig 1)

Fig 1



After re-grinding many times, the cutting edges become too thick. Such chisels are unsuitable for resharpening. They should be forged and brought to shape before grinding. (Fig 2)

Fig 2



Before commencing grinding, the following procedure should be observed.

Ensure the wheel guards are in place, and are securely fastened.

Inspect the condition of the grinding wheel for breakage and cracks.

Wear safety goggles.

When switching on the grinding machine, stand aside untill the wheel reaches the operating speed.

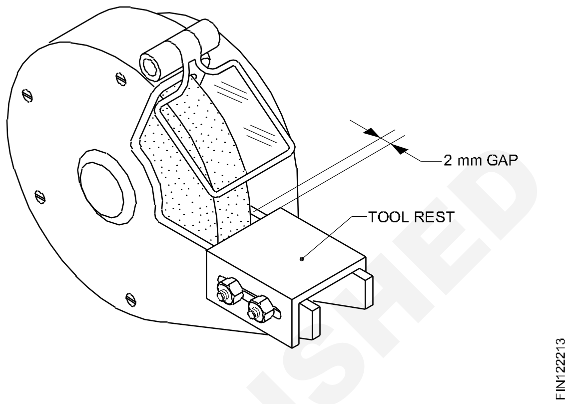
Inspect the tool rest

If there is too much of gap between the tool-rest and the wheel, adjust it, and position it as close to the wheel as possible. (Fig 3)

Ensure that there is sufficient coolant in the container.

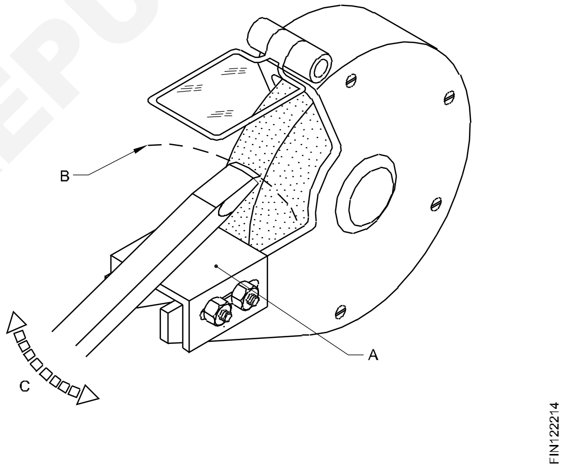
While grinding, rest the body of the chisel on the tool-rest (A) and allow the point to touch the wheel. (Fig 4)

Fig 3



Rock the point slightly on both sides in an arc (B) to provide a slight convexity at the cutting edge. This will help to avoid digging in the sides while chipping. (Fig 4)

Fig 4



Keep moving the chisel across the face (C) of to Prevent formation of curves and grooves at the cutting edge.

Dip the chisel frequently in the coolant to avoid overheating. Overheating will draw the temper of the chisel.

If the chisel-head is mushroomed, it should be cleaned by grinding. (Fig 5)

Use only the front of the grinding wheel. (Fig 4) Do not grind on the sides. (Fig 6)

Use goggles while using a grinder

Any damage to the grinding wheel, if noticed should be reported to the instructor.

Do not use cotton waste or other material for holding the chisel while grinding.

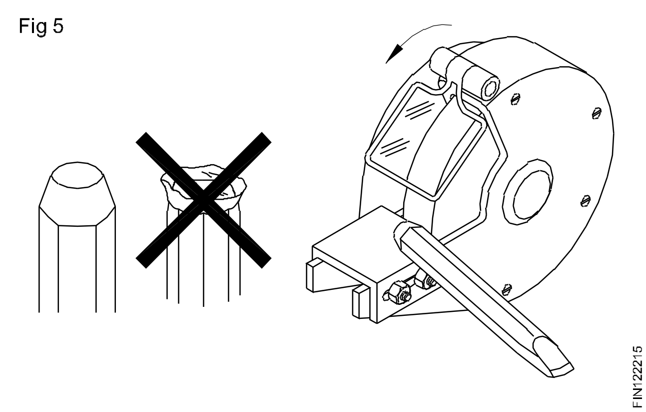


Fig 5

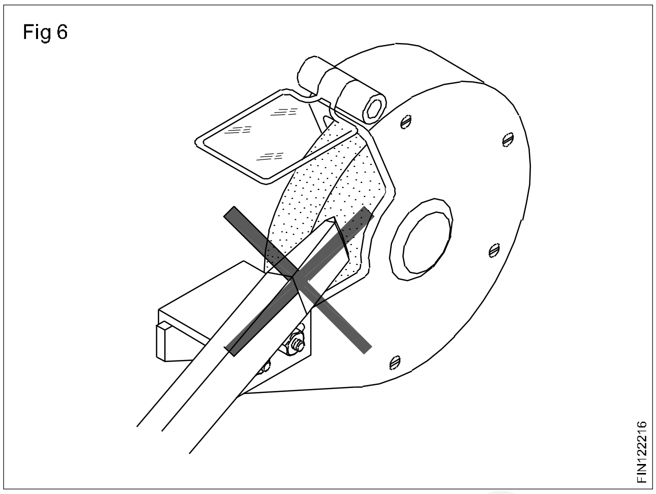


Fig 6

Identification of tools & equipment in sheet metal trade

Objectives: At the end of this lesson you shall be able to
- **identify marking tools used in sheet metal**
- **use measuring tools in sheet metal**
- **list out production tools used in sheet metal trade**
- **identify machinery used in sheet metal trade.**

The Instructor will explain major marking tools, measuring tools, production tools used in sheet metal trade.

In sheet metal there are some tools used for marking some used for marking & measuring, some tools used for production purposes like hammers, shear, swage etc. Identify from the given figures which category they belong, its name and specific use in table 1.

Fig 1

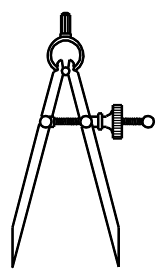


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Fig 2

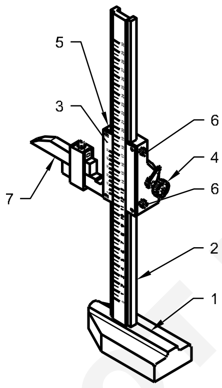

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Fig 3

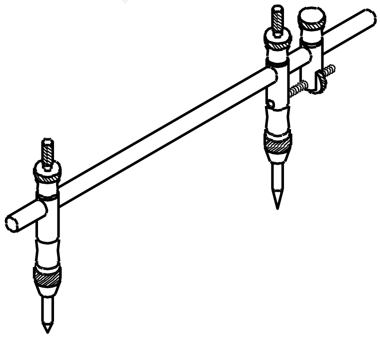

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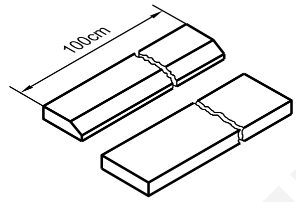
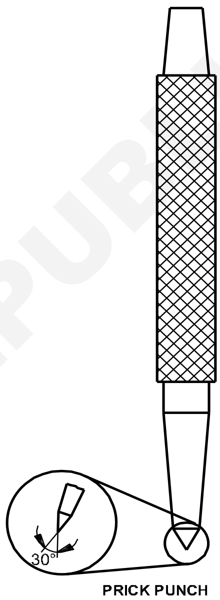
Fig 4



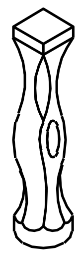
SM1102D4

Fig 5



SM1102D5

Fig 6



SM1102D6

Fig 7

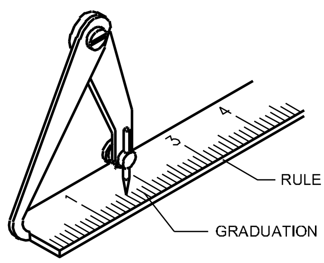


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Fig 8

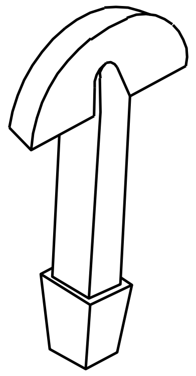


Fig 8

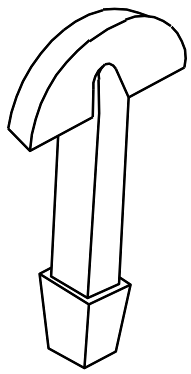


Fig 9

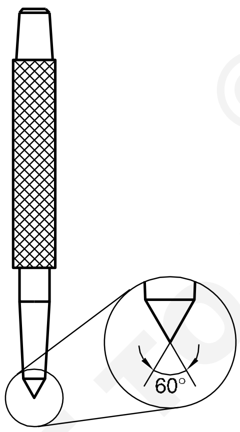


Fig 10

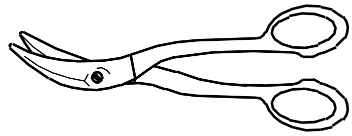
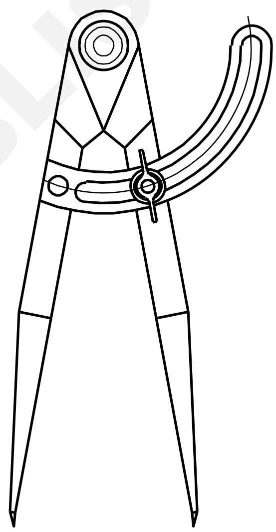


Fig 11

Fig 12



Sheet metal and 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 enameled.

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.

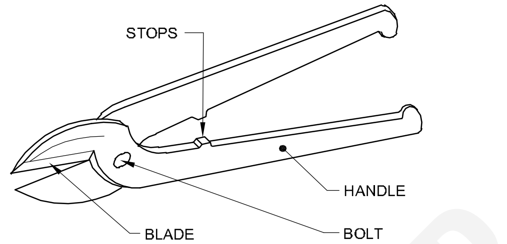
There are two types of snips.

– Straight snips

– Bent snips

Parts of a straight snip (Fig 1)

Fig 1



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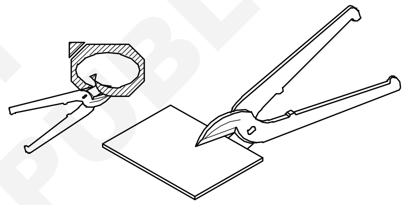
– Handle (1)

– 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)

Fig 2



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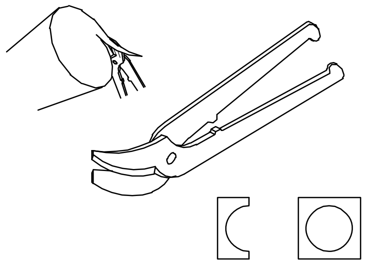
Bent snip: Bent snips have curved blades used for cutting internal curves. For trimming a cylinder keep the lower blade on the outside of cut. (Fig 3)

Fig 3



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Sheet metal seams and folding tools

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

• **state the types of seams.**

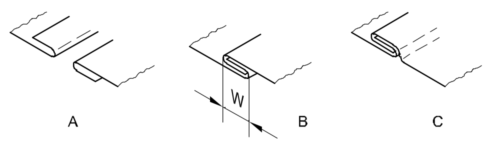
Introduction

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.

Fig 1



STEPS IN FORMING A GROOVED SEAM.

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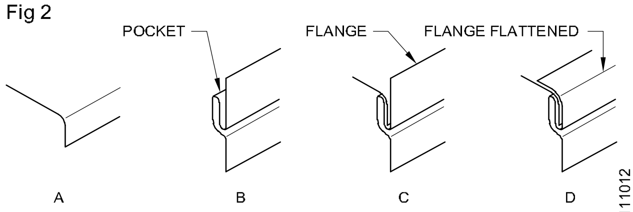
2 **Pittsburgh seam:** This seam is also called hammer lock or hobo lock. This seam is used as a longitudinal corner seam for various types of pipes such as duct work. The single lock is placed in a pocket lock and then the flange is hammered over, step by step as shown in Fig 2.

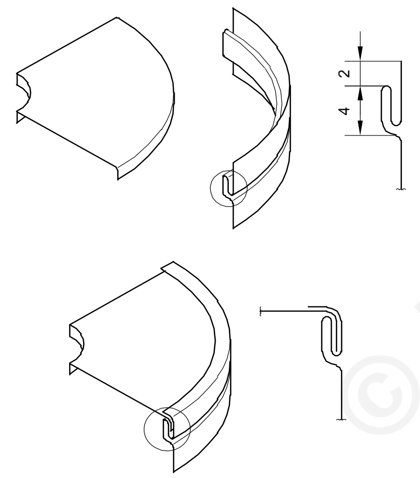
Fig 2



STEPS IN FORMING THE PITTSBURGH SEAM.

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.

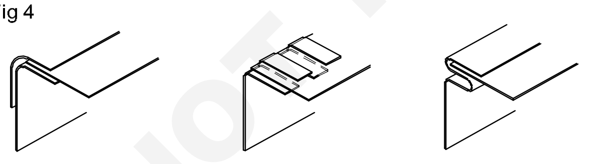
Fig 3



PITTSBURGH SEAMS CAN BE FORMED ON CURVES.

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.

Fig 4

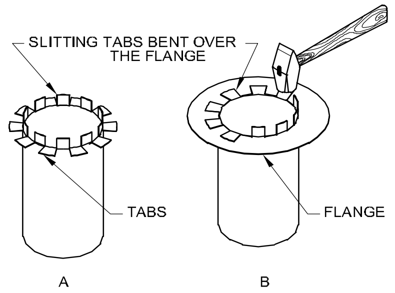


Dovetail seams are used mainly on round or elliptical pipe and rarely on rectangular ducts.

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

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

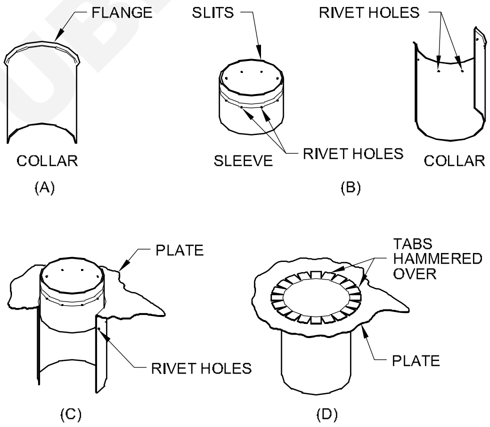


PLAIN DOVETAIL SEAM.

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.

Fig 6



STEPS IN FORMING A FLANGE DOVETAIL SEAM.

C Beaded dovetail seam

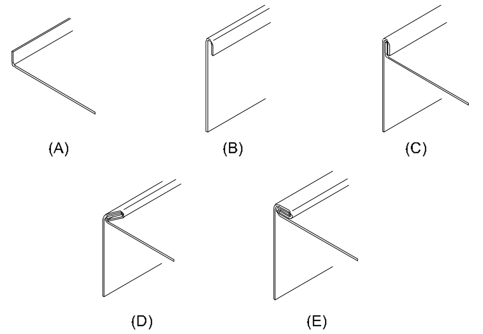
This is similar to the plain dovetail seam, except a bead is formed around one end of the cylinder by a beading machine. This bead acts as the stop for the flange to rest upon and the tabs are bent over to hold the flange in the desired place.

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.

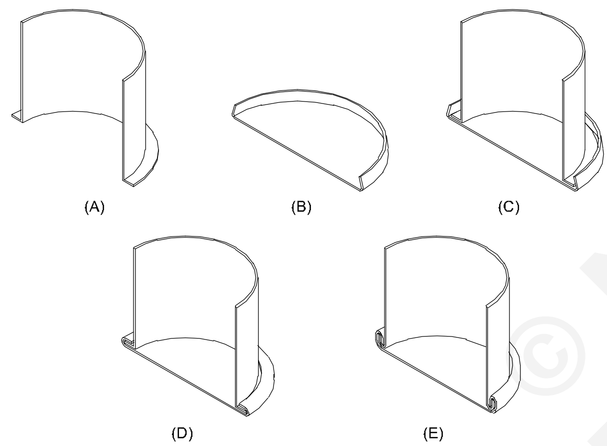
Fig 7



MAKING A DOUBLE SEAM.

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.

Fig 8



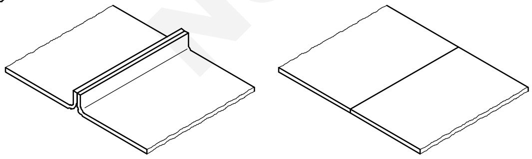
STEPS IN MAKING A BOTTOM DOUBLE SEAM.

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.

Fig 9

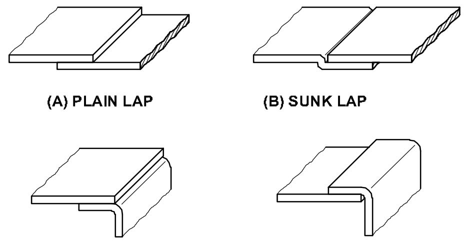


(A) FLANGE-BUTT SEAM (B) BUTT

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.

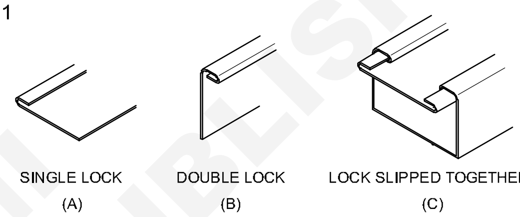
Fig 10



7 Slip joint seam

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

Fig 11

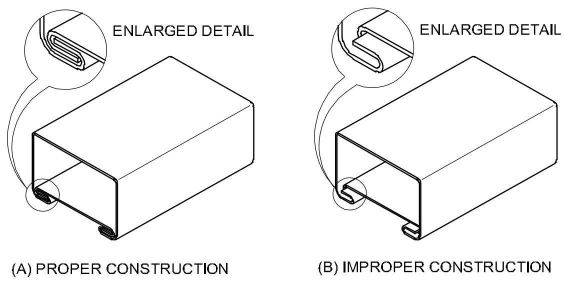


SLIP JOINT SEAM.

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.

Fig 12



PROPER AND IMPROPER JOINING OF SLIP JOINT SEAMS.

Locked grooved joint (Seam)

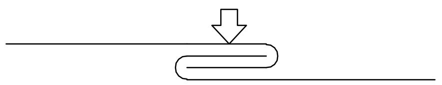
Objectives: At the end of this lesson you shall be able to
- **state the purpose of a joint**
- **state the use of the groover**
- **determine the allowance for the locked grooved joint**
- **know the type of shears**
- **know the uses of shears**
- **know about the shearing force**
- **know the blade 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).

Fig 1



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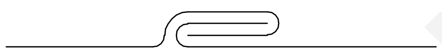
When the grooved joint is clinched down, making one side plane using a groover is called a "Locked grooved joint". (Fig 2)

Fig 2



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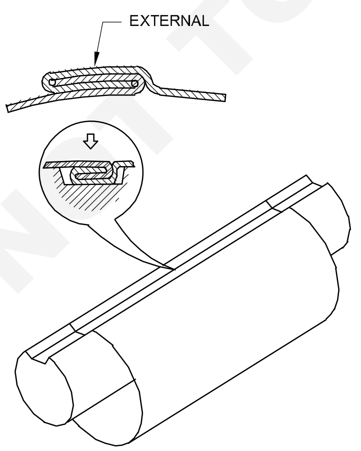
External and internal locked grooved joints: This joint is used to join the two ends of a sheet metal to form a circular shape in longitudinal direction. When the seam is formed outside as shown in Fig 3 then it is called 'external locked grooved joint'.

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

Fig 3



INTERNAL GROOVE

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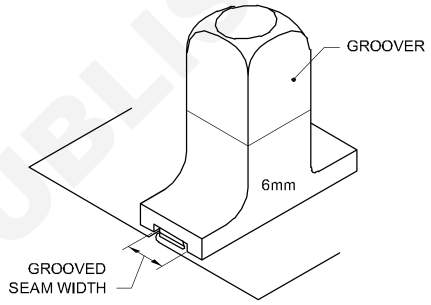
Hand groover: The hand groover is made up of cast steel and is used to make external locked grooved joint.

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.

Fig 4



SIZE OF GROOVE & SEAM

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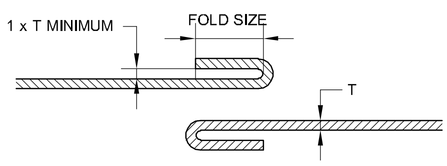
Locked grooved joint allowance: To arrive the size (width) of the fold to suit a particular groover, subtract the thickness by 3 times from the width of the groove. (Fig 5)

Fig 5



EDGE FOLDS

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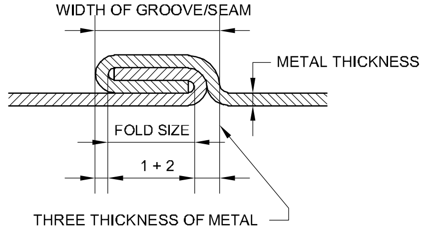
For example, the width of the groover is 6 mm and the sheet thickness is 0.5 mm,

Then the width of the fold

= 6 - (3 x 0.5)

= 4.5 mm (See Fig 6).

Fig 6



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Stake Joint

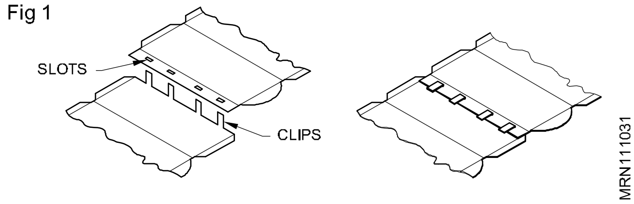
Objectives: At the end of this lesson you shall be able to
- **state the applications of stake joint**
- **state the types of stake joints.**

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)

Fig 1



Type of stake joint

A Straight stake joint B Zigzag stake joint

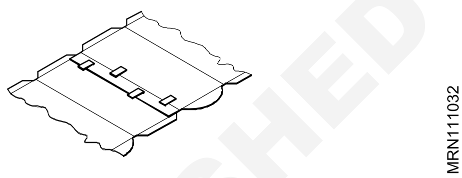
Straight stake joint

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)

Fig 2



Folding tools

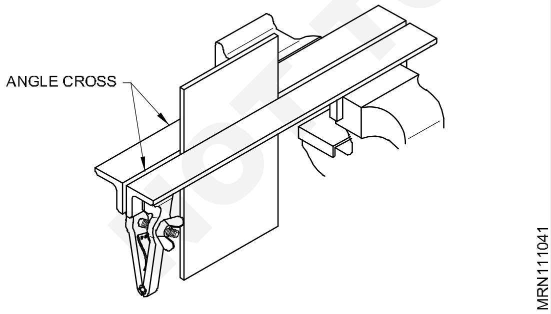
Objectives: At the end of this lesson you shall be able to
- **state the uses of different folding tools.**

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 90^0. For longer sheets lengthy angles will be used along clamp (or) hand vice. (Fig 1)

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

Fig 2

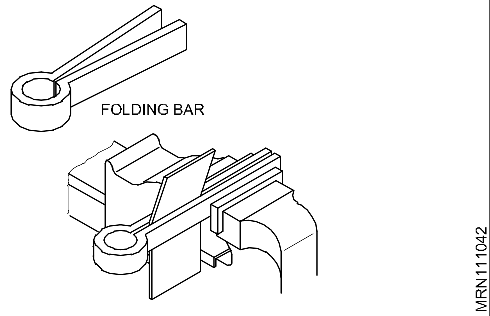
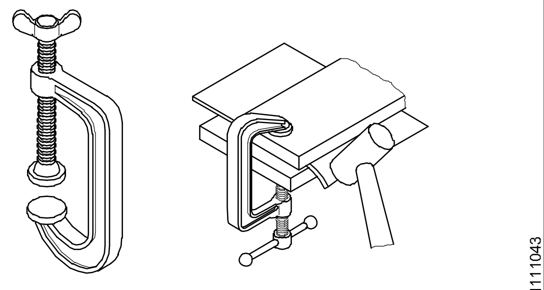


Fig 3



'C' CLAMP / 'G' CRAMP

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

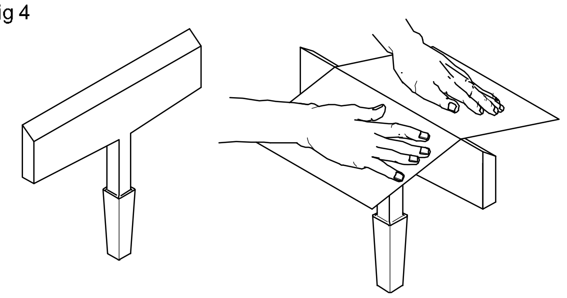
– Square stake

– 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)

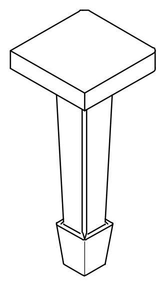
Fig 4



HATCHET STAKE

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

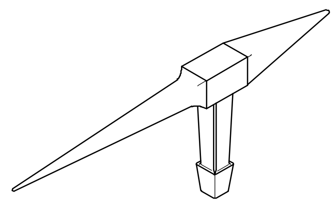
Fig 5



SQUARE STAKE

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)

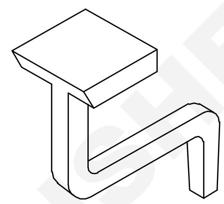
Fig 6



BLOW HORN STAKE

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

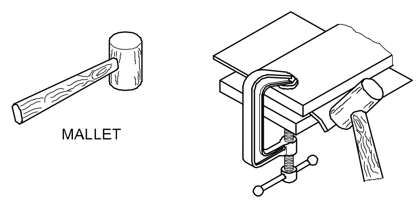
Fig 7



BEVEL-EDGED SQUARE STAKE

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 8

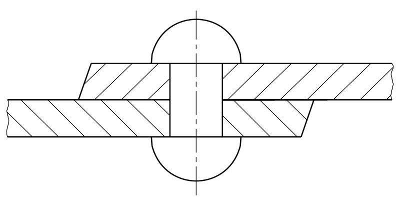


Securing metal sheets by riveting

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)

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:

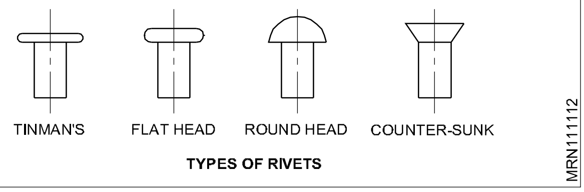
– tinmen's rivet

– flat head rivet

– round head rivet

– countersunk head rivet.

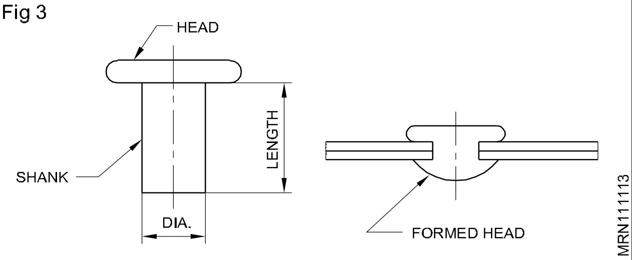
Fig 2



TYPES OF RIVETS

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

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

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

The shank length is given by

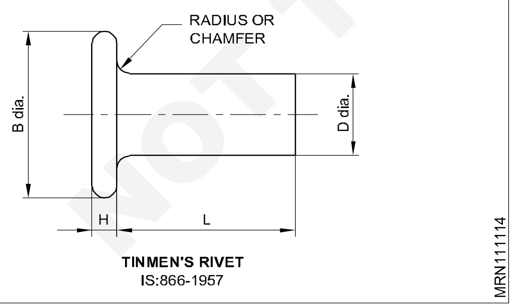
$$L = T + T + \left(\frac{11}{2}D\right)$$

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)

Fig 4



TINMEN'S RIVET
IS:866-1957

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

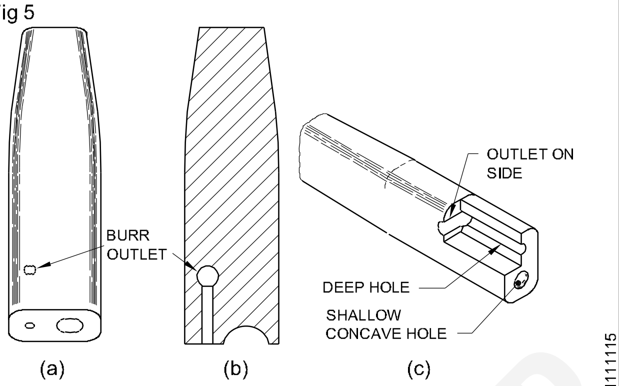
While riveting by hand, it can be done with a hammer and a rivet set.

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.

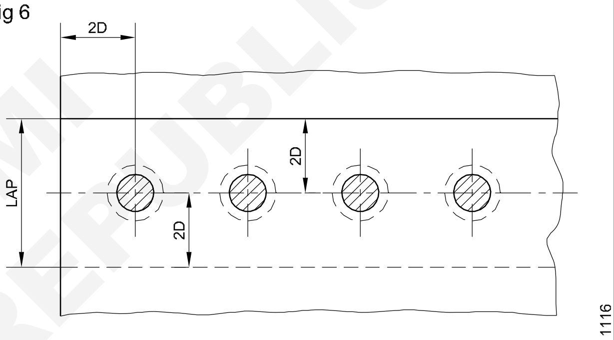
Fig 5



SECTION OF A 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.

Fig 6

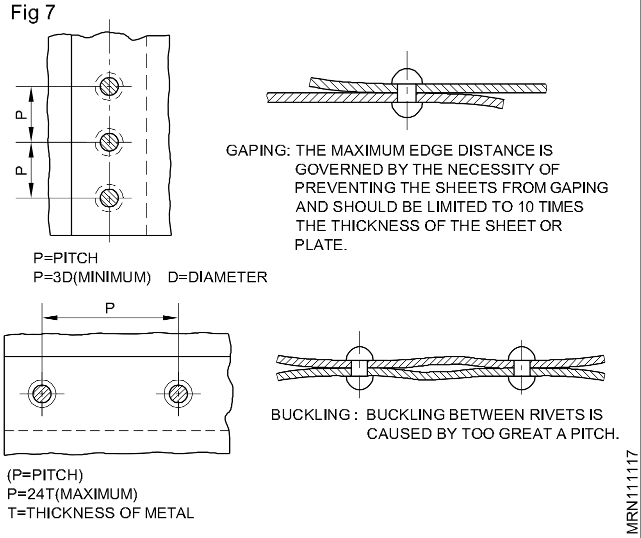


EDGE DISTANCE = TWICE THE DIAMETER OF RIVET (MINIMUM)
MINIMUM LAP = FOUR TIMES DIAMETER OF RIVET

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.

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 liquefied metal (solder).

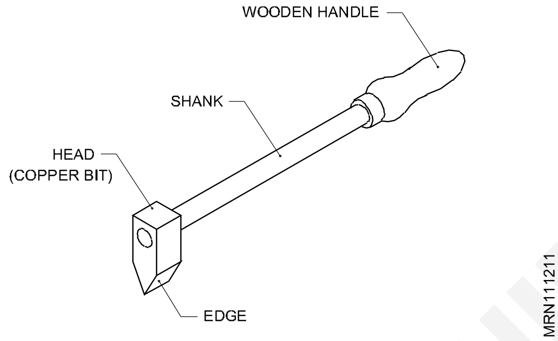
The melting point of the solder is lower than that of the materials being joined.

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.

Fig 1



A soldering iron has the following parts.

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

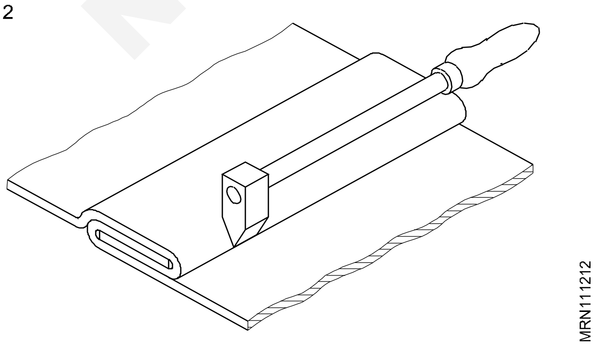
Shape of head

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)

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)

Fig 3

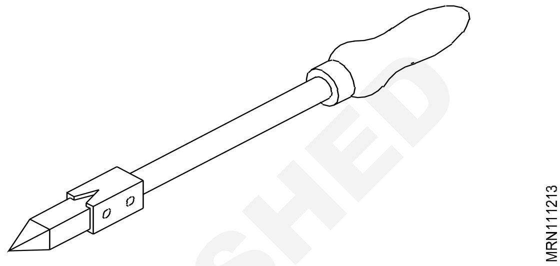


Fig 3a

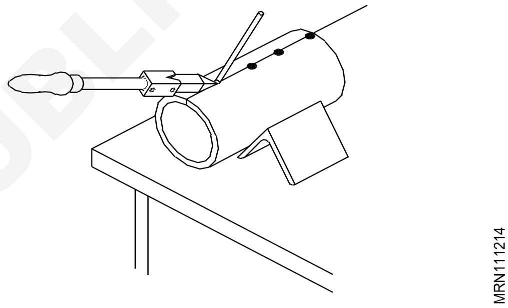
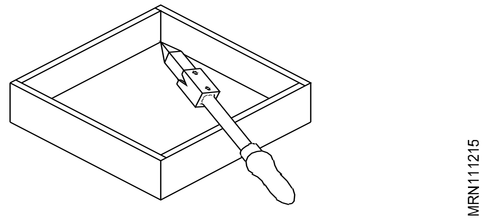


Fig 3b

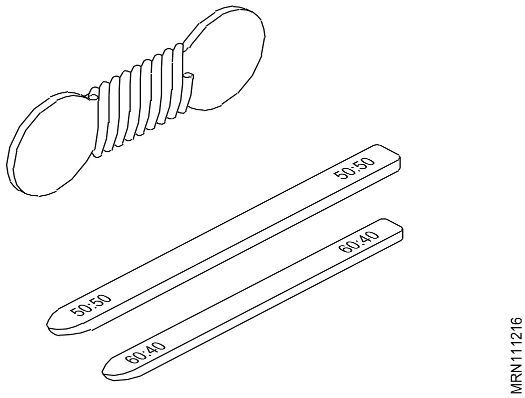


Solders

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, antinomy, 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.

Fundamental of electricity - conductors - insulators - wire size measurement - crimping

Objectives: At the end of this lesson you shall be able to
- **define electricity and atom**
- **explain about the atomic structure**
- **define the fundamental terms and definition of electricity**
- **state the type of supply, polarity and the effects of electric current**
- **state the conductors, insulators, wires - size measurement methods**

Introduction

Electricity is one of the today's most useful sources of energy. Electricity is of utmost necessity in the modern world of sophisticated equipment and machinery.

Electricity in motion is called electric current. Whereas the electricity that does not move is called static electricity.

Examples of static electricity

- Shock received from door knobs of a carpeted room.
- Attraction of tiny paper bits to the comb.

Structure of matter

Electricity is related to some of the most basic building blocks of matter that are atoms (electrons and protons). All matter is made of these electrical building blocks, and, therefore, all matter is said to be 'electrical'.

Atom

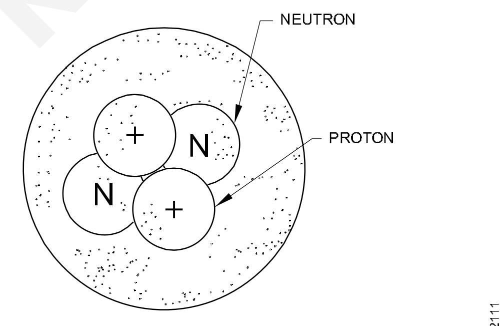
Matter is defined as anything that has mass and occupies space. A matter is made of tiny, invisible particles called molecules. A molecule is the smallest particle of a substance that has the properties of the substance. Each molecule can be divided into simpler parts by chemical means. The simplest parts of a molecule are called atoms.

Basically, an atom contains three types of sub-atomic particles that are of relevance to electricity. They are the electrons, protons and neutrons. The protons and neutrons are located in the centre, or nucleus, of the atom, and the electrons travel around the nucleus in orbits.

Atomic structure

The Nucleus

Fig 1



NUCLEUS OF AN ATOM

The nucleus is the central part of the atom. It contains the protons and neutrons in equal numbers shown in Fig 1.

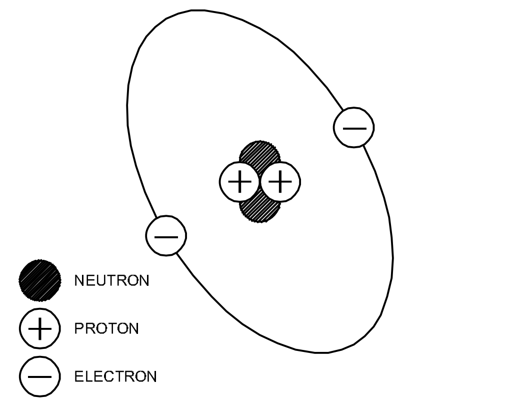
Protons

The proton has a positive electrical charge. (Fig 1) It is almost 1840 times heavier than the electron and it is the permanent part of the nucleus; protons do not take an active part in the flow or transfer of electrical energy.

Electron

It is a small particle revolving round the nucleus of an atom (as shown in Fig 2). It has a negative electric charge. The electron is three times larger in diameter than the proton. In an atom the number of protons is equal to the number of electrons.

Fig 2



REVOLVING OF ELECTRON

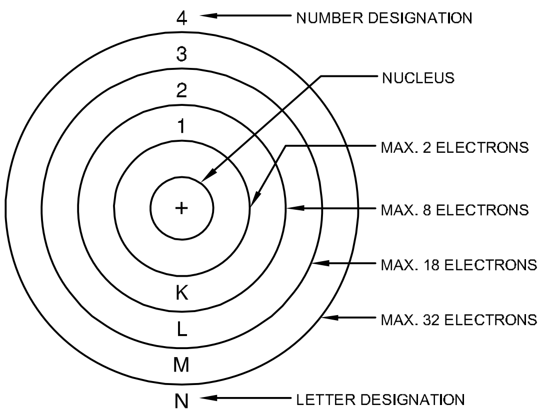
Neutron

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

Energy shells

In an atom, electrons are arranged in shells around the nucleus. A shell is an orbiting layer or energy level of one or more electrons. The major shell layers are identified by numbers or by letters starting with 'K' nearest the nucleus and continuing alphabetically outwards. There is a maximum number of electrons that can be contained in each shell. Fig 3 illustrates the relationship between the energy shell level and the maximum number of electrons it can contain.

Fig 3

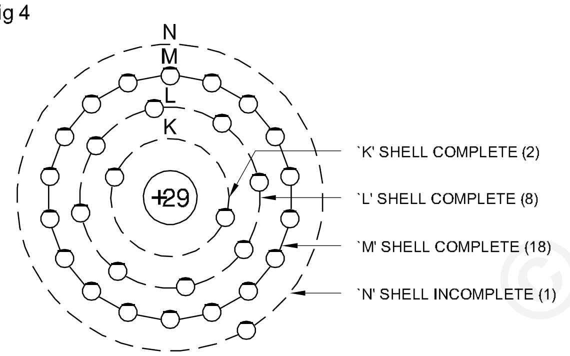


SHELL LEVEL AND ELECTRONS

ELN132113

If the total number of electrons for a given atom is known, the placement of electrons in each shell can be easily determined. Each shell layer, beginning with the first, is filled with the maximum number of electrons in sequence. For example, a copper atom which has 29 electrons would have four shells with a number of electrons in each shell as shown in Fig 4.

Fig 4

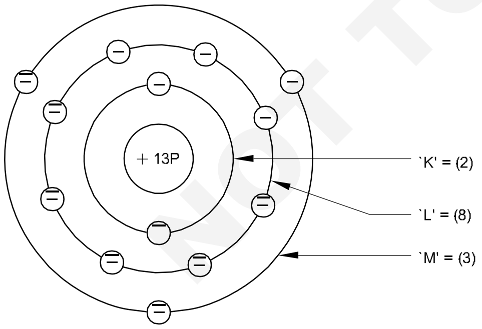


COPPER ATOM

ELN132114

Similarly an aluminium atom which has 13 electrons has 3 shells as shown in Fig 5.

Fig 5



ALUMINIUM ATOM

ELN132115

Electron distribution

The chemical and electrical behaviour of atoms depends on how completely the various shells and sub-shells are filled.

Atoms that are chemically active have one electron more or one less than a completely filled shell. Atoms that have the outer shell exactly filled are chemically inactive. They are called inert elements. All inert elements are gases and do not combine chemically with other elements.

Metals possess the following characteristics.

- They are good electric conductors.
- Electrons in the outer shell and sub-shells can move more easily from one atom to another.
- They carry charge through the material.

The outer shell of the atom is called the valence shell and its electrons are called valence electrons. Because of their greater distance from the nucleus, and because of the partial blocking of the electric field by electrons in the inner shells, the attracting force exerted by nucleus on the valence electrons is less. Therefore, valence electrons can be set free most easily. Whenever a valence electron is removed from its orbit it becomes a free electron. Electricity is commonly defined as the flow of these free electrons through a conductor. Though electrons flow from negative terminal to positive terminal, the conventional current flow is assumed as from positive to negative.

Conductors, insulators and semiconductors

Conductors

A conductor is a material that has many valance electrons permitting electrons to move through it easily. Generally, conductors have many valence shells of one, two or three electrons. Most metals are conductors.

Some common good conductors are Copper, Aluminium, Zinc, Lead, Tin, Eureka, Nichrome, are conductors, where as silver and gold are very good conductors

Insulators

An insulator is a material that has few, if any, free electrons and resists the flow of electrons. Generally, insulators have full valence shells of five, six or seven electrons. Some common insulators are air, glass, rubber, plastic, paper, porcelain, PVC, fibre, mica etc.

Semiconductors

A semiconductor is a material that has some of the characteristics of both the conductor and insulator. Semiconductors have valence shells containing four electrons.

Common examples of pure semiconductor materials are silicon and germanium. Specially treated semiconductors are used to produce modern electronic components such as diodes, transistors and integrated circuit chips.

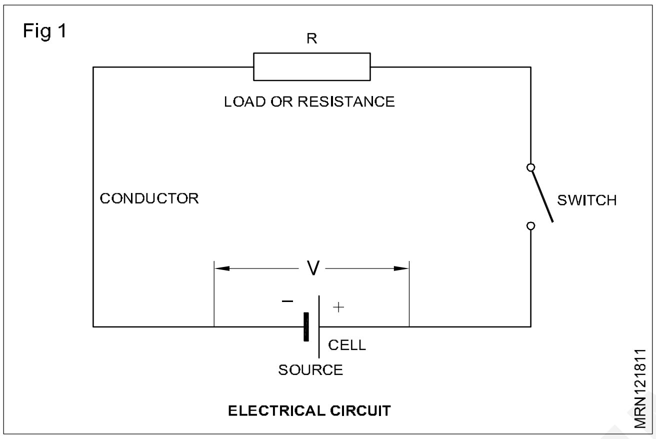
Simple electrical circuit and its elements

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.

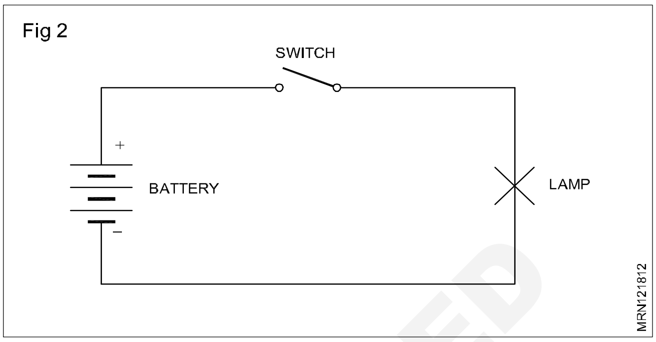
In addition to the above, the circuit may have insulators (PVC or rubber) to confine the current to the desired path, and a protection device (fuse) to interrupt the circuit in case of malfunction of the circuit (excess current).

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 x 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 kilo-ampere = 1 kA = 1000 A = 1 x 10^3A

1 milli-ampere = 1 mA = 1/1000 A = 1 x 10^{-3}A

1 micro-ampere = 1 μA = 1/1000000 A = 1 x 10^{-6}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 filed 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. 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.

Fig 3

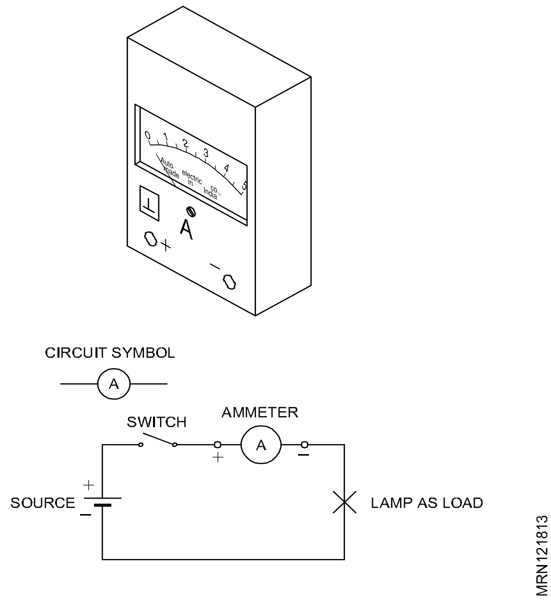
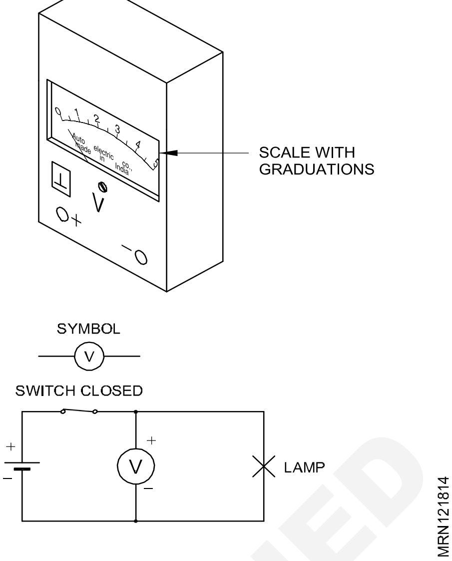


Fig 4



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.

For the decimal or decimal sub-multiples of the volt, we use the following expressions.

1 kilo-volt = 1 kV = 1000 V
= 1×10^{3}V

1 milli-volt = 1 mV = 1/1000 V
= 1×10^{-3}V

1 micro-volt = 1 μV = 1/1000000 V = 1×10^{-6}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 W).

For the decimal multiples or decimal sub-multiples of the ohm we use the following expressions:

1 megohm = 1 MW = 1000000W = 1×10^{6}W

1 kilo-ohm = 1 kW = 1000W = 1×10^{3}W

1 milli-ohm = 1 mW = 1/1000W = 1×10^{-3}W

1 micro-ohm = 1 μW = 1/1000000W = 1×10^{-6}W

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)

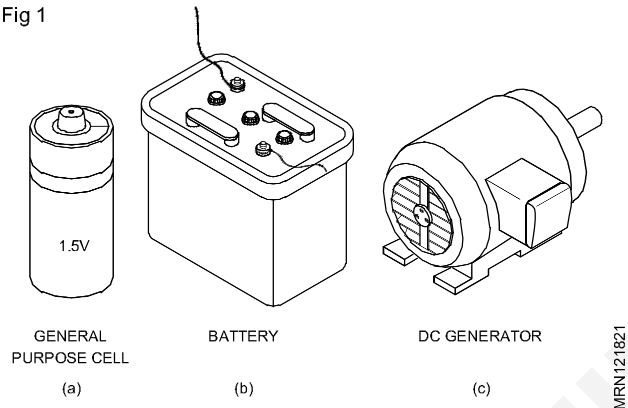
There are two types of electrical supply in use for various technical requirements. The alternating current supply (AC) and the direct current supply (DC).

- DC is represented by this symbol.
- AC is represented by this symbol.

DC Supply

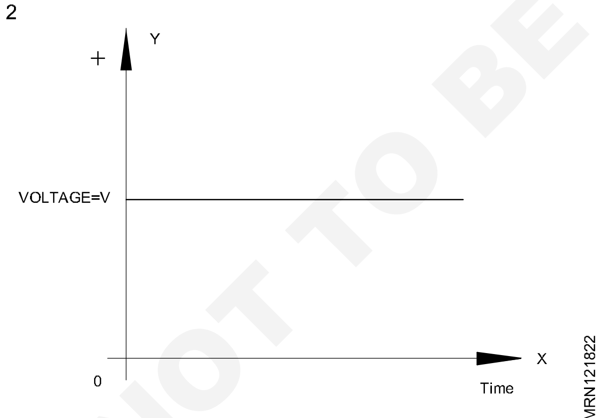
The most common sources of DC supply are the cells/ batteries (Figs 1a and 1b) and DC generators (dynamos). (Fig 1C)

Fig 1



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)

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).

Fig 3

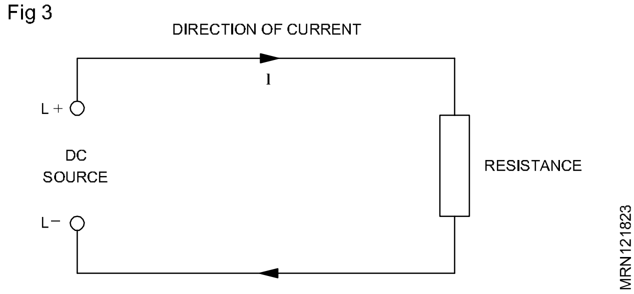


Fig 4

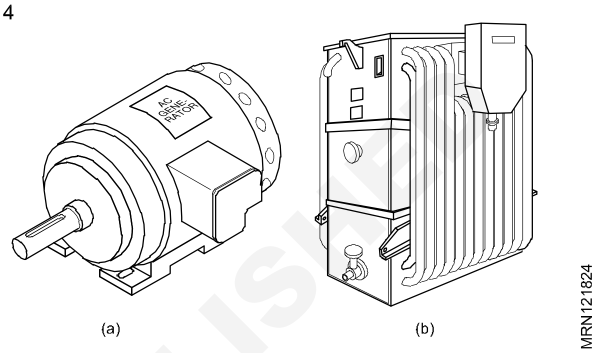
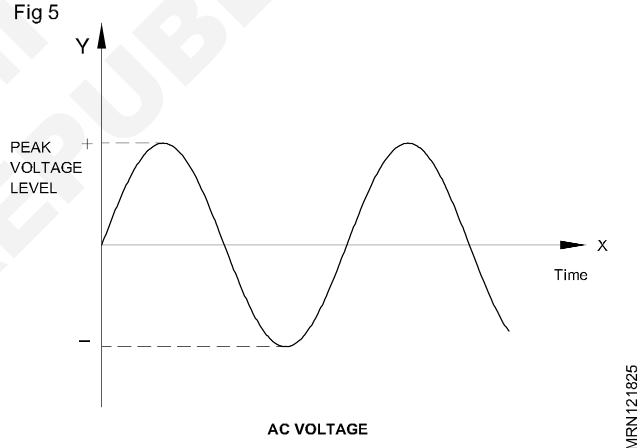


Fig 5



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.

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.

Fig 1

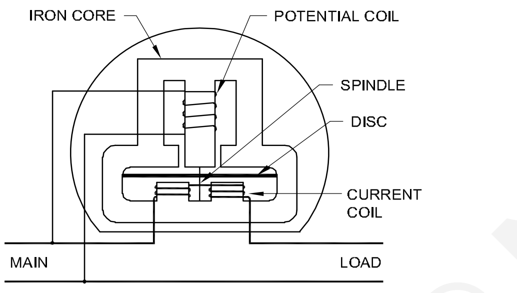


DIAGRAM OF AN INDUCTION TYPE WATT-HOUR METER

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.

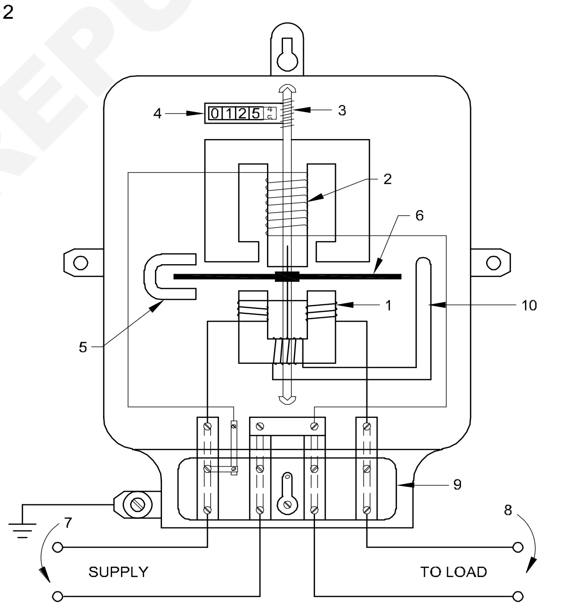
Functioning of energy meter

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.

Fig 2



1 CURRENT COIL
2 VOLTAGE COIL
3 WORM GEAR
4 RECORDING MECHANISM
5 PERMANENT MAGNET
6 ALUMINIUM DISC
7 SUPPLY TERMINALS
8 LOAD TERMINALS
9 TERMINAL BLOCK
10 SHADING COIL

Meter constant

It is the number of revolutions the disc makes for one kWh of energy consumed.

Number of revolutions per kWh = 3600 x 1000 watt sec.

$$\text{One rev.} = \frac{3600 \times 1000}{\text{Meter constant}}.$$

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

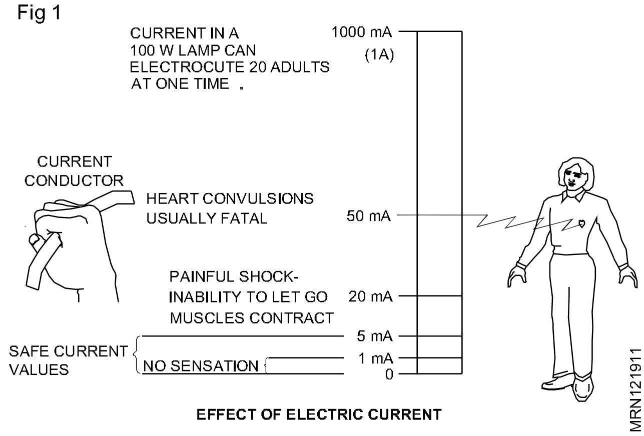
A system of earthing in which the parts of an installation specified to be earthed are connected to the general mass of earth, and in addition, are connected within the installation to the neutral conductor of the supply system.

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.

Fig 1



EFFECT OF ELECTRIC CURRENT

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.

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)

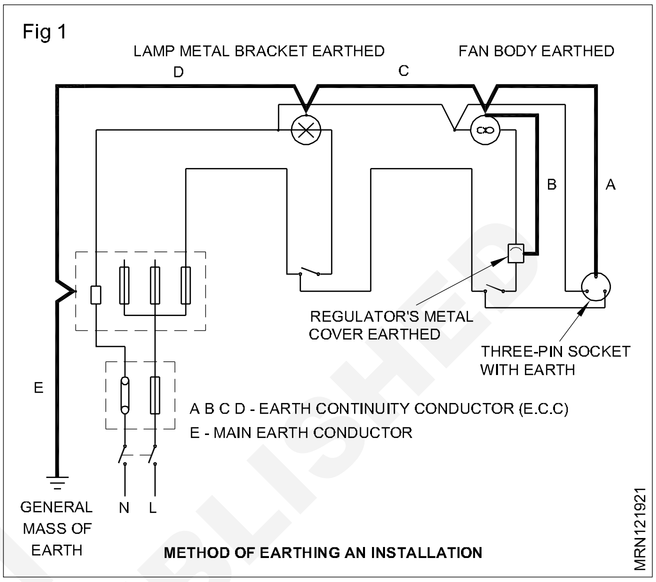
Let us say that the general mass of earth has a resistance (impedance) of 30 ohms and the earth continuity conductor (Route A,B,C,D and E) has a resistance of 20 ohms. Then the faulty current in a 240 V supply system will be

$$= \frac{\text{Supply volts}}{\text{Earth resistance} + \text{ECC resistance}}$$

$$= \frac{240}{30 + 20} = \frac{240}{50} = 4.8 \text{ amps}$$

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.



METHOD OF EARTHING AN INSTALLATION

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.

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 semiconductors 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 behaviors 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.

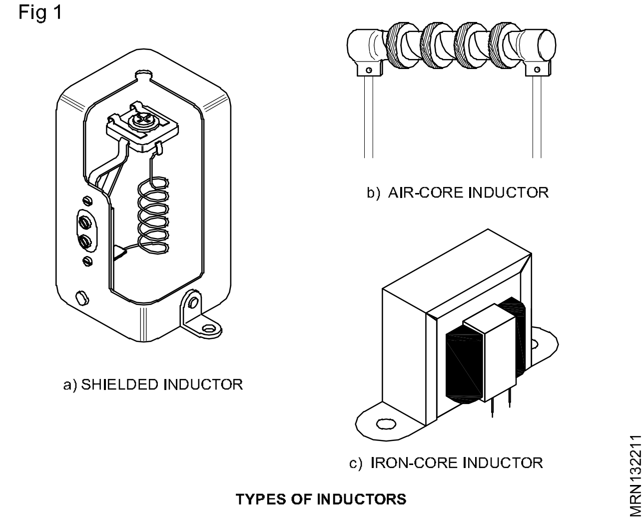
For letter coding, incase of capacitor, the letter 'p', 'n', 'm' shall be used as multipliers. Where $p = 10^{-12}$, $n = 10^{-9}$ and $m = 10^{-6}$ farads, and letter code for tolerance on capacitor is the same as in resistor.

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).

Fig 1



TYPES OF INDUCTORS

While specifying the inductance the following factors to be considered

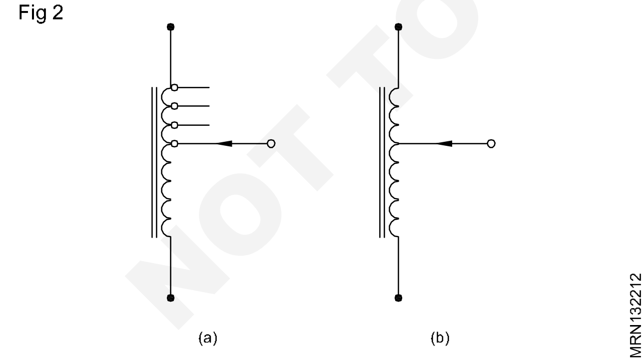
- nominal value of inductance in Henry / millihenry / micro (m) henry
- tolerance in percentage (±5/10/20%)
- type of winding like single layer, double layer, millinery and pie (p) etc.
- type of core like air core, iron core, ferrite core
- type of application like audio frequency (AF), Radio frequency (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

Fig 2

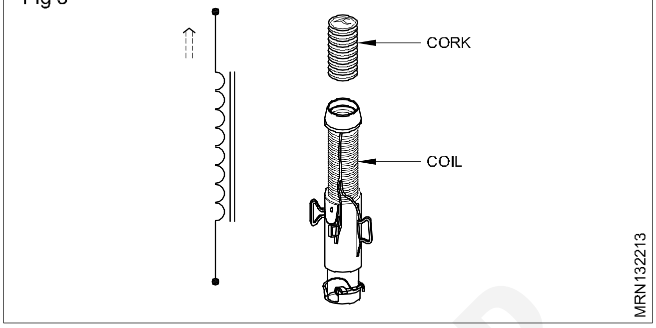


– adjusting the core of a coil as shown in Fig 3.

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.

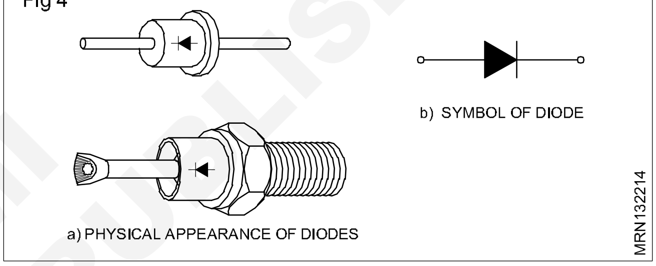
Active components : In electronic circuits, components other than resistors, capacitors and inductors are also used. Namely, transistors, diodes, vacuum tubes, SCRs, diacs, zener-diode etc. The application of electrical circuit laws (Ohm's law etc.) in the circuit containing the above components will not give correct results. i.e. these components do not obey. Ohm's law, Kirchoff's law etc. These components are called active components.

Fig 3



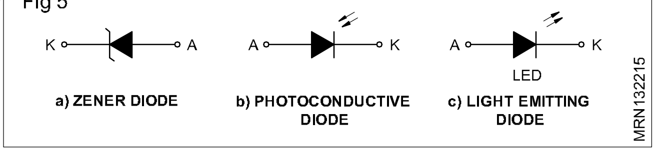
The different active components and the method of representing them by symbols in the circuit diagram are given below. (Fig 4)

Fig 4



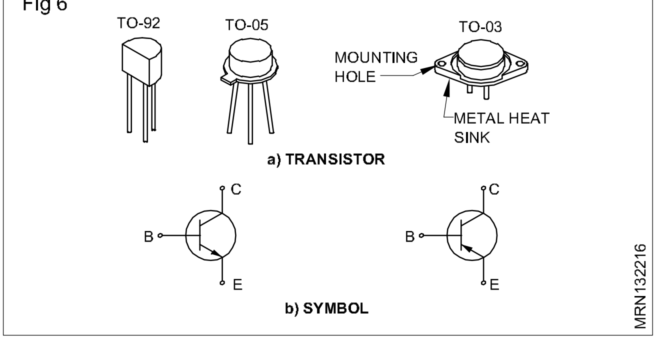
The different types of diodes (Fig 5) used for specific purposes are represented by the symbols given.

Fig 5



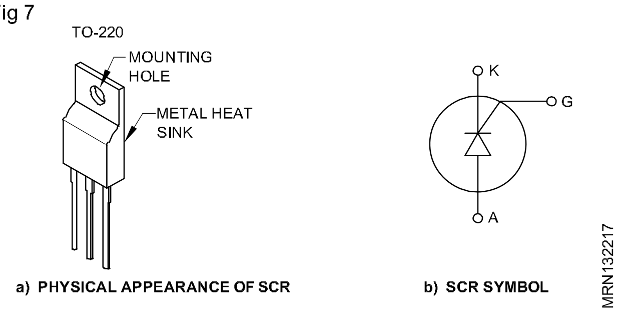
Transistor : Figure 6a shows the physical appearance of transistors. There are two symbols to represent a transistor. (Fig 6b). The selection of a symbol is based on either the NPN or the PNP type of transistor.

Fig 6



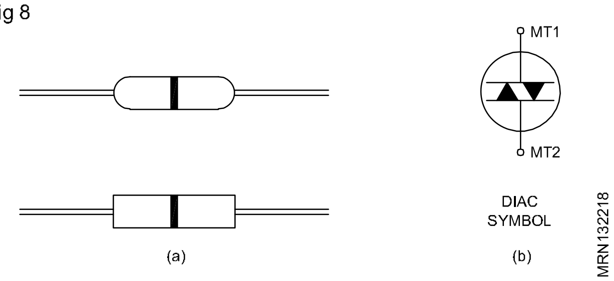
SCR (Silicon controlled rectifier) : Figure 7a shows the physical appearance of one type of SCR and the symbol is shown in Fig 7b. SCRs are also called thyristors and used as switching devices.

Fig 7



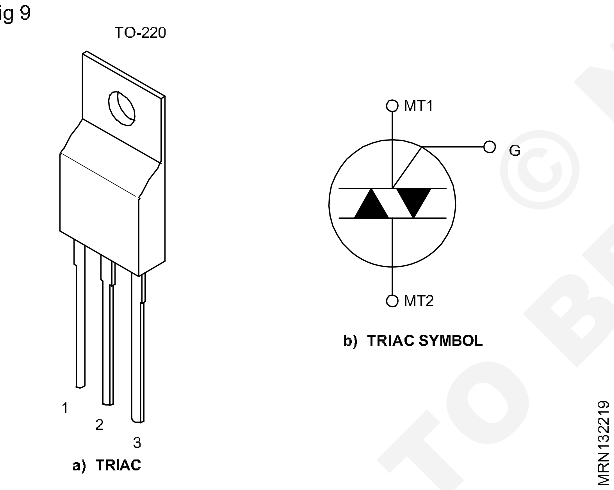
Diac : A diac (Fig 8a) is a two-lead device like a diode. It is a bidirectional switching device. Its symbol is shown in Fig 8b.

Fig 8



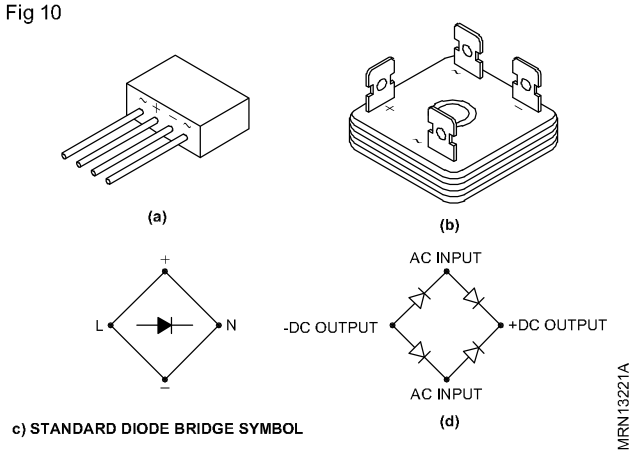
Triac : A trial is also a semiconductor device with three leads like two SCRs in parallel. The trial can control the circuit in either direction. (Fig 9)

Fig 9



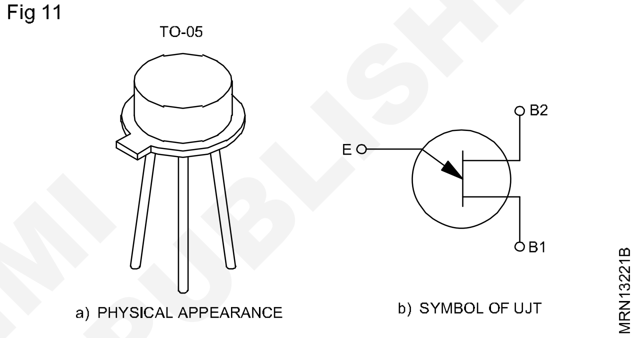
Bridge rectifier or diode bridge : It is a single package of four semiconductor diodes connected in bridge circuit. The input AC and the output DC leads are marked and terminated as shown in the Figure 10.

Fig 10



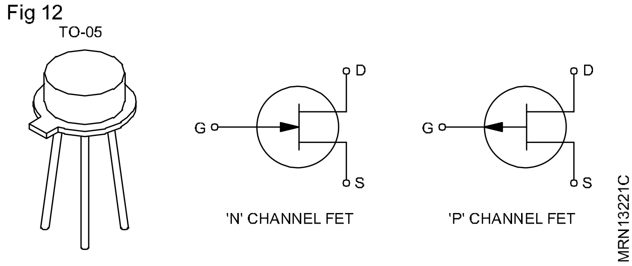
UJT (Uni-junction transistor) : It has two doped regions with three leads and has one emitter and two bases. (Fig 11)

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.

Fig 12



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 consists 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 sulphate

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-conducive 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 reactor 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;

1000 Ω	= 1 x 1000 Ω	= 1 x kiloΩ	= 1 K Ω
10,000 Ω	= 10 x 1000 Ω	= 10 x kiloΩ	= 10 K Ω
100,000 Ω	= 100 x 1000 Ω	= 100 x kilo Ω	= 100 K Ω
1000,000 Ω	= 1000 x 1000Ω	= 1000 x kiloΩ	= 1000 KΩ
		= 1000kΩ	= 1MΩ

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.

FIXED VALUE RESISTORS

- Carbon composition resistors
- Wire-wound resistors
- Film resistors
  - Carbon - film resistors
  - Metal film resistors
  - Metal oxide film resistors
  - Cermet film resistors
  - Integrated resistors
- Printed resistors

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, Manganic 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.

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.

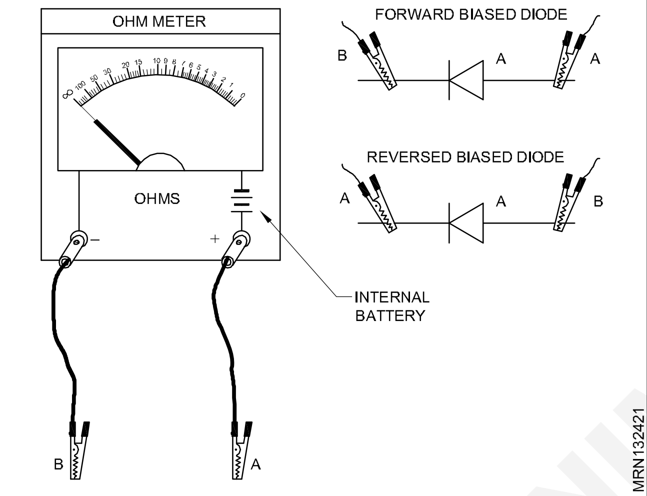
Recall that there will be a battery inside an ohmmeter or a multimeter in the resistance range. This battery voltage comes in series with the leads of the meter terminals. In Fig 10, the lead A is positive, lead B negative.

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.

Fig 1



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.

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

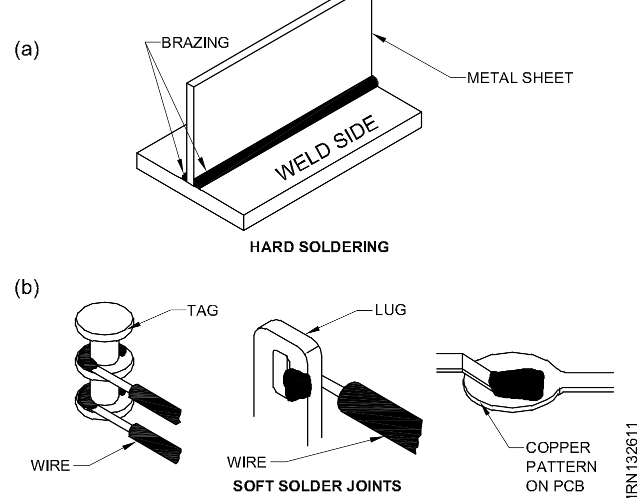
There are two types of soldering,

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.

Fig 1



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.

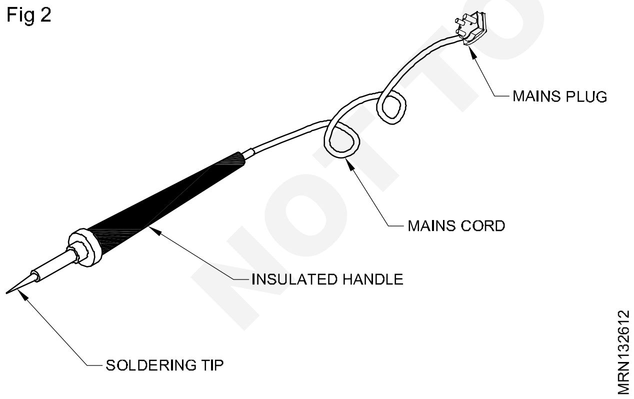
In soldering, as the metal surface is wetted (free flow of liquid solder over a surface) by the solder, a complex chemical reaction, bonds the solder to the metal surface.

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.

Fig 2



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 unstriped 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 re-skinned 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

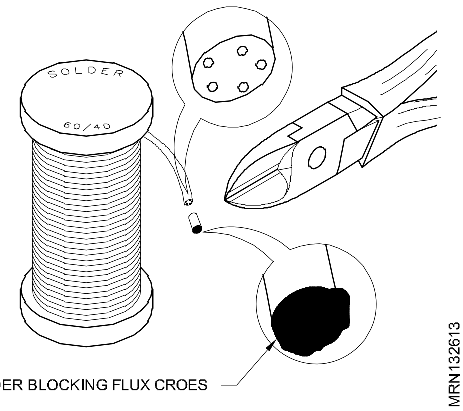
For electronic soldering applications, solder of tin and lead of 60/40 proportion is used. This solder proportion has a melting point of 200°C which is the required temperature for general purpose soldering irons.

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.

Fig 3



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 it 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 lot of unwanted heat and were fragile. Hence vacuum tubes became absolute as soon as transistors came to market.

Fig 1

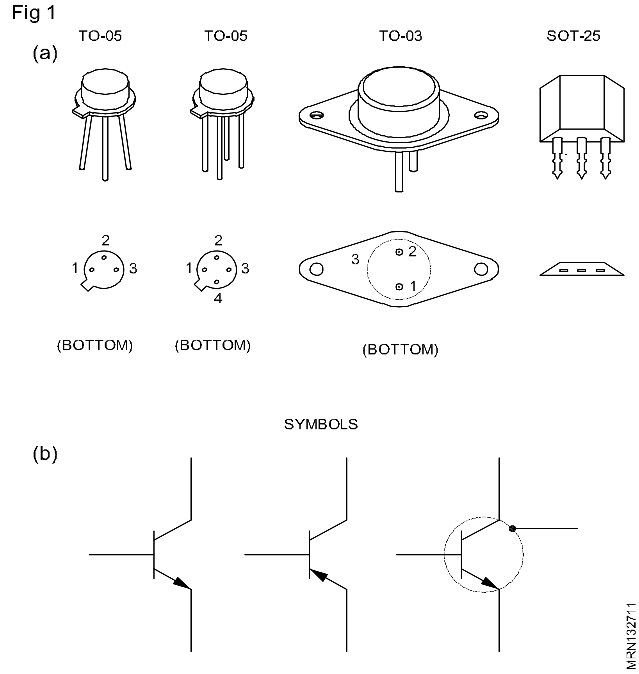


Fig 2

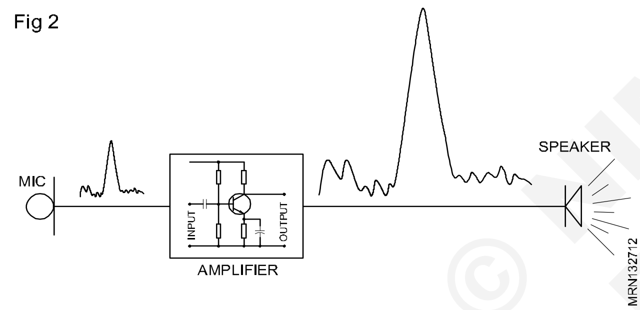
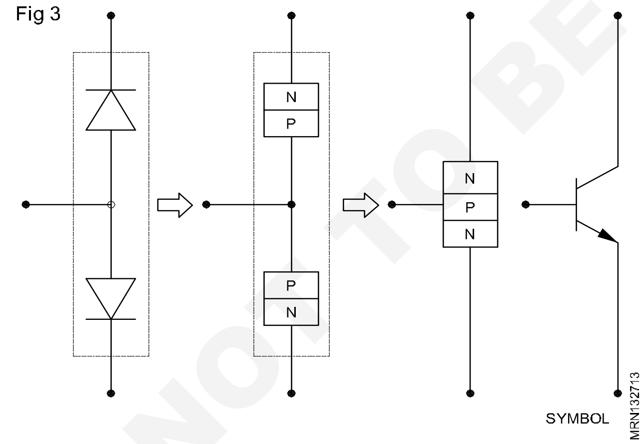


Fig 3



Transistors were invented by Walter H. Brazil and John Barlow of Bell Telephone Laboratories on 23rd Dec. 1947. Compared to vacuum tubes (also known as valves), transistors have several advantages. Some important advantages are listed below;

- Very small in size
- 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.

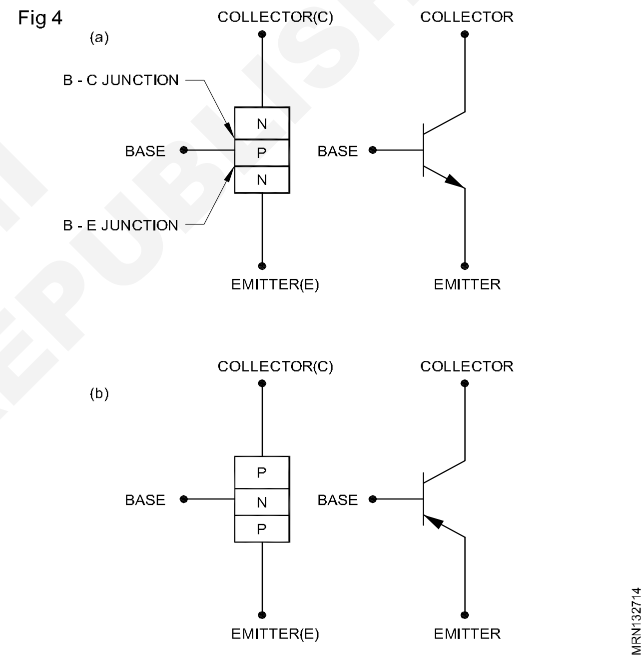
- Germanium transistors
- Silicon transistors

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.

Fig 4



- NPN transistors
- PNP transistors

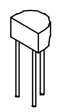
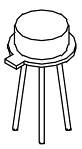
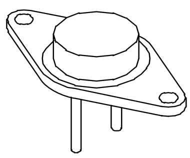
Both NPN and PNP transistors are equally useful in electronic circuits. However, NPN transistors are preferred for the reason that NPN has higher switching speed compared to PNP.

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, 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.,

Low power transistors (less than 2 watts)	**Medium power transistors** (2 to 10 watts)	**High power transistors** (more than 10 watts)
Fig5 TO-92 	TO-05 	TO-03 

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.

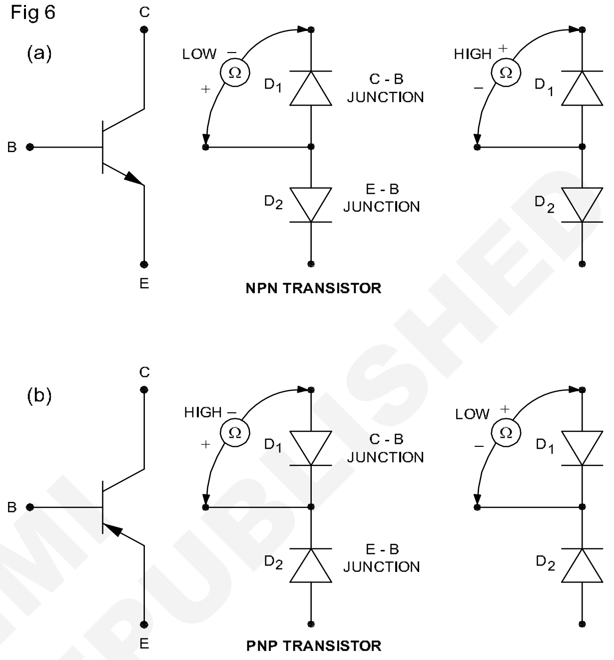
Testing transistors using ohmmeter

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.

Fig 6



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.

Zener diodes - working principle

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 differences between rectifier diodes and zener diodes**
- **list the similarities between rectifier diodes and zener diodes**
- **name the main application of zener diodes**
- **list the important specifications of a zener diode**
- **interpret the specifications of some zener types without referring to data book.**

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.

$$\text{Load regulation factor \%} = \frac{V_{NL} - V_{FL}}{V_{NL}} \times 100$$

where,

V_{NL} = DC output at no load or open circuit

and $V_{FL}\leftrightarrow$ = 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.

$$\text{\% Load regulation} = \frac{12 - 11}{12} \times 100 = 8.33\%$$

In practice the load regulation of a good power supply should be less than 0.1 %.

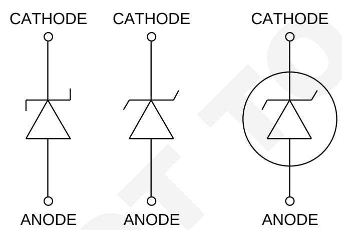
Regulating the DC output voltage for variations in the input AC level is termed as line regulation. This is discussed in further units.

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.

Fig 1



ZENER DIODE SCHEMATIC SYMBOLS

The difference between a rectifier diode and a zener diode are listed below;

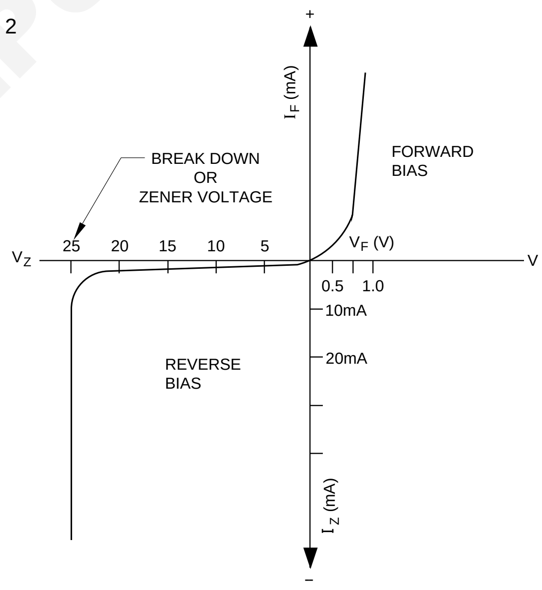
- Compared to normal rectifier diodes, zener diodes are heavily doped.
- Unlike ordinary diodes which do not work in the break-down region, zener diodes work only in the breakdown region.
- General rectifier diodes are used in forward-biased condition, whereas zeners are always used in reverse-biased 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.

Fig 2



ZENER DIODE CONDUCTION CHARACTERISTICS

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 break-down 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.

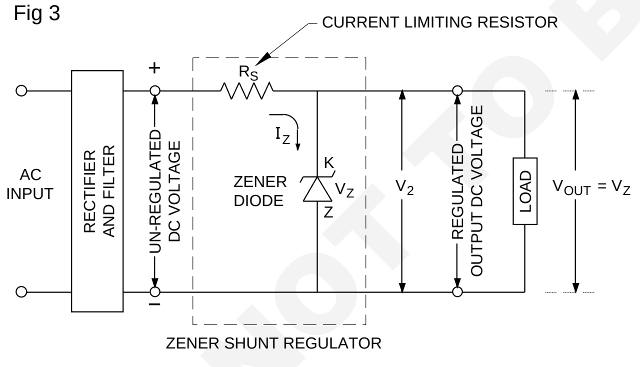
Because the zener diode is designed to operate as a breakdown device, the zener can be brought out of condition easily. A zener is brought out of its zener conduction by lowering the reverse-biased voltage below the zener voltage or by reversing the polarity of the applied voltage.

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.

Fig 3

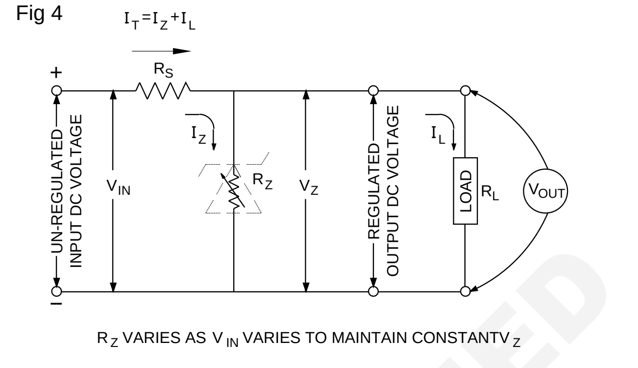


In Fig 3, the zener begins to conduct in the reverse-biased condition as the voltage across it reaches the zener voltage V_Z. The voltage across the zener remains constant immaterial of the input DC voltage. Since the load is in parallel with the zener, the voltage across the load V_{OUT} will be same 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.

Referring to Fig 4, the zener can be looked at as an automatically changing resistance. Total current through the resistance R_S is given by,

Fig 4



$$I_T = I_Z + I_L$$

Thus the voltage across R_S is,

$$V_R = (I_Z + I_L)\, R_S$$

If the input DC voltage V_{IN} increases, output voltage V_{OUT}, tends to increase. In the meantime, the zener conducts more heavily, causing more current (more I_Z) to flow through R_S. Hence, more voltage drop occurs across R_S. This increase in drop across R_S offsets the increase in the output voltage V_{OUT}, thus retaining the voltage across load R_L at its original value. Likewise, if the value of R_L is decreased (increased I_L), current through the zener I_Z decreases, retaining the value of I_T through R_S. This ensures sufficient load current through the load R_L without decrease in the level of V_{OUT}.

Zener specifications

Like in rectifier diodes, the type-code number is marked generally on the body of the zener. From the type-code marked, detailed specifications of the zener can be found referring to any standard diode data manual.

Important zener diode specifications are listed below;

– **Nominal Zener voltage, V_{Z}:**: This is the reverse biased voltage at which the diode begins to conduct in reverse bias.

– **Zener voltage tolerance**: Like the tolerance of a resistor, this indicates the percentage above or below V_Z. For example, 6.3 V ± 5 percent.

– **Maximum zener current, I_z,max**: This is the maximum current that the zener can safely withstand while in its reverse-biased conduction (zener) mode.

– **Maximum power dissipation, P_Z** is the maximum power the zener can dissipate without getting damaged.

– **Impedance (Z_Z)**: The impedance of the zener while conducting in zener mode.

- **Maximum operating temperature** : The highest temperature at which the device will operate reliably.

These specifications of zener diodes are given in diode data books. However a limited list of the most commonly used zener diodes is given in Table No. 27 of the Pocket Table book.

The example given below enables you to interpret the specifications of certain types of zener diodes without the need to refer diode data book:

Example 1: The type-code printed on a zener is BZ C9V1.

BZ C9V1

B	Z	C	9V1
silicon	zener	5% tolerance	9.1V

Example 2: The type-code printed on a zener is 1Z 12.

1Z 12

1	Z		12
Means a semiconductor with one PN junction	zener	No tolerance code means, 10% tolerance	12V

Other popular zener diode type-codes are, 1N750, 1N4000, ZF27, ZP30, DZ12, BZ148, Z6, etc.

Zener diodes - designing regulators

Objectives : At the end of this lesson you shall be able to
- **state the need for minimum current through the zener**
- **state the worst case conditions to be considered while designing a zener regulator**
- **calculate the value and wattage of a series resistor**
- **calculate the required wattage of a zener for a given application.**

Designing a simple zener regulator

In lesson 6.8 it was discussed that if the voltage across a zener tends to increase or decrease, it results in increase or decrease in the current I_Z, through the zener. This variation in I_Z results in the voltage across the series resistor R_S to increase or decrease, thus keeping the voltage across the zener, and, hence, the voltage across the output/load constant.

From this it is clear that, to make a voltage regulator circuit using zener, a resistor and a zener diode are required. The value of the resistor should be chosen so as to meet the following conditions;

- Under full load condition (i.e., I_L=max), at least the minimum reverse current should flow through the zener such that the zener remains to be in the zener break-down condition.

The voltage drop across R_S should be such that,

$$V_Z + V_{RS} = V_{IN}$$

where, V_Z is the zener voltage and also the required output voltage V_{OUT} of the regulator.

NOTE: For the zener to hold the output voltage constant, the zener must remain in the break-down region under all conditions.

- Under no load condition, the series resistor R_S must restrict the current through the zener, such that, the power dissipation across the zener is within the specified limit of the device.

The voltage drop across R_S should be such that,

$$V_Z + V_{RS} = V_{IN}$$

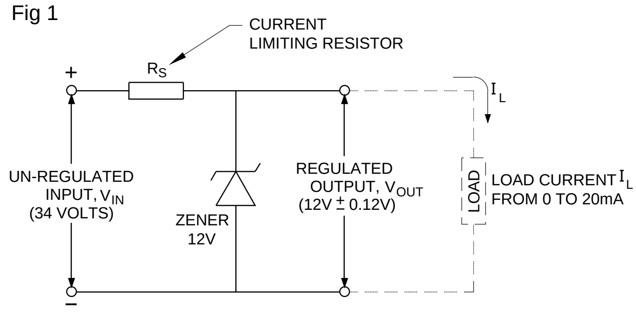
The design steps for a simple zener regulator circuit is given below through an example:

Example: A zener regulator circuit is needed to supply a constant output voltage of 12V DC ± 0.1V. The load current may vary (depending on load resistance) from 0 to 100mA. The unregulated input to the regulator is 34V DC (maximum).

Design steps:

1 Draw a schematic of regulator as shown in Fig 1.

Fig 1



2 Choose a zener of V_Z = 12 volts as the output voltage required is 12 Volts. Choose the zener with a tolerance of ≥10%, so that the output will be 12 V DC ± 0.12 V.

3 From the specifications of the zener, find I_Z. Say the I_Z of the chosen zener is = 20mA.

4 Calculate the current through the zener in the worst conditions as explained below;

One of the worst conditions is, when the input voltage V_{IN} is minimum and, the load current is maximum. For this condition, choose the minimum I_Z that should flow through the zener to keep it in reverse-ON condition.

In the example considered, I_Z = 20mA.

Since, $I_T = I_Z + I_{L(max)}$

For the given example,

I_T = 20mA + 100 mA = 120 mA.

The other worst condition is, when maximum current flows through the zener as the load current is zero or minimum and the source voltage is maximum. In the example considered, minimum I_L = 0 mA.

When I_L = 0 mA, current through the zener will be maximum and is,

120 mA – 0 mA = 120 mA.

5 Calculate the zener wattage.

Integrated circuit voltage regulators

Objectives: At the end of this lesson you shall be able to
- **state the meaning of integrated circuits**
- **state the two main types of IC voltage regulators with examples**
- **design voltage regulators for the required output**
- **modify a fixed voltage regulator to a variable output regulator.**

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, consisted 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 **IC**s. Integrated circuits (ICs) can consist 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.

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,

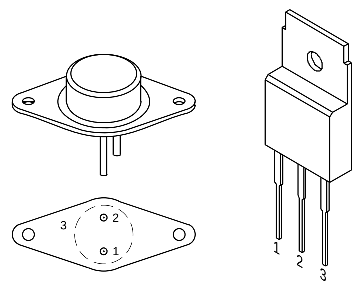
1 Fixed output voltage regulator ICs

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.

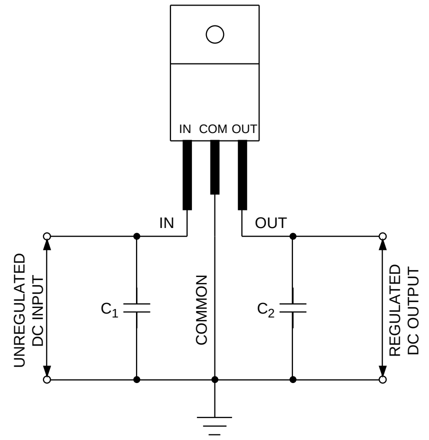
Fig 1



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 0.220µF to 1µF. It is important to note that C_1 should be connected as close to the IC as possible.

Fig 2



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 0.1µF to 10 µF.

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, 7812, 7912 etc.

A list of popular three terminal regulators is given in Pocket Table Book, Table No.30.

Specifications of three terminal IC regulators

For simplicity in understanding, let us consider the specification of a three terminal IC µA7812. The table given below lists the specifications of µA7812.

Parameter	Min.	Typ.	Max.	Units
Output voltage	11.5	12	12.5	V
Output regulation		4	120	mV
Short-circuit output current		350		mA
Drop out voltage		2.0		V
Ripple rejection	55	71		dB
Peak output current		2.2		A

– **Output voltage:**

This specification indicates the regulated DC output voltage that can be obtained from the IC. As can be seen from the sample specification table given above, the manufacturer specifies minimum, typical and maximum output voltages. While using this IC take the typical value as this value corresponds to the output voltage at IC under normal input and load conditions.

– **Output regulation**

This indicates the amount by which the output voltage may vary at rated maximum load condition. For example, in µA7812 IC, the output voltage may vary by 4 mV from its rated 12 V DC when the rated typical load current is 2.2A.

– **Short circuit output current**

This indicates the shorted current I_{SC} if the output gets shorted. In µA 7812 the output current is limited to 350mA when the output terminals are shorted.

– **Drop out voltage**

For instance, in µA7812 in which the output voltage is +12 V, the input unregulated DC voltage to the regulator must be higher than the output voltage. The specification drop out voltage indicates, the minimum positive difference between the input and output voltages for the IC to operate as a regulator. For example, in, µA7812 the unregulated input voltage should be atleast 2 volts more than the regulated DC output of 12V. This means for µA7812 the input must be atleast 14V.

The difference between the voltage across the input and output of the IC should also not to be very high as this causes unwanted dissipation. As a thumb rule, the input voltage to the regulator shall be restricted to a maximum of twice the output voltage of the regulator. For example, for µA7812, the unregulated input voltage should be more than 14V, but less than 24V.

– **Ripple rejection**

This indicates the ratio of ripple rejection between the output to input, expressed in decibels.

– **Peak output current**

This indicates the highest output or load current that can be drawn. Above this rated maximum current the safety of the IC is not guranted.

Identification of output voltage and rated maximum load current from IC type number

– 78XX and 79XX series are **3 Terminal voltage regulators.**

– All 78XX series are **positive output voltage regulators.**

– All 79XX series are **negative output voltage regulators.**

The term XX indicates the rated output regulated voltage.

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 Vastly Petro also discovered the electric arc and subsequently proposed possible practical applications such as welding. In 1881-82, a Russian Inventor NIkolai Benardos and polish Stainslaw 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 Vladmir mitkevich proposed using a three-phase electric arc for welding. In 1919, alternating current welding was invented by C.J. Holslag 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 die to harmful rays (Ultra violet and infrared 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.

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-liquefied 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	Electro slag
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	Thermite
UW	Ultrosonic

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.

Co$_2$ 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-di-oxide 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 othr 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 o 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, liquefied petroleum gas (LPG) are used along with oxygen to get a 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/miter 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).

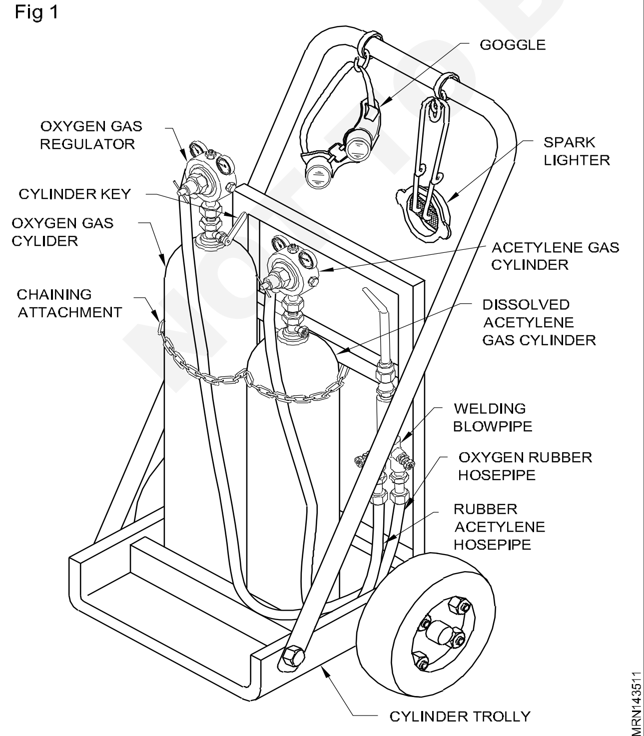
25 **Electrode** (Flux coated) A metal stick which is coated with flux and having parts indicated as stub end, tip,bare/core wire and flux coating. The size of this is determined by size of bare/core wire diameter. (This is used in shielded Metal Arc welding as consumable material).

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 feaures of oxygen and acetylene gas regulators**
- **distinguish between the house-connectors used in oxygen and acetylene regulators**
- **describe the function of hose-protectors**
- **state the functions of blowpipes and nozzles.**

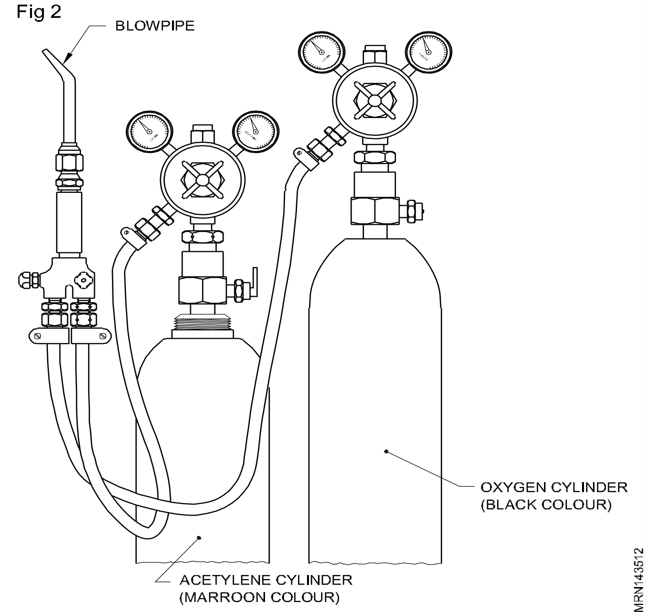
Oxy-acetylene welding is a method of joining metals by heating them to the melting point using a mixture of oxygen and acetylene gases. (Fig 1)

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 m^3 with the pressure ranging between 120 to 150 kg/cm^2. Oxygen gas cylinder valves are right hand threaded.

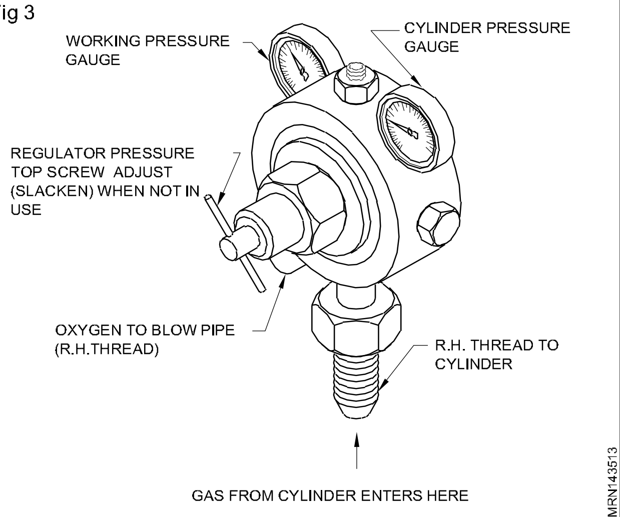
Fig 2



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 6m^3 with the pressure ranging between 15-16 kg/cm^2.

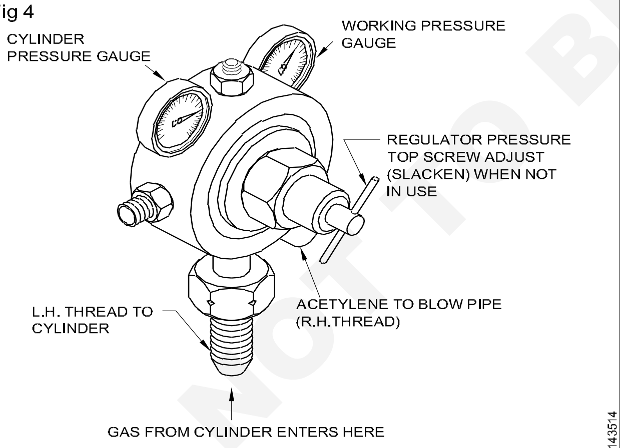
Oxygen pressure regulator: This is used to reduce the oxygen cylinder gas pressure according to the required working pressure and to control the flow of oxygen at a constant rate to the blowpipe. The threaded connections are right hand threaded. (Fig 3)

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)

Fig 4



ACETYLENE PRESSURE REGULATOR

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)

Fig 5

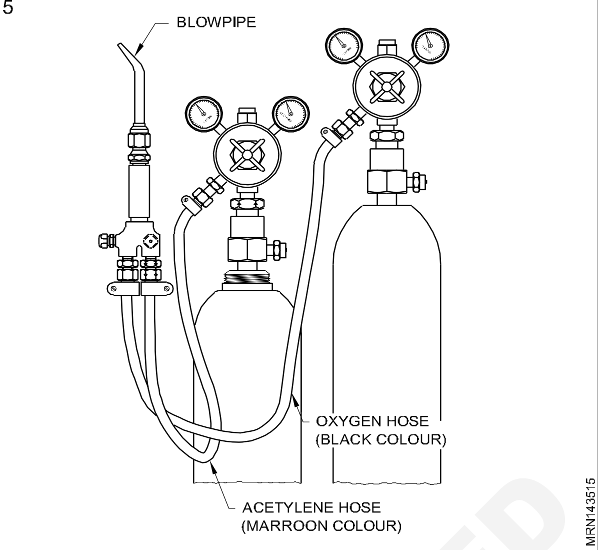
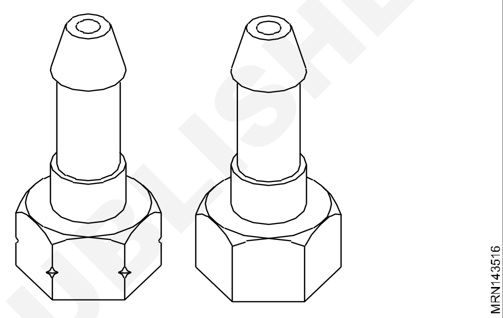
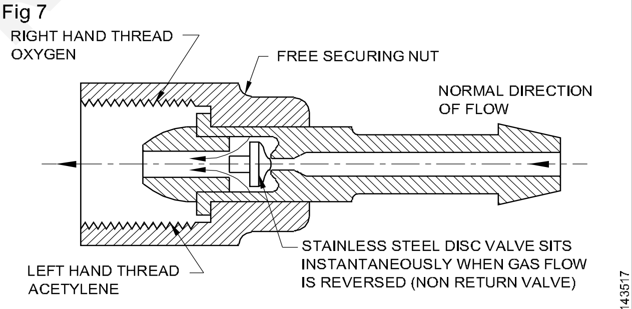


Fig 6



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)

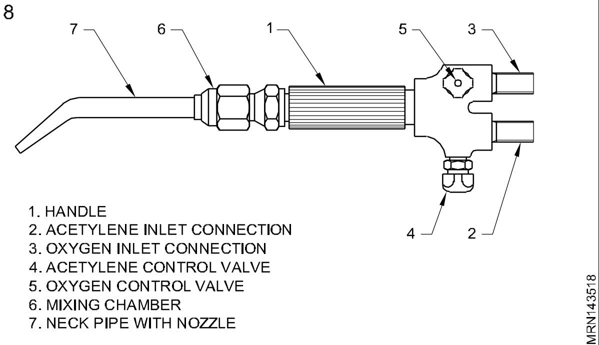
Fig 7



HOSE PROTECTOR

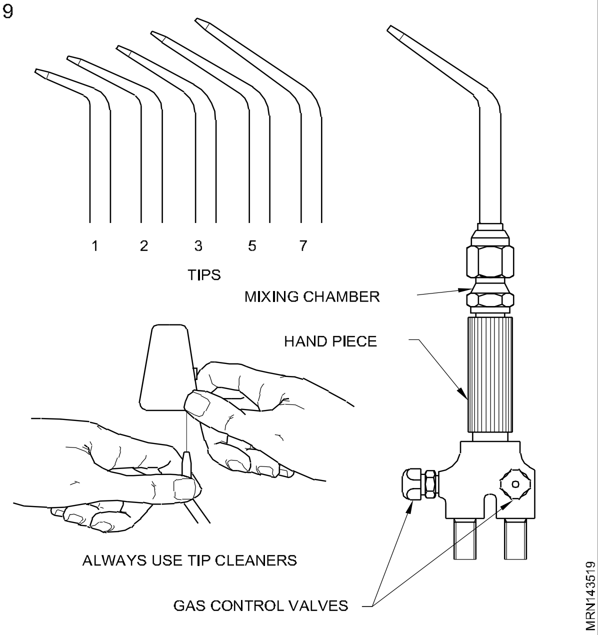
Blowpipe and nozzle: Blowpipes are used to control and mix the oxygen and acetylene gases to the required proportion. (Fig 8)

Fig 8



A set of interchangeable nozzles/tips of different sizes is available to produce smaller bigger flames. (Fig 9)

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

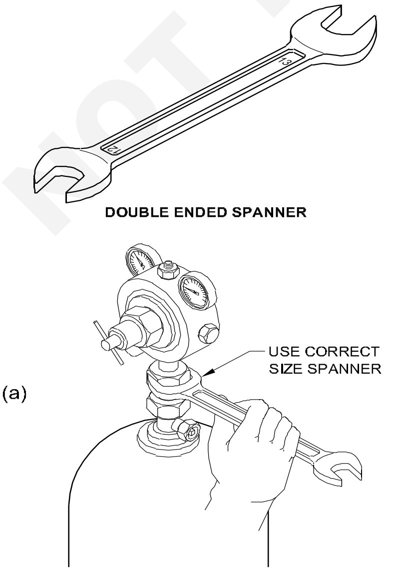
Gas welding hand tools

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.

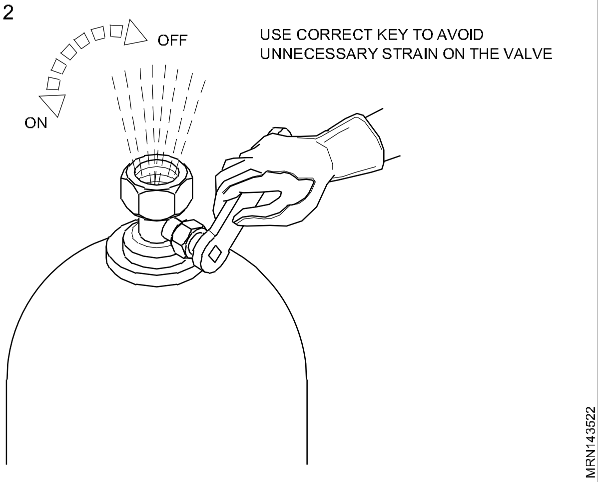
Fig 1



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.

Fig 2



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.

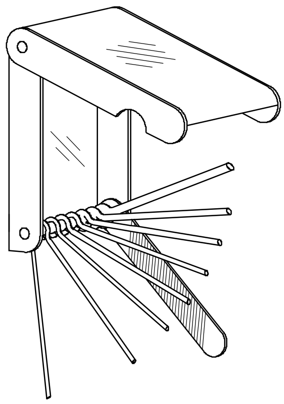
Nozzle or tip cleaner

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.

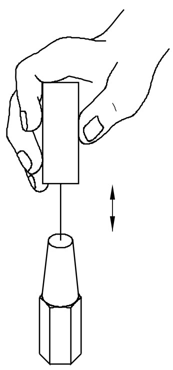
Tip cleaner: A Special tip cleaner is supplied with the torch container. For each tip there is a kind of drill and a smooth file Fig 3.

Fig 3



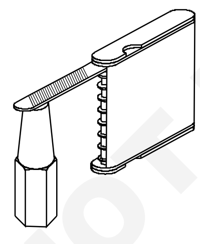
Before cleaning the tip, select the correct drill and move it, without turning, up and down through the tip Fig 4.

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.

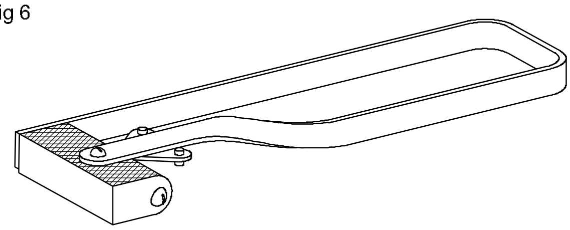
Fig 5



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 pf 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.

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.

Fig 6



ALWAYS USE A SPARKLIGHTER TO LIGHT A TORCH

Fig 7

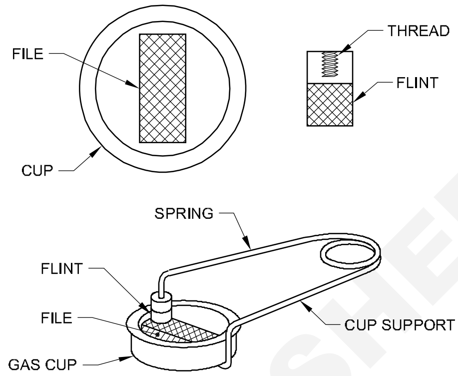
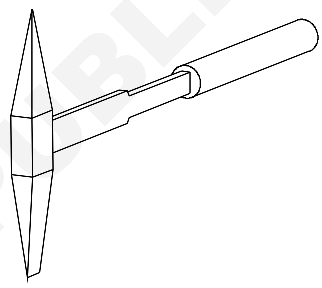


Fig 8

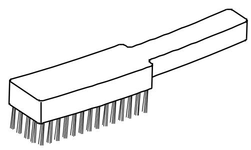


CHIPPING HAMMER

Care should be taken to maintain the sharp chisel edge and the point for effective chipping of slag.

Carbon steel wire brush: A carbon steel wire brush is shown in Fig 9. It is used for

Fig 9



WIRE BRUSH

- Cleaning the work surface from rust, oxide and other dirt etc. prior to welding.
- Cleaning the interbred 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

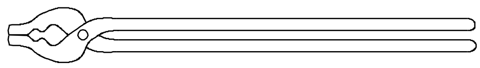
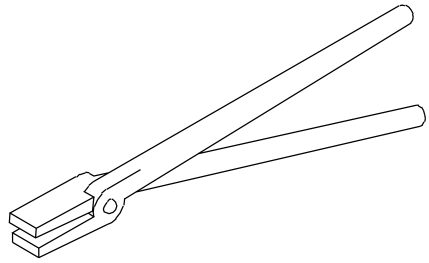


Fig 11



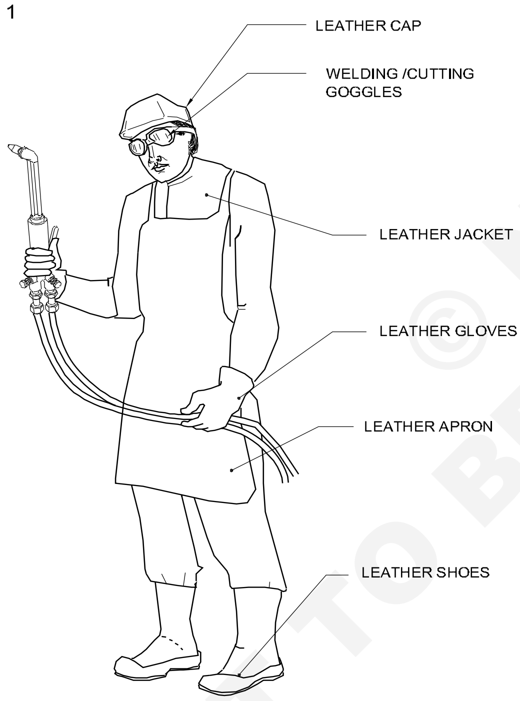
Safety in gas cutting process

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)

Fig 1



WEAR PROTECTIVE CLOTHING

Always use safety apparel

Goggles, gloves and other protective clothing must be warn.

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)

Fig 2

Keep fire- fighting equipment handy and ready.

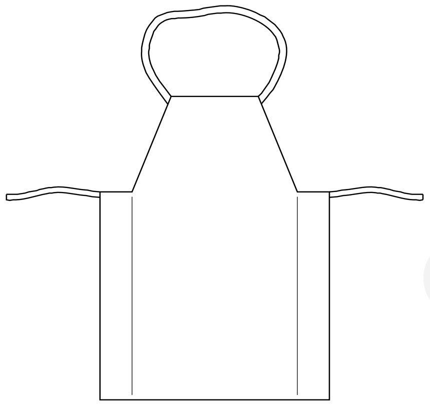
1 Safety apparels
   - a Leather apron (Fig 4)
   - b Leather gloves (Fig 5)
   - c Leather cape with sleeves (Fig 6)
   - d Industrial safety shoes

2 a Hand screen
   - b Adjustable helmet
   - c Portable fire proof canvas screens

3 Chipping/grinding goggles

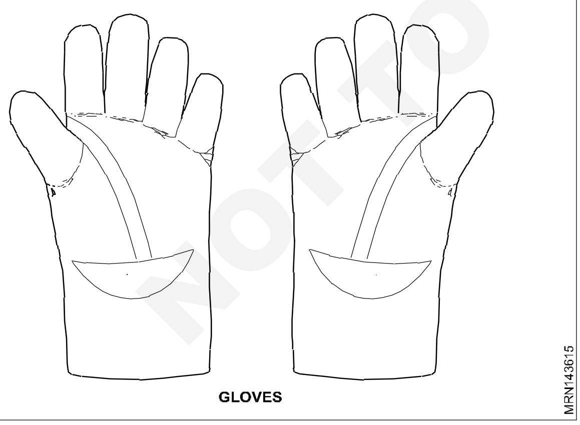
Fig 3

Fig 4



APRON

Fig 5

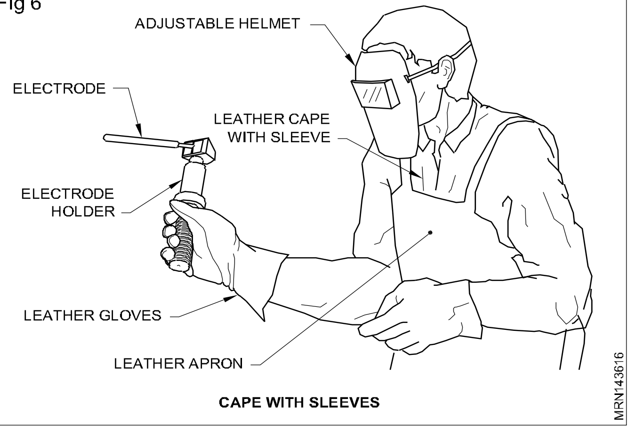


GLOVES

4 Respirator and exhaust ducting

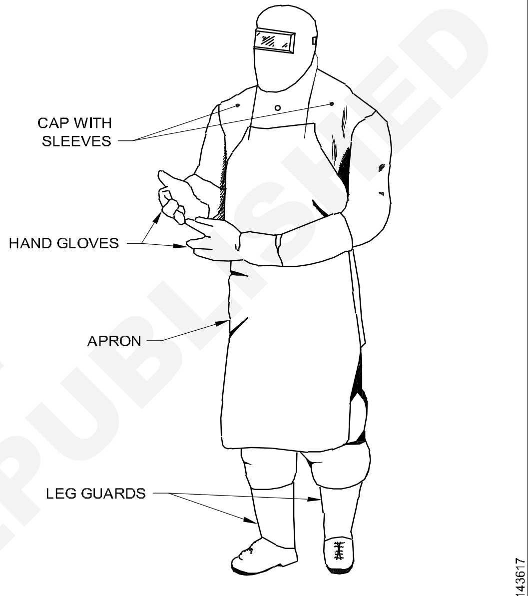
The leather apron, gloves, cape with sleeves and leg guard Fig 4,5,6 and 7 are used to protect the body, hands, arms, neck & chest of the welder from the heat radiation and hot spatters from the arc & also from the hot slag particles flying from the weld joint during chipping off the solidified slag.

Fig 6



CAPE WITH SLEEVES

Fig 7



LEG GUARDS

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.

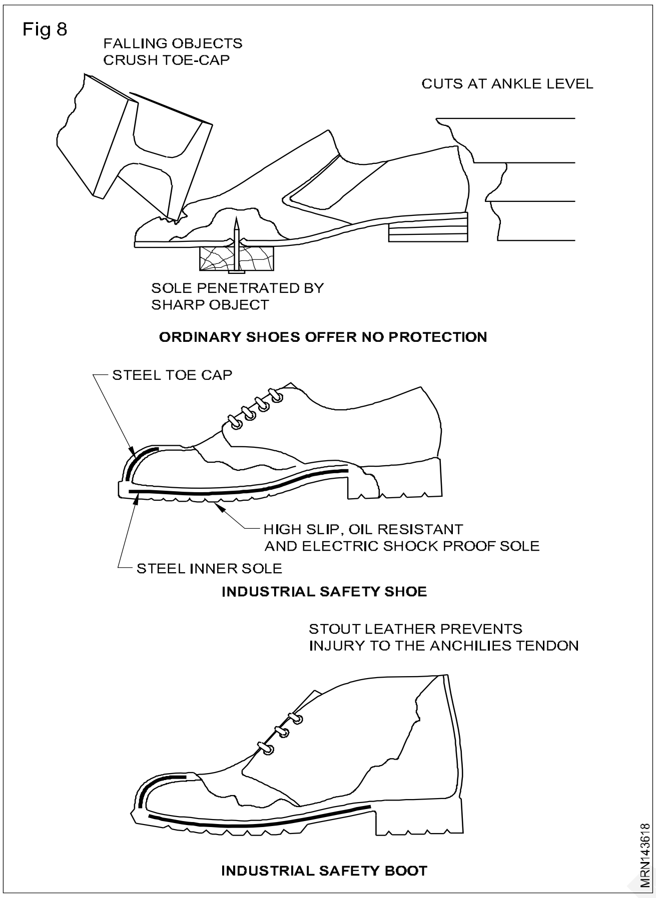
Welding hand screens and helmet: These are used to protect the eyes and face of a welder from arc radiation and sparks during arc welding.

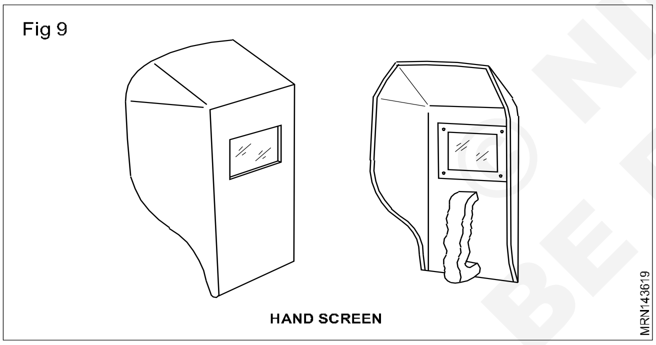
A hand screen is designed to hold in hand. (Fig 9)

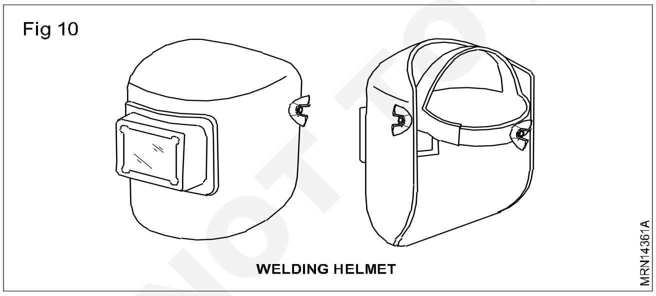
A helmet screen is designed to wear on the head. (Fig 10)

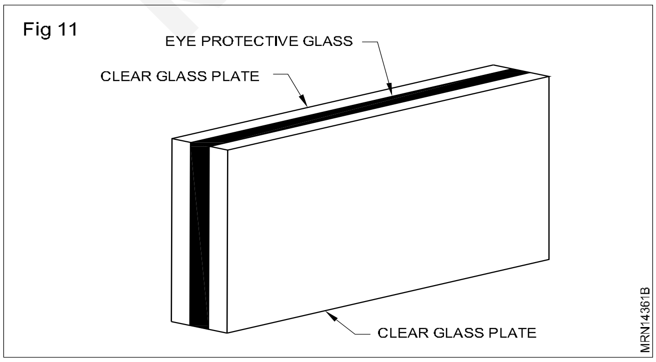
Clear glasses are fitted on each side of the coloured glass to protect it from weld spatters. (Fig 11)

The helmet screen provides better protection and allows the welder to use his both hands freely.









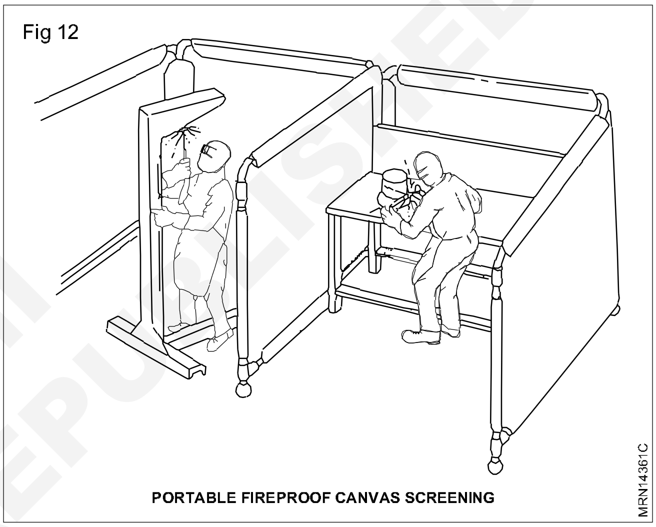
Coloured (filter) glasses are made in various shades depending on the welding current ranges. (Table1)

Table 1

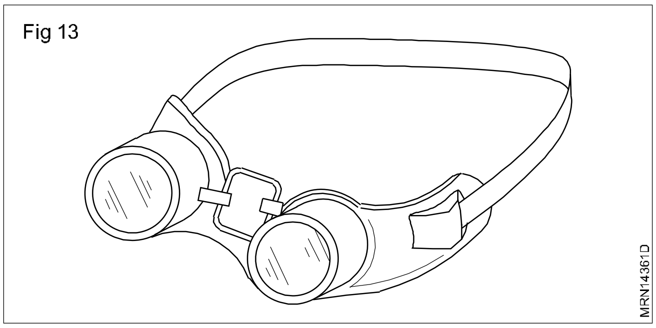
Recommendations of filter glasses for manual metal arc welding

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



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.

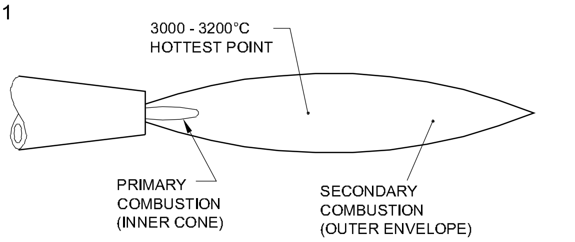
Features of neutral flame: Oxy-acetylene flame consists of the following features by appearance.

- 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.

Fig 1



PRIMARY AND SECONDARY COMBUSTION STAGES IN THE OXY-ACETYLENE FLAME

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.

Primary combustion: It takes place in the inner cone right in the tip of the nozzle. (Fig 1)

In the bright nucleus:

$C_2 H_2 \uparrow 2C + H_2$ + Heat

In the inner cone - first burning stage:

$2C + H_2 O_2 \uparrow 2CO + H_2$ + Heat

CO and H_2 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

$2CO + O_2 \uparrow 2CO_2$ + Heat

$2H_2 + O2 \uparrow 2H_0O$ + Heat

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.

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.

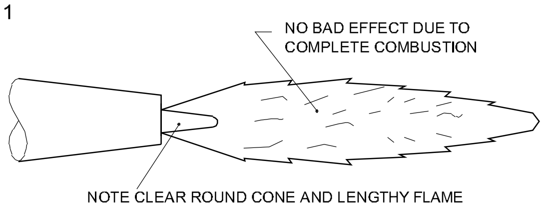
Three different types of oxy-acetylene flames as given below can be set.

- Neutral flame
- Oxidising flame
- Carburising flame.

Characteristics and uses

Neutral flame (Fig 1): Oxygen and acetylene are mixed in equal proportion in the blowpipe.

Fig 1



NEUTRAL FLAME
(EQUAL QUANTITIES OF OXYGEN AND ACETYLENE)

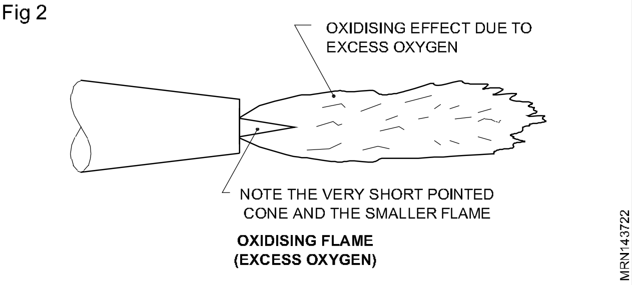
Complete combustion takes place in this flame.

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.

Fig 2

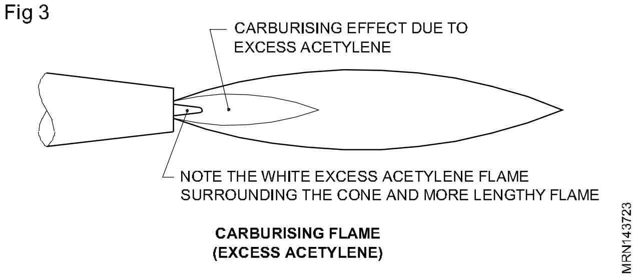


The flame has an oxidising effect on metals which prevents evaporation of zinc/tin in brass welding/brazing.

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.

Fig 3



Uses : Useful for stellateing (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	Stellate	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**.

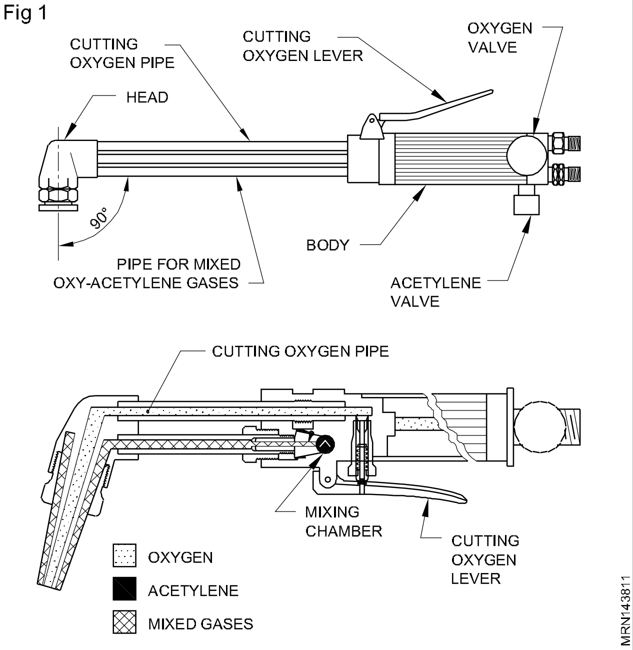
Cutting equipment: The oxy-acetylene cutting equipment is similar to the welding equipment, except that instead of using a welding blowpipe, a cutting blowpipe is used. The cutting equipment consists of the following.

- 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.

Fig 1



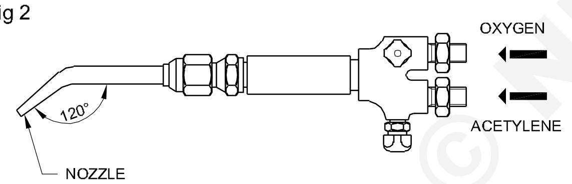
The cutting tip is made with an orifice in the centre surrounded by five smaller holes. The centre opening permits the flow of the cutting oxygen and the smaller holes are for the preheating flame. Usually different tip sizes are provided for cutting metals of different thicknesses.

Oxy-acetylene cutting procedure: Fix a suitable size cutting nozzle in the cutting blowpipe. lignite 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).

Fig 2

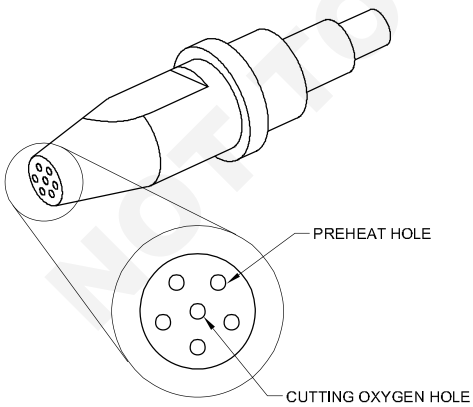


WELDING BLOWPIPE

MRN143812

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)

Fig 3

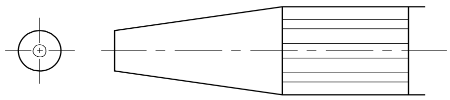


CUTTING TIP

MRN143813

The nozzle of the welding blowpipe has only one hole in the center for the heating flame. (Fig 4)

Fig 4



WELDING NOZZLE

MRN143814

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

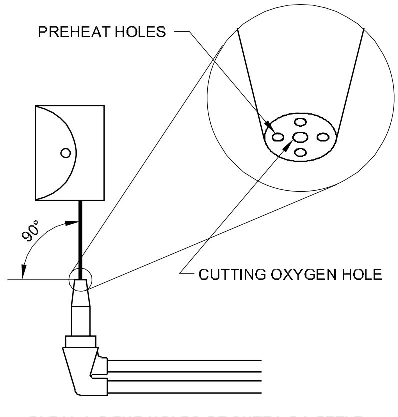
However, the oxidation of metals has also certain useful effects, i.e a stream of pure oxygen if applied (used) on a red hot mild steel plate through a nozzle, the plate will get cut into 2 pieces. Hence the principle of oxidation is effectively used in gas cutting and gouging of mild steel.

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.

Fig 5



CLEANING THE HOLES OF CUTTING NOZZLE

MRN143815

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

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 codling	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

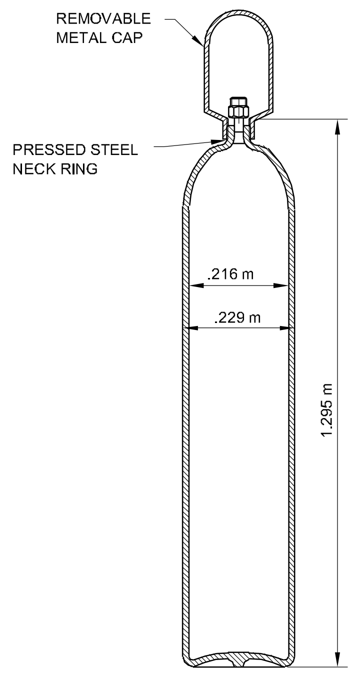
Oxygen gas cylinder: It is a seamless steel container used to store oxygen gas safely and in large quantity under a maximum pressure of 150 kg /cm^2, for use in gas welding and cutting.

Constructional features of oxygen gas cylinder (Fig1)

It is made from seamless solid drawn steel and tested with a water pressure of 225kg/cm^2. 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)

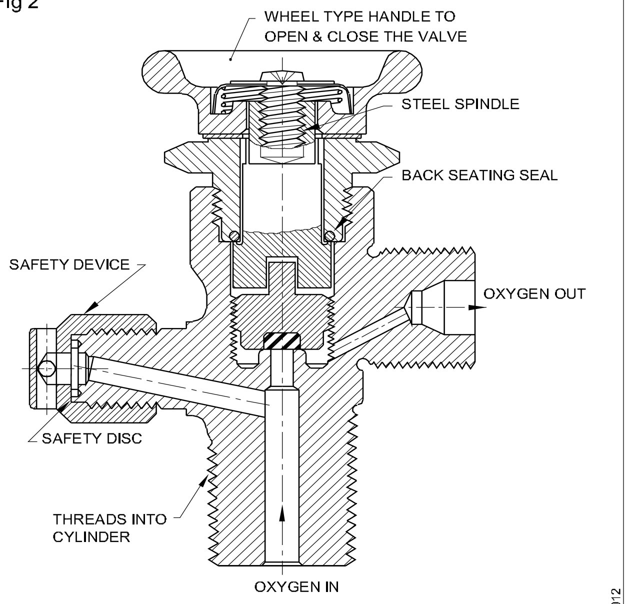
Fig 1



CONSTRUCTIONAL FEATURE OF OXYGEN GAS CYLINDER

MRN144011

Fig 2



CONSTRUCTIONAL FEATURES OF A CYLINDER VALVE

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.**

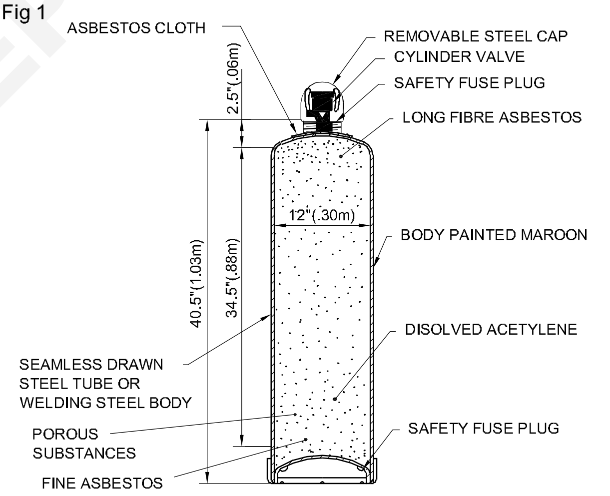
Charging of gas in oxygen cylinder: The oxygen cylinders are filled with oxygen gas under a pressure of 120-150 kg/cm². The cylinders are tested regularity and periodically. They are annealed to relieve stresses caused during 'on the job' handling. They are periodically cleaned using caustic solution.

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/cm² 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 $3.5m^3$-$8.5m^3$.

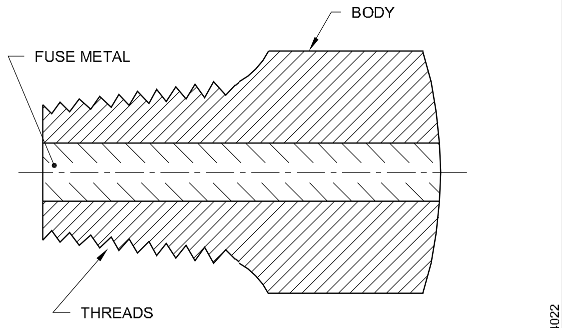
The base of the D A cylinder (Curved inside) is fitted with fuse plugs which will melt at a temperature of app. 100°C. (Fig 2) In case the cylinder is subjected to high temperature, the fuse plugs will melt and allow the gas to escape, before the pressure increases enough to harm or rupture the cylinder. Fuse plugs are also fitted on the top of the cylinder.

Fig 1



CONSTRUCTIONAL FEATURES OF A DISSOLVED ACETYLENE GAS CYLINDER

Fig 2



CONSTRUCTIONAL FEATURE OF A FUSE PLUG FITTED WITH THE CYLINDER TOP AND BOTTOM

Method of charging D A 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 (1/3rd 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 25X15=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.**

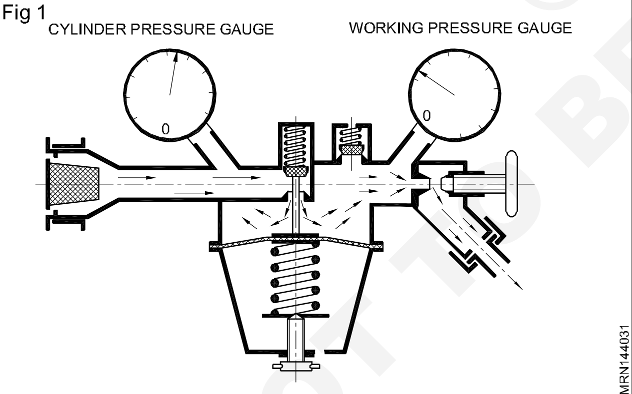
Types of regulators

- 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)

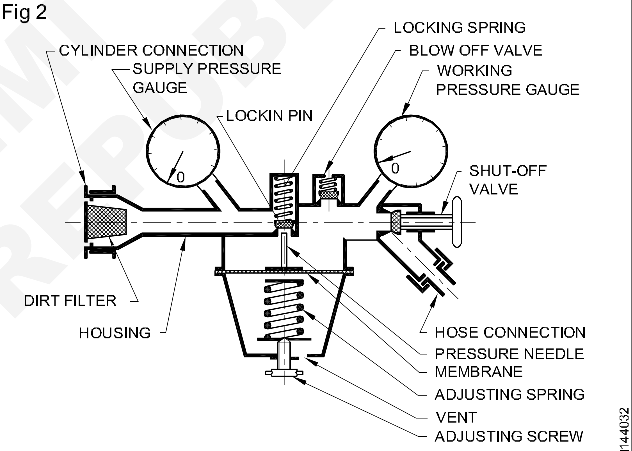
Fig 1



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)

Fig 2

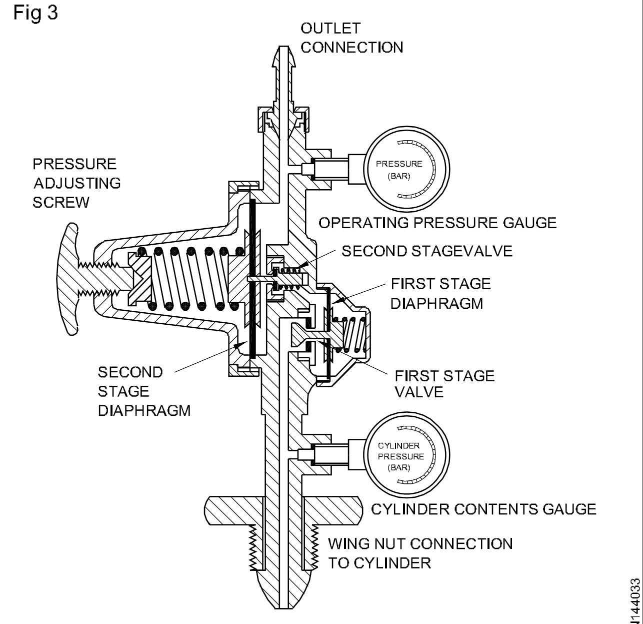


SINGLE STAGE REGULATOR

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/mm^2 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.

Fig 3



TWO STAGE REGULATOR

Single stage regulators may be used with pipelines and cylinders. Two stage regulators are used with cylinders and manifolds.

Systems of oxy- acetylene welding

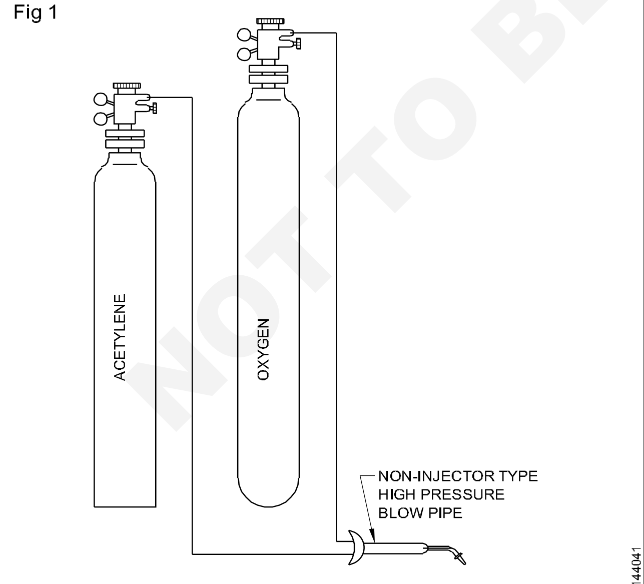
Objectives : At the end of this lesson you shall be able to
- **explain the low pressure and the high pressure systems of oxy-acetylene plants and systems**
- **distinguish between low pressure and high pressure blowpipes**
- **state the advantages and disadvantages of both systems.**

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)

Fig 1



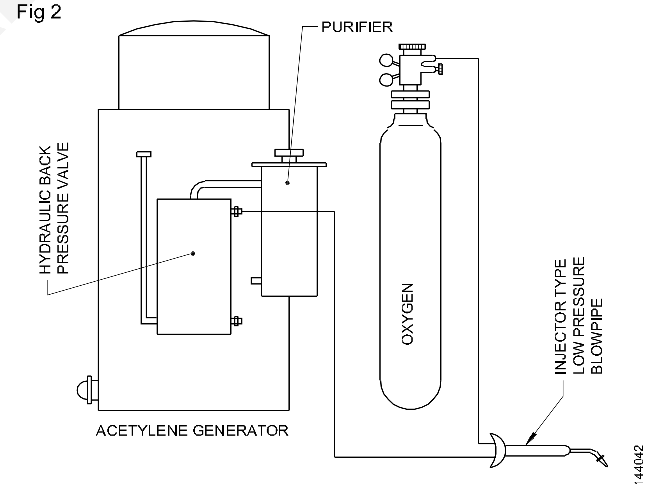
HIGH PRESSURE OXY-ACETYLENE PLANT

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)

Fig 2



LOW PRESSURE OXY-ACETYLENE PLANT

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.)

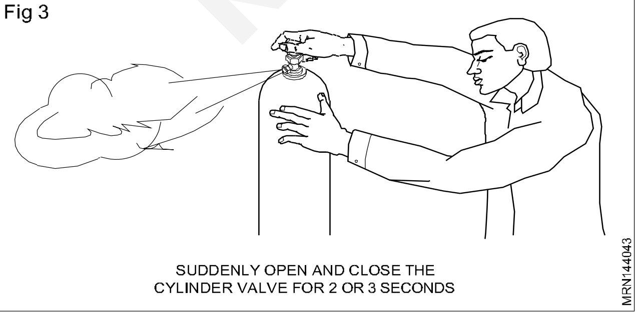
Watch the working pressure gauge.

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)

Fig 3



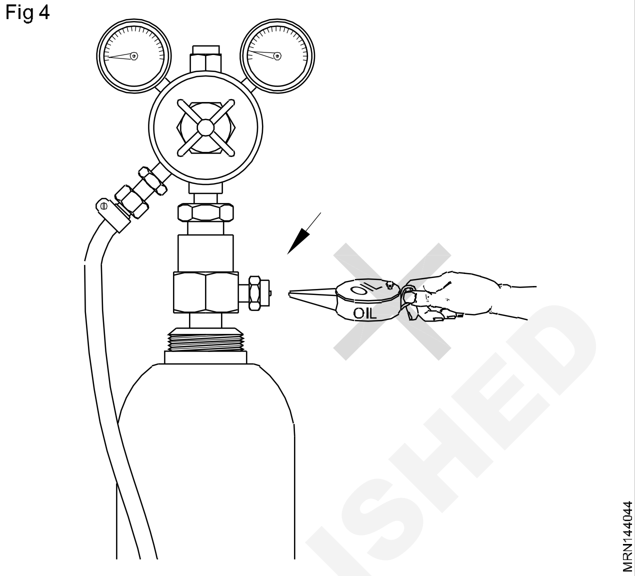
SUDDENLY OPEN AND CLOSE THE CYLINDER VALVE FOR 2 OR 3 SECONDS

Open the cylinder valve slowly and allow the gas to pass to the regulator (cylinder) content gauge.

Loosen the pressure screw.

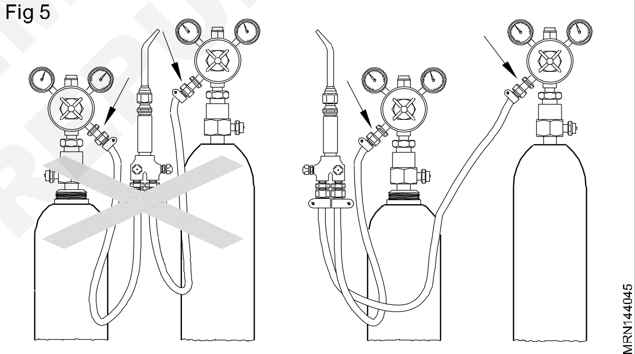
Do not use oil in regulator connections. (Fig 4)

Fig 4



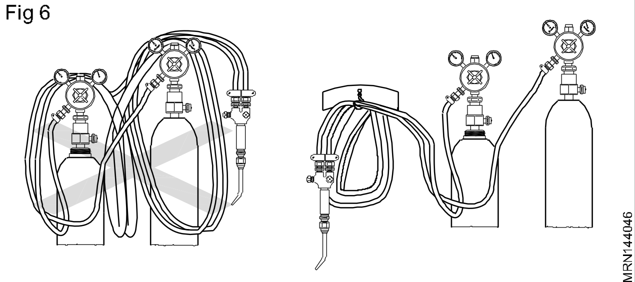
Do not fix the oxygen and acetylene regulators close together. (Fig 5)

Fig 5



Do not wind the hose on the regulators. (Fig 6)

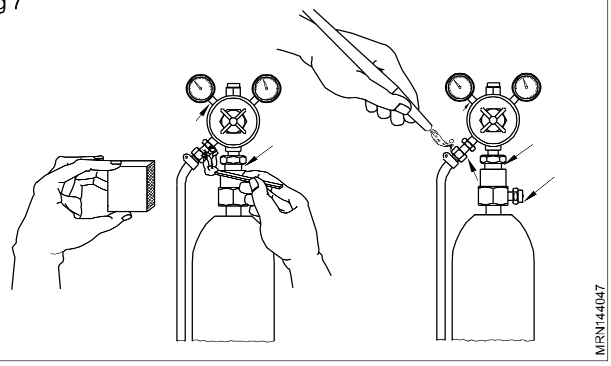
Fig 6



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.

Fig 7



Flashback and back fire

Objectives : At the end of this lesson you shall be able to
- **state the causes of backfire, flash back and their preventive methods.**

Backfire: At certain times during flame ignition in gas welding a small explosion of the flame occurs at the torch tip. The flame occurs at the torch tip. The flame may or may not go off. This is backfire.

The flame may or may not go off. This backfire

Causes: A backfire is caused whn

- The gas pressure setting is low
- The nozzle is overheated
- The nozzle orifice is blocked by carbon or spark deposits.
- The nozzle touches the molten pool.
- There is leakage near the nozzle.
- Eliminate the causes before proceeding further to avoid backfire.

Flashback

Sometimes during backfire, the flame goes off and the burning acetylene gas travels backward in the blowpipe towards the regulator or cylinders. This is known as flashback

Indications of flashback A Sharp squealing sound inside the blowpipe may be heard.

Heavy black smoke and sparks come out of the nozzle. (Fig 1)

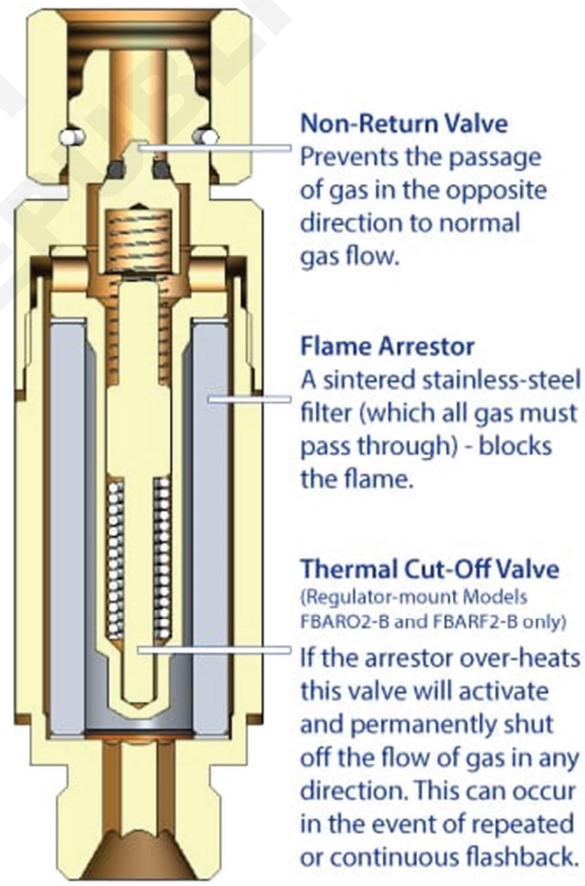
The blowpipe handle starts heating.

Immediate steps: Close the blowpipe valves (oxygen first).

Immerse the blowpipe in water and close the cylinder valves.

If the backfire or flashback is not checked in time it may cause serious accidents to men and machines.

Fig 1



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 confirming 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:

a the type and composition of base metal

b the base metal thickness

c the type of edge preparation

d the weld is deposited as root run, intermediate runs or final covering run

e welding position

f 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 per-cent 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.
Stellate: 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
Stellate: Grade 6	Hard facing of components subjected to shock and abrasion, (Surface fusion technique with excess acetylene flame.)	-do-
Stellate: 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 nece-ssary for brazing copper alloys.
Silver-copper-zinc (61 per-cent 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 necess-ary 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 per-cent 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.

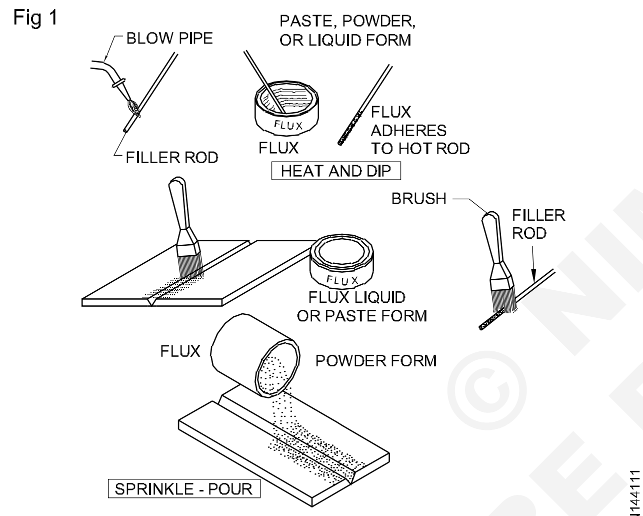
The function of flux in gas welding: To dissolve oxides and to prevent impurities and other inclusion that could affect the weld quality.

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.

Fig 1



METHOD OF APPLICATION

MRN144111

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)

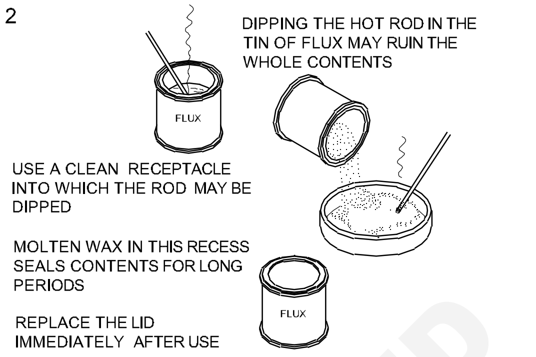
Though the inner envelope of an oxy-acetylene flame offers protection to the weld metal, it is necessary to use a flux in most cases. Flux used during welding not only protects the weldment from oxidation but also from a slag which floats up and allows clean weld metal, to be deposited. After the completion 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

Fig 2



METHOD OF STORING FLUX

MRN144112

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 between fusion and braze welding

Soldering	Braze welding
Make a temporary joint	Makes a temporary joint
Soldering process differ from fusion welding in the sense that there is no direct melt of the base metal being welded	Requires less heat as a filler metal with a lower melting point is fused into the pre-heated joint.
The filter alloy flow between two closely adjacent faces by capilary action	A distinct colour change is seen.
Solder is alloy of lead and tin	Less distortion is possible.
The filler metal ned soldering have a melting point below 420°C	Cannot be done without a proper flux.
Solder flex used depends upin for	Can be done without dismantling the parts
Various material	Can be done with a lesser skill.

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

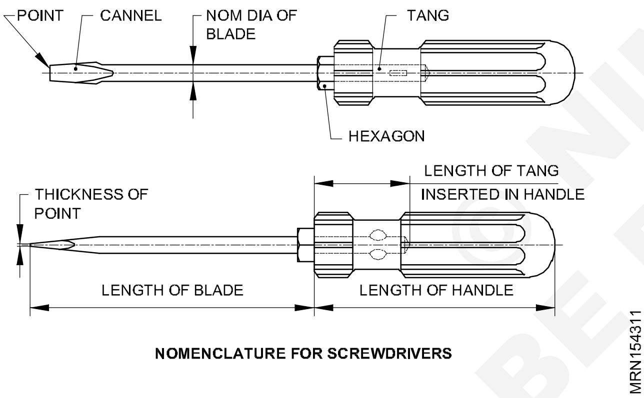
Diagonal cutting plier: It is used for cutting small diameter wires and cables especially when they are close to terminals. It is also used to remove the insulation from cables and cords. It can be used for splitting and removing cutter pins.

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.

Fig 1



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.

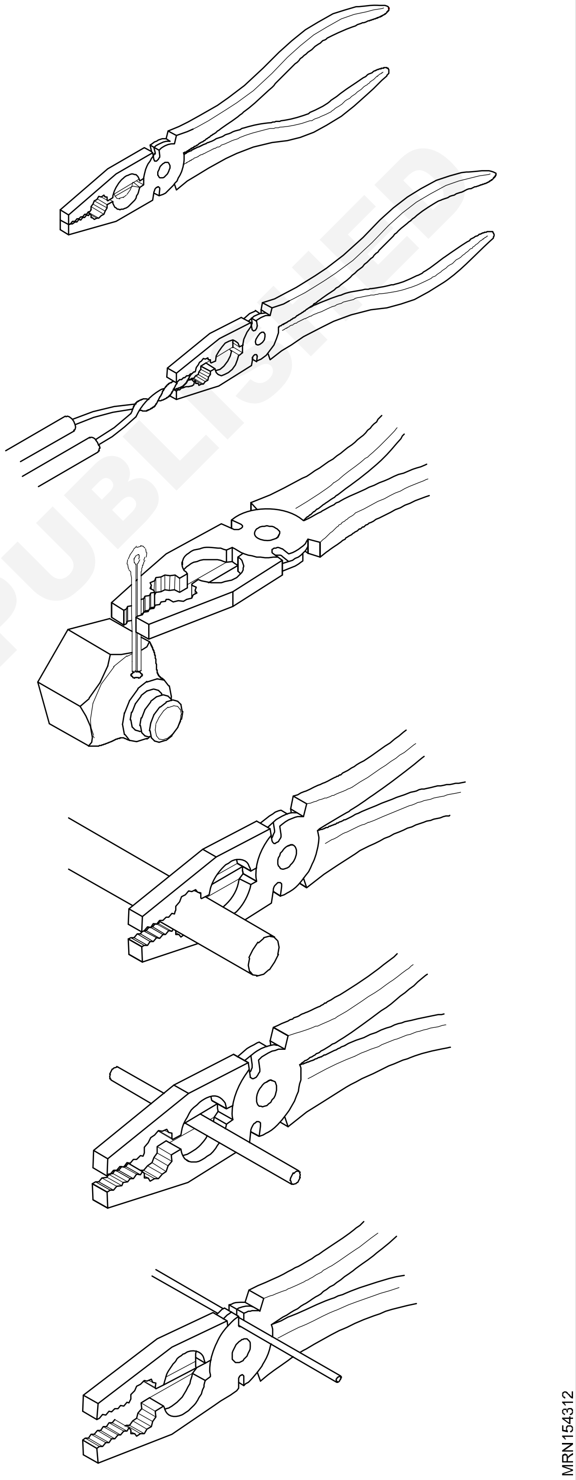
They also have a pair of SIDE CUTTERS which are used to cut small diameter wires and cables.

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



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.

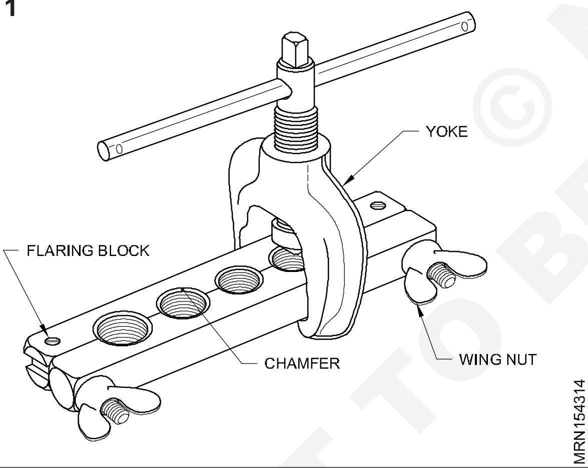
In 1935, Frederick McKinley Jones produced an automatic refrigeration system for lonhaul trucks. From a small, slow start in the late 1930d, air conditioning of automobiles has also grown rapidly.

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.

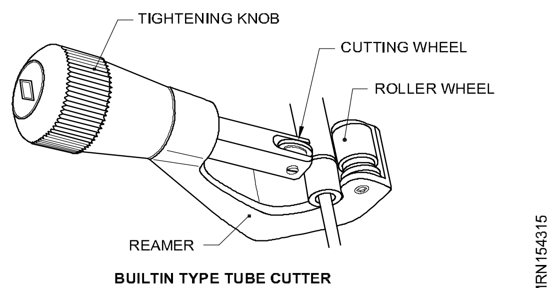
Fig 1



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.

Fig 2

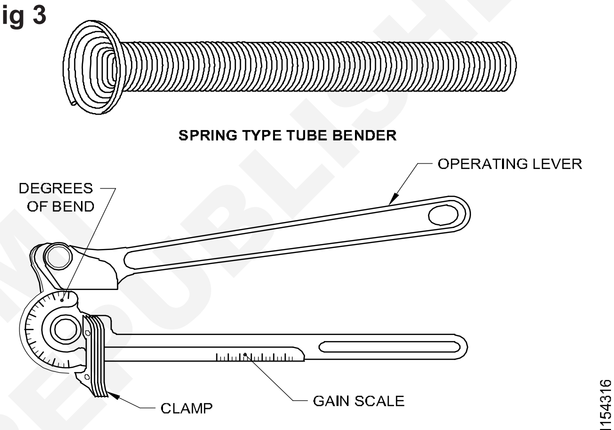


BUILTIN TYPE TUBE CUTTER

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.

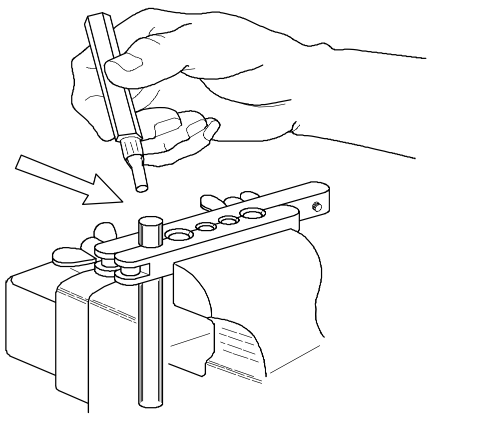
Fig 3



MECHANICAL TYPE TUBE BENDER

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.

Fig 4

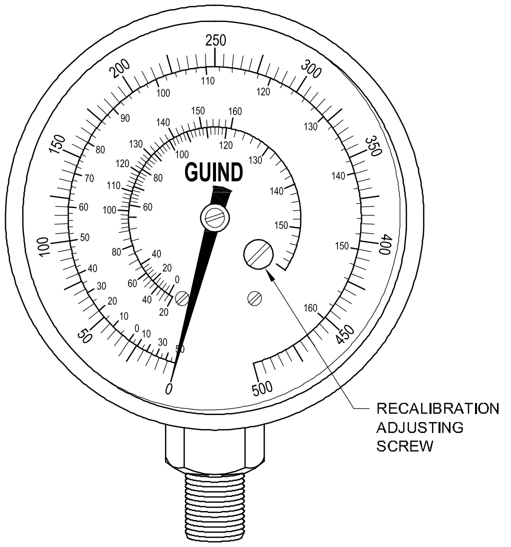


Pinching tools: It is used for sealing or closing the diameter of copper tubes. It consists of two bars forming jaws and holes of various sizes and are clamped together with using nuts and bolts. The tube is pinched off both the two jaws.

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.

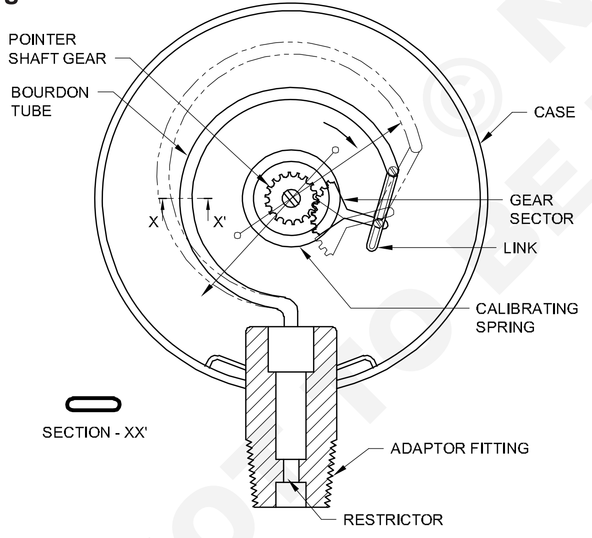
A pressure rise in Bourdon tube makes it tend to straighten. This movement will pull on the link, which will turn the gear sector counter clockwise. The pointer shaft will then turn clockwise to move the needle. Most popular gauges have a 2½" dial and are connected into refrigeration system with 1/8"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

Fig 5



PRESSURE GAUGE

Fig 6



INTERNAL CONSTRUCTION OF PRESSURE GAUGE

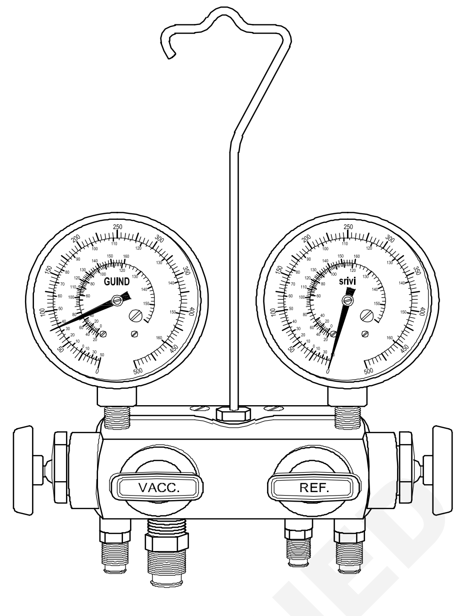
Compound gauge (Fig 7) : It measure both pressure and vacuum. It is usually calibrated from 0 to 30 Hg and from 0 to 200 PSIG.

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

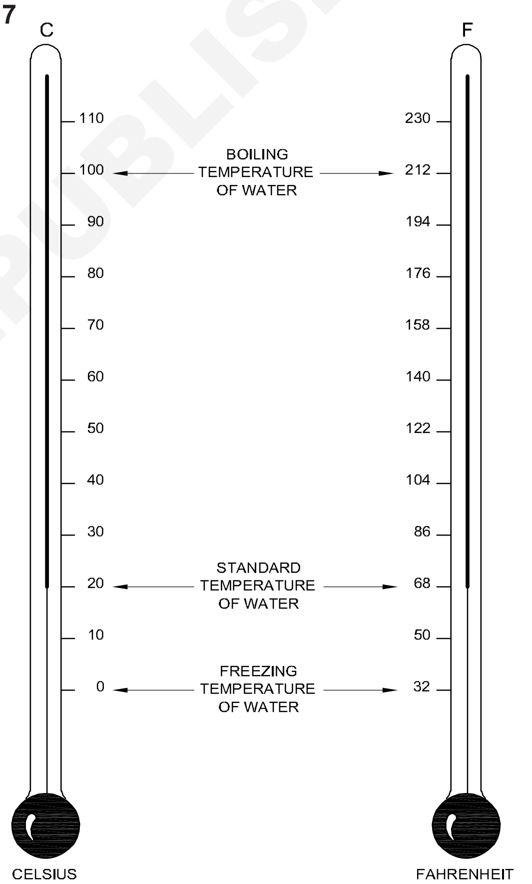
– the temperature of boiling point

Fig 6



COMPOUND GAUGE

Fig 7



A COMPARISON OF CELSIUS AND FAHRENHEIT THERMOMETER SCALES

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).

Fig 8

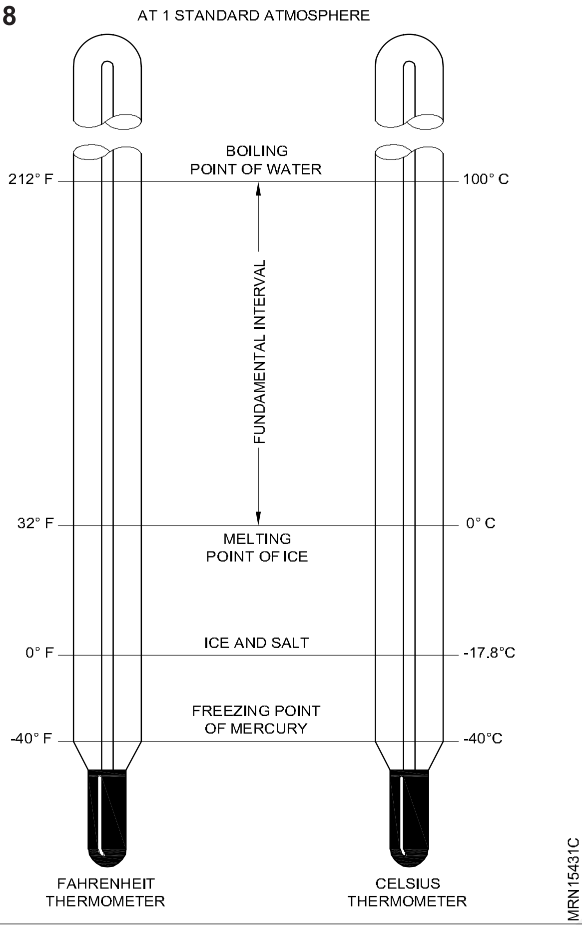
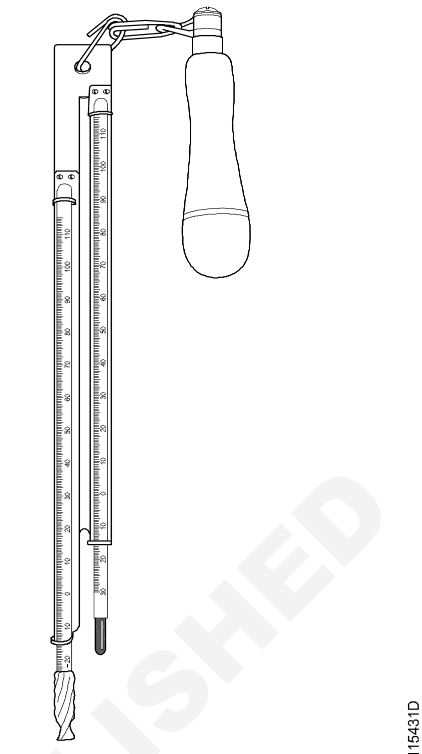


Fig 9



SLING PSYCHROMETER

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.

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.

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

- Head spindle
- Speed selector
- Pointer lock S button
- 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

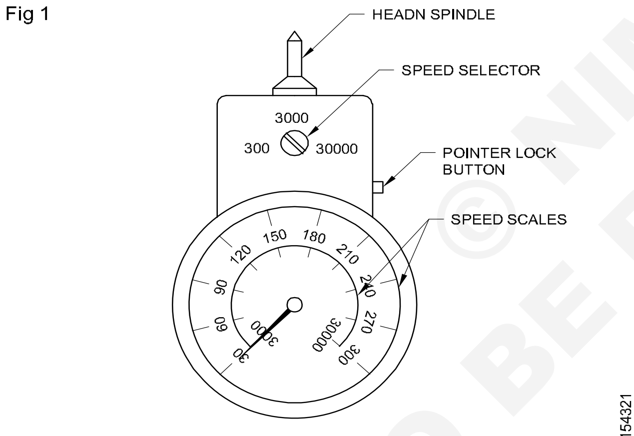
In practice both the methods are being used by electricians.

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

- Revolution counter and stop watch
- Tachometer

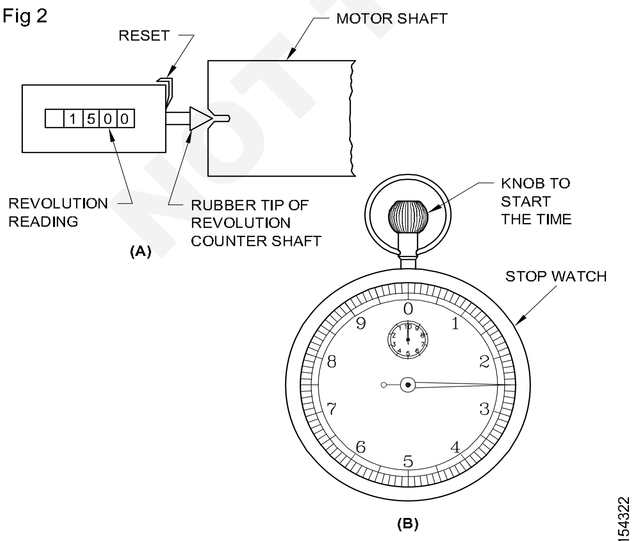
Revolution counters: Revolution counters are of two types; one is a dial type counter which is an earlier version and has become obsolete (Fig 1). The other type is a digital counter which is shown in (Fig 2). The spindle of the counter which is provided with a conical rubber bush is placed in the countersunk 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.

Fig 1



TACHOMETER

Fig 2

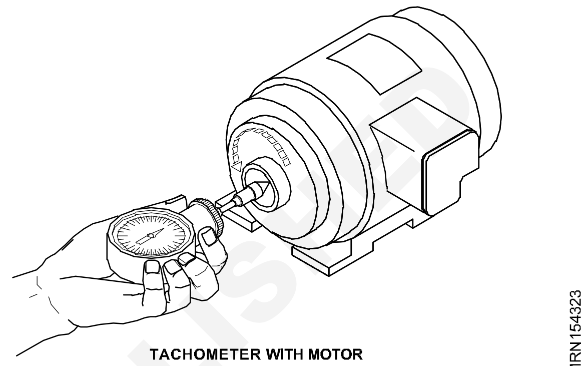


REVOLUTION COUNTER

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.

Fig 3



TACHOMETER WITH MOTOR

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

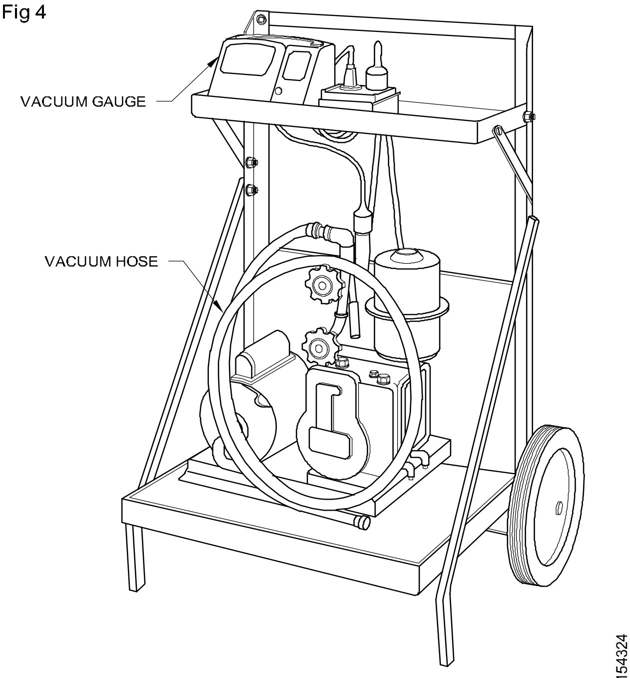
Applications: Tachometers are of two types

– 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)

Fig 4



PORTABLE HIGH-VACUUM PUMP

– 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

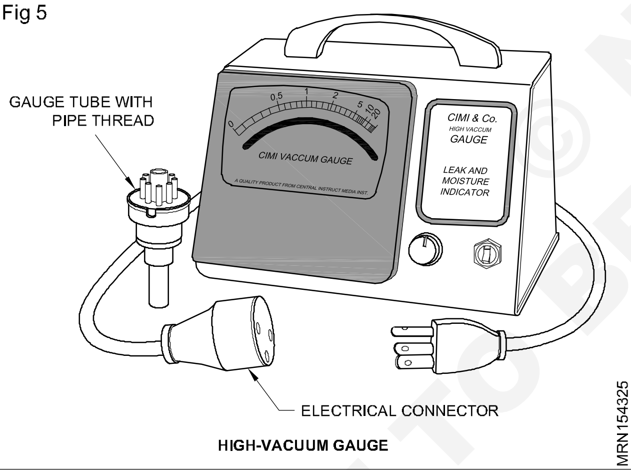
– vacuum gauge

– vacuum hose

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.

Fig 5



HIGH-VACUUM GAUGE

Compressor main parts

Reservoir: A tank for storage of air

Motor: Drives the engine (compressor)

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

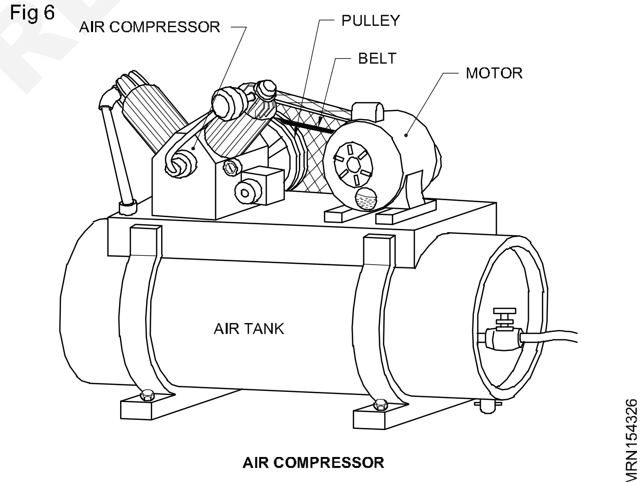
– It is used to test the leakage by building up pressure

– 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 6



AIR COMPRESSOR

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.

T 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.

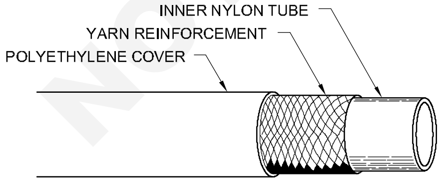
It is also available in all sizes as copper tube.

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.

Fig 1

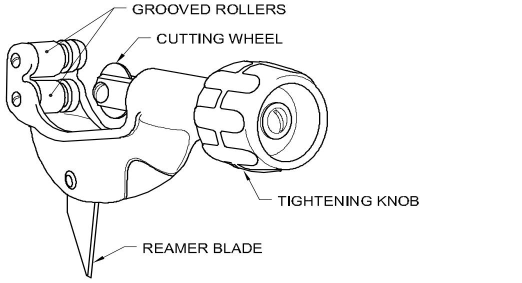


THERMOPLASTIC HOSE (FLEXIBLE TUBING)

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.

Fig 2

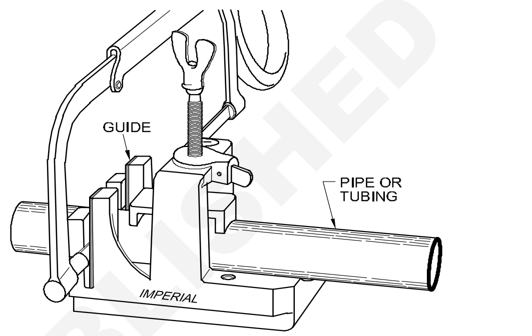


TUBE CUTTER WITH REAMER

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)

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.

Fig 4

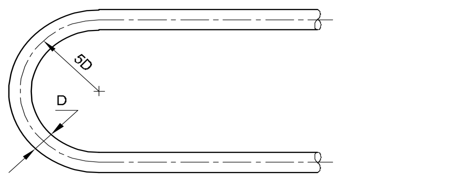


Fig 5

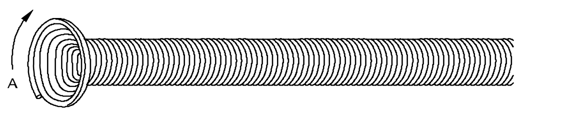
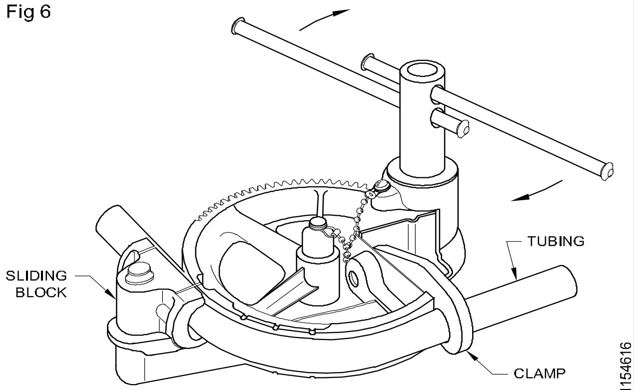
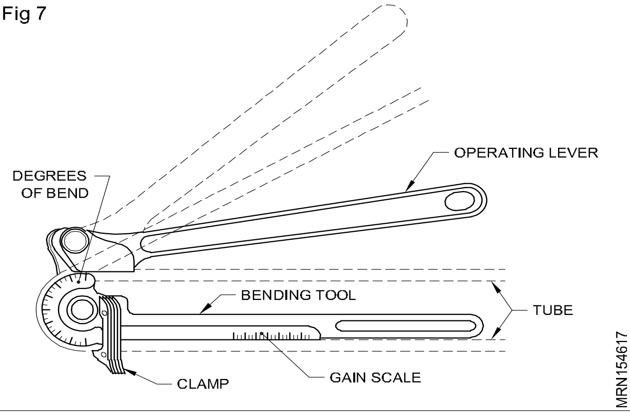


Fig 6



ACCURATE TUBE BENDER

Fig 7

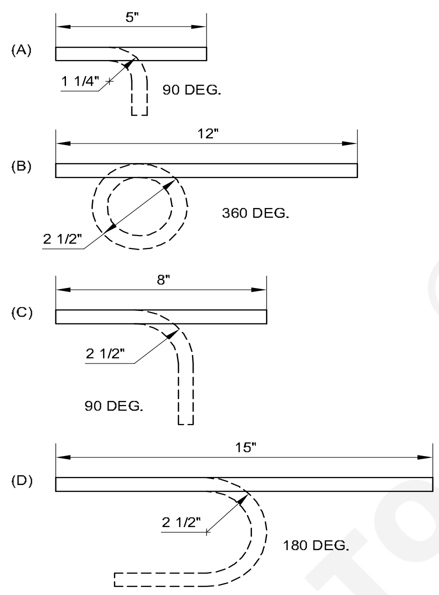


An external bending spring for 6mm OD tubing may be used as an internal bending spring for 12mm OD tubing.

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.

Fig 8

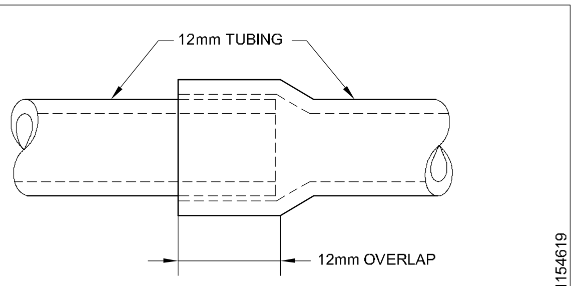


SOME PRACTICE BENDS ON TUBING

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)

Fig 9



SWAGING ON COPPER TUBING

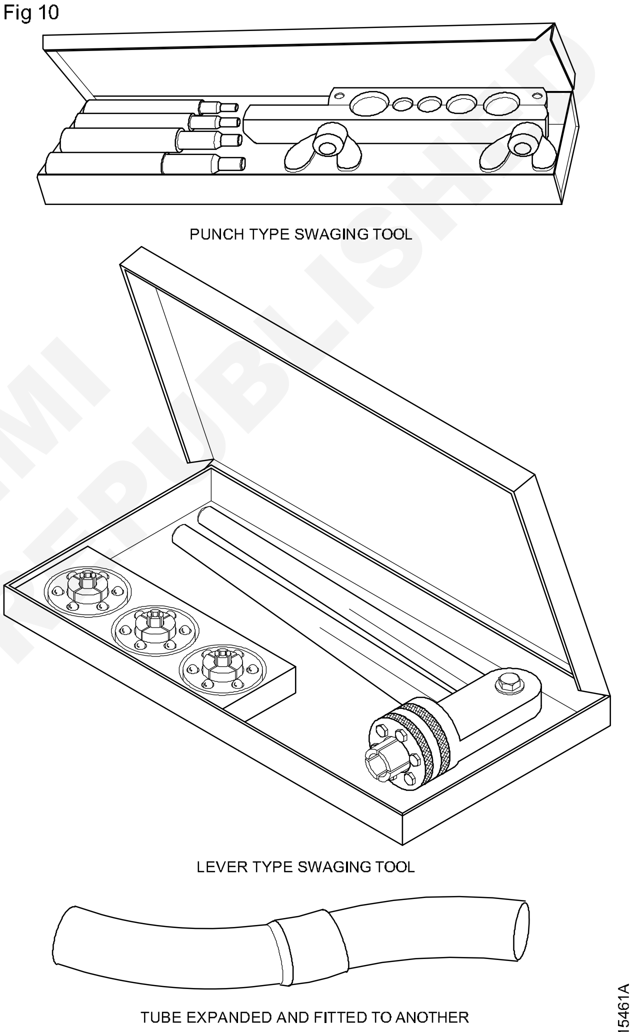
Two types of swaging tools are commonly used. The punch type and the lever type. In both cases, different tool sizes are available.

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.

Fig 10



SWAGING TOOLS

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

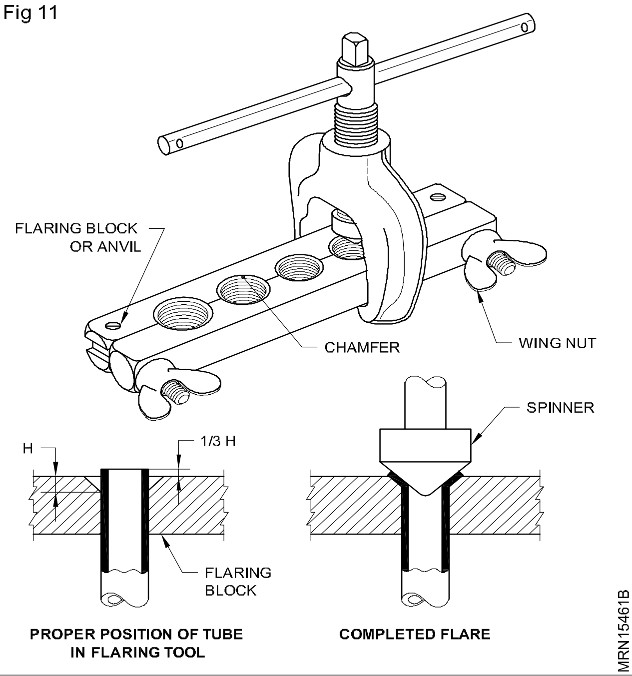
Types of flaring: There are two types of flaring

– Single thickness flare

– Double thickness flare

Single thickness flare: It can be made on smaller size copper tubing. (Fig 11)

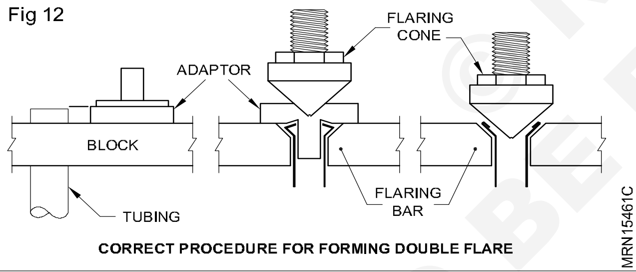
Fig 11



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



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/cm^2

The gas which is employed can be used for testing.

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

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

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 13

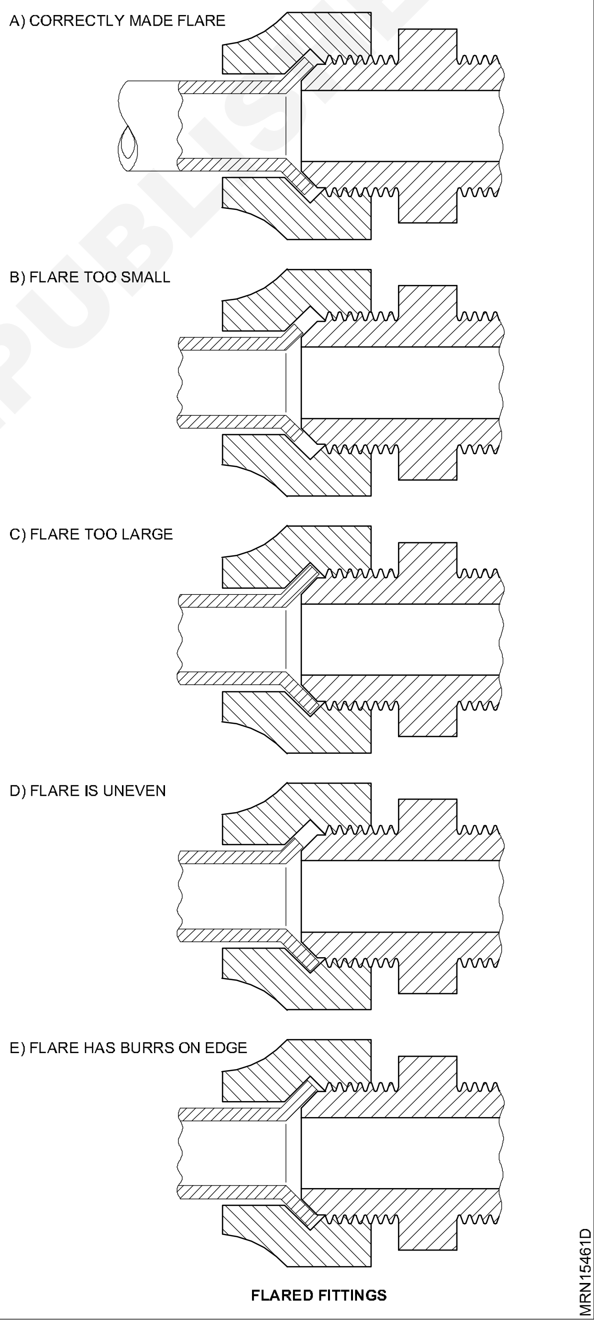
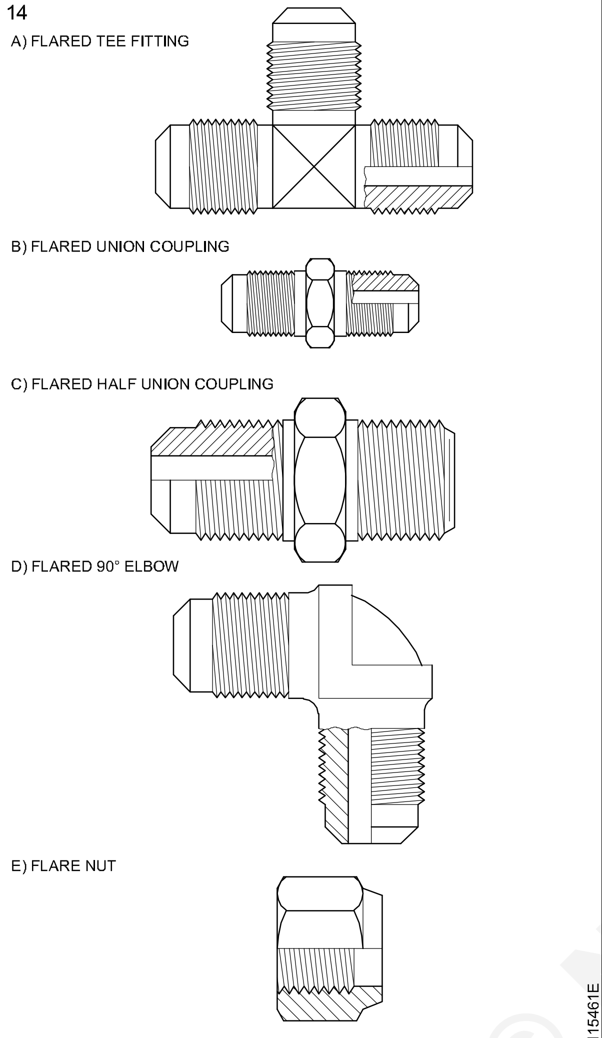
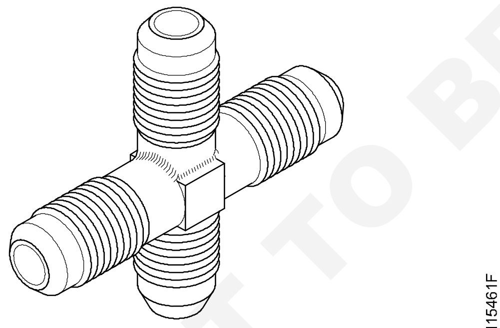


Fig 14



FLARED TYPE FITTINGS

Fig 15



CROSS

Fig 16

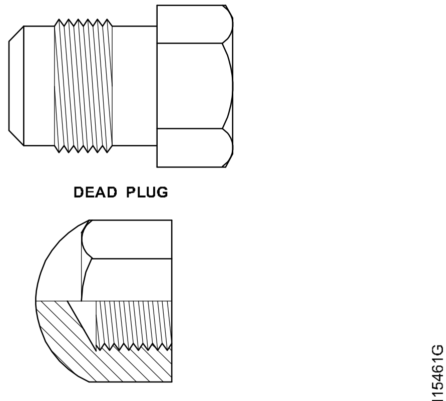
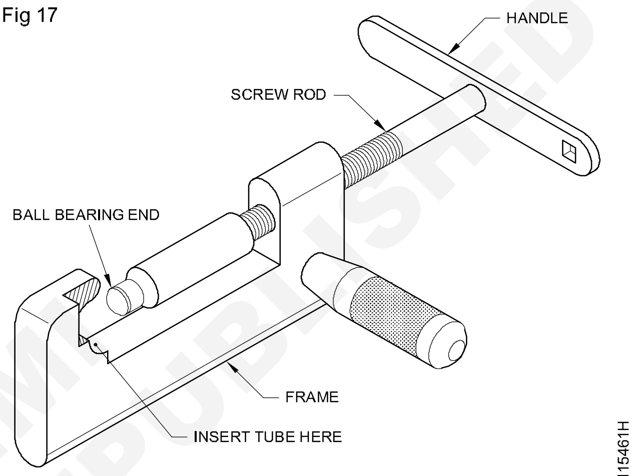


Fig 17



PINCH-OFF TOOL

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 recommened 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, reducing repair time and defects.

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.

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 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 Keal/Kg or BTU.

The change in internal energy is denoted by $\triangle$U.

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

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

P (RT) = 10 kw/ 3.5168525

= 2.8434516 (or) 2.84

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.

Sub-Cooling

If the temperature of the refrigerant liquid is less than its saturation temperature, the liquid is said to being sub-cooled condition. If the pressure of a liquid say R-22, is 13.8 kg/cm^{2}G (195.9PSIG)from the tables we can find that its saturation temperature is 37.8^0C(100^0F). But if the liquid is cooled to 35^0C (95^0F) without allowing the pressure to drop down below 13.8 kg/cm^{2}G (195.9 PSIG) by some means, the liquid is said to be sub-cooled by 37.8-35=3.8^0C (100-95=5^0F).

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-called 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 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. Like wise 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

Types of refrigeration systems and applications

Objectives: At the end of this lesson you shall be able to
- **explain function of refrigeration**
- **explain types of refrigerating 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

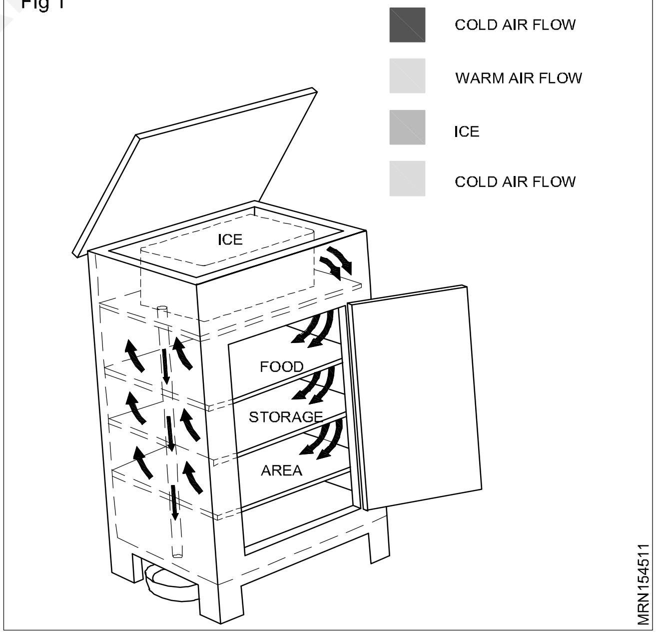
Ice refrigeration system

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 0^0C (centigrade) and refill the ice after melting.

A 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 32^0F, ice and salt mixture may be used.

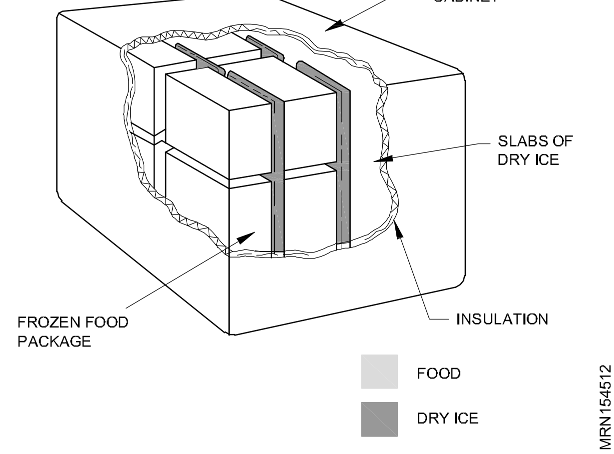
Fig 1



Dry ice refrigeration (Fig 2)

Solid carbon dioxide is known as dry ice. It directly change solid to vapour stack by absorbing heating and maintained a temperature at -78^0C. 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.

Fig 2



Liquid gas refrigeration system

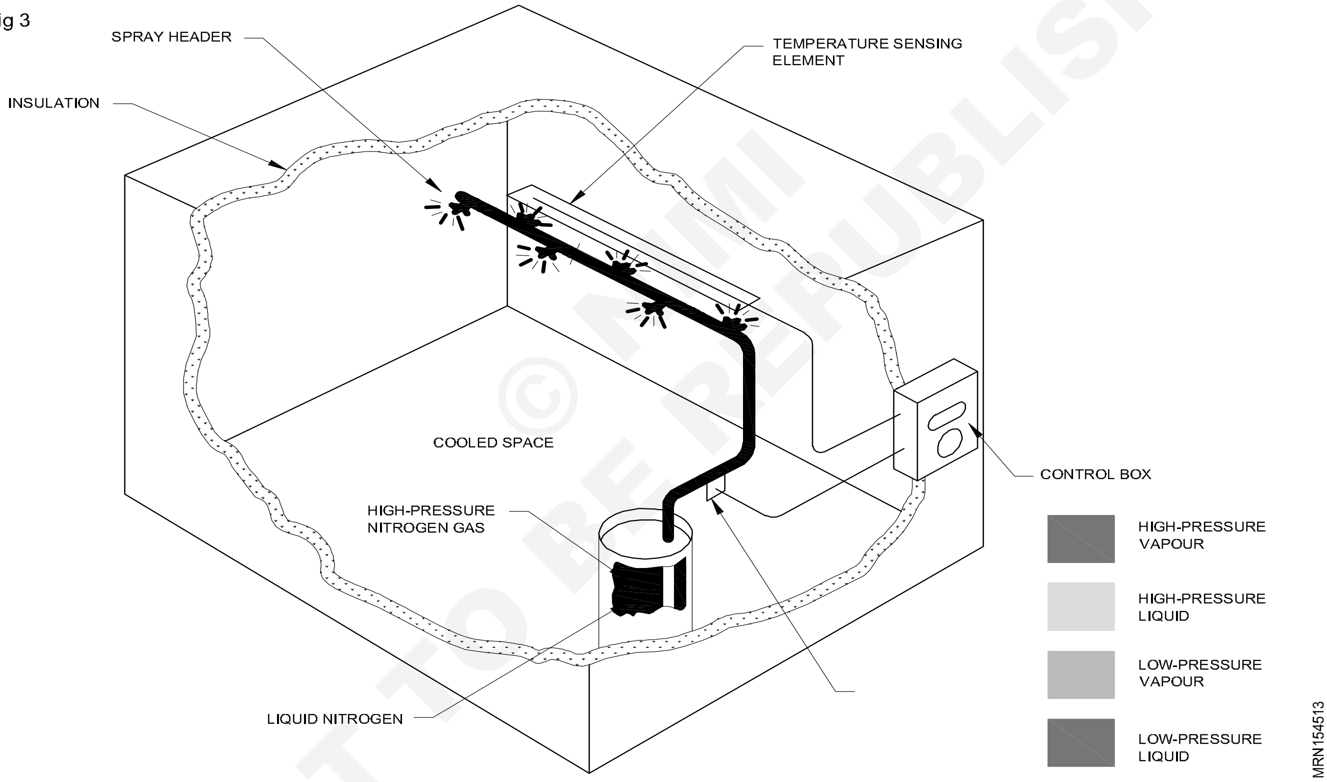
In this system the non poisonous liquid (Nitrogen) is used to cool the space. This system is called as expandable refrigerant refrigeration system also or chemical refrigeration.

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.

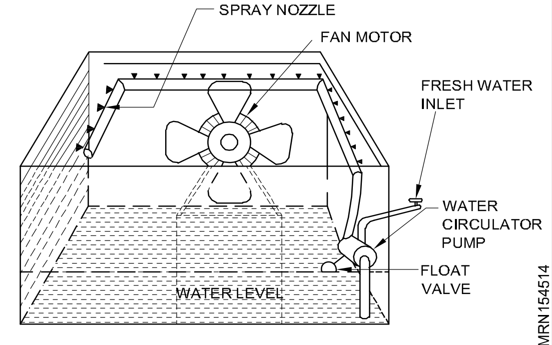
Fig 3



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)

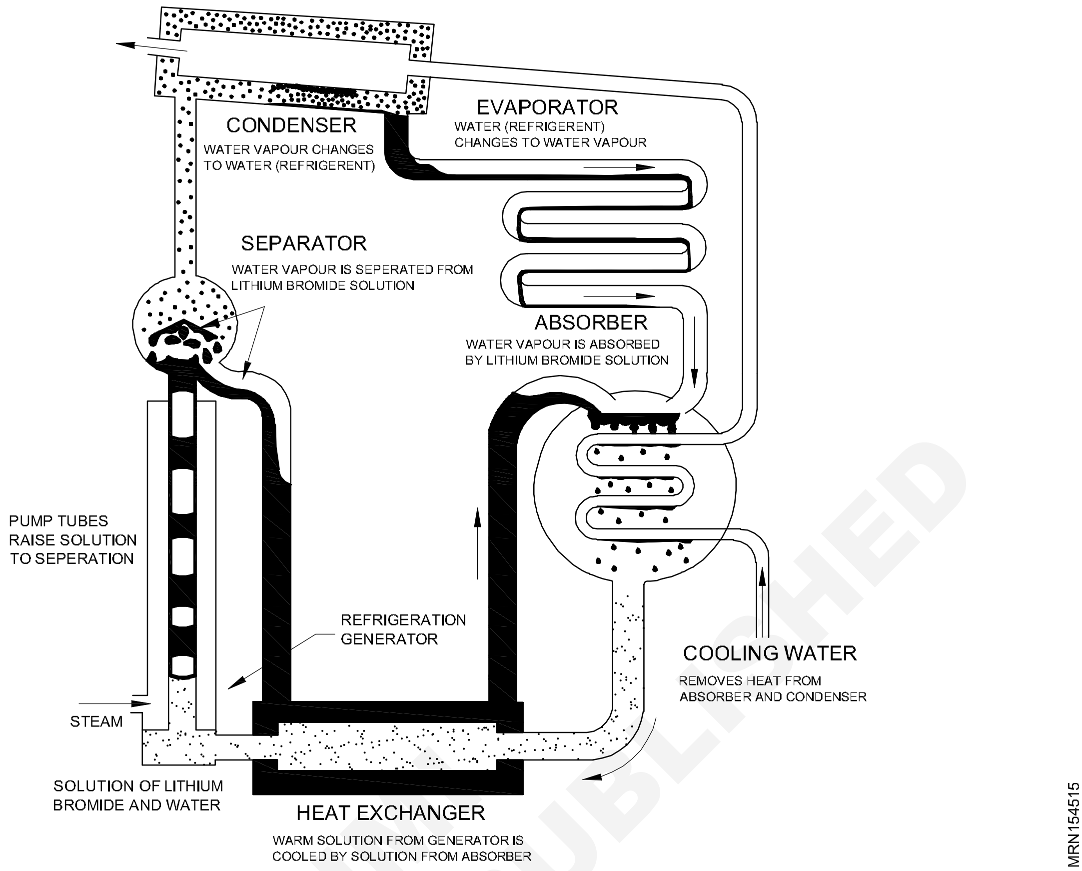
Fig 4



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)

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 absorbant 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, there by 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 liquefied 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 upto 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 absorbs are inter connected so the refrigerant vapour formed in the evaporator is absorbed by the absorbent in the absorber to maintaining the refrigerant vapour pressure in one evaporator at the low level required for continuous vapourization of liquid refrigerant to obtain refrigeration. To recovered 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.

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 vapourization 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

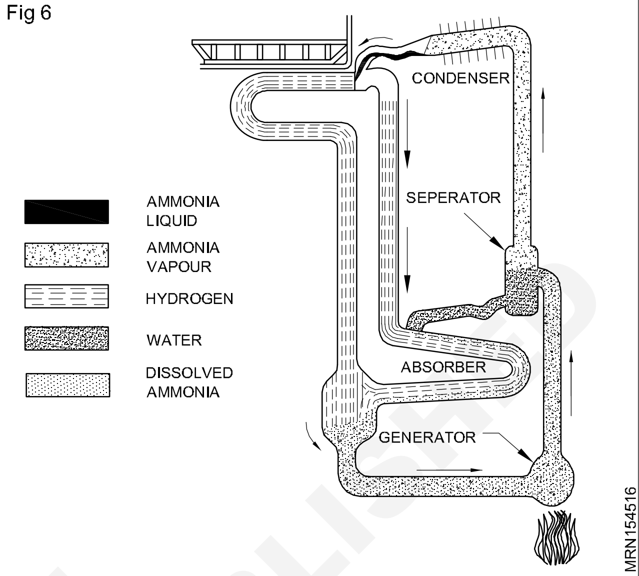
In three fluid absorption system a lighter gas compared to the refrigerant vapour is introduced into the system. The pumping system is eliminated. As such a complete leak-proof silent system is achieved. It consists of a generator where heat transfer with weak solution is bubble form moves up to the separator. The weak solution then returns to the absorber through a liquid seal, while the vapour condenses the 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

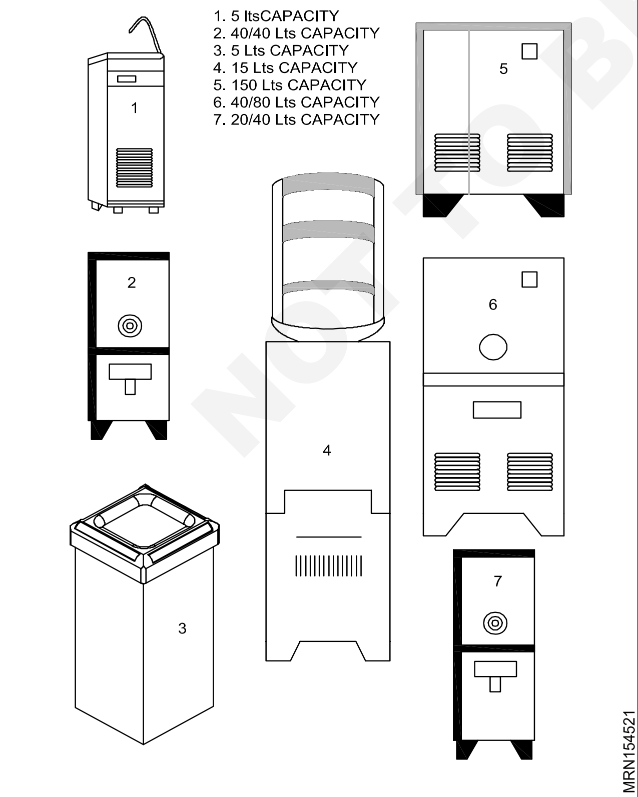


Application of vapour compression system

Objectives: At the end of this lesson you shall be able to
- **explain the devices of vapour compression system.**

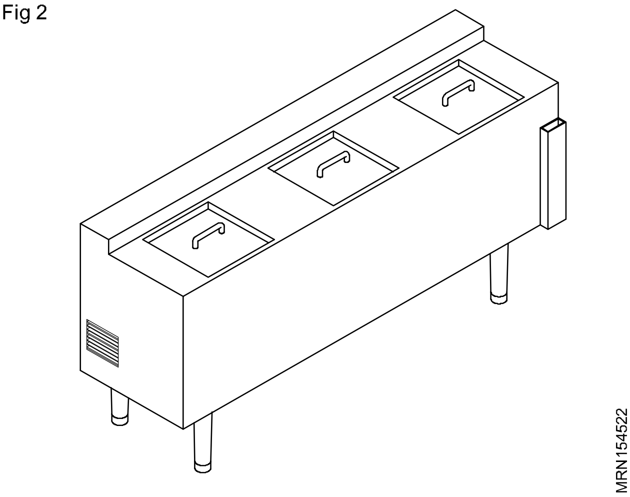
Water Cooler: Water cooler becomes an important aspect to quench thirst of human/people at various centre's such as restaurants, theatres, offices, commercial complex etc (Fig 1).

Fig 1



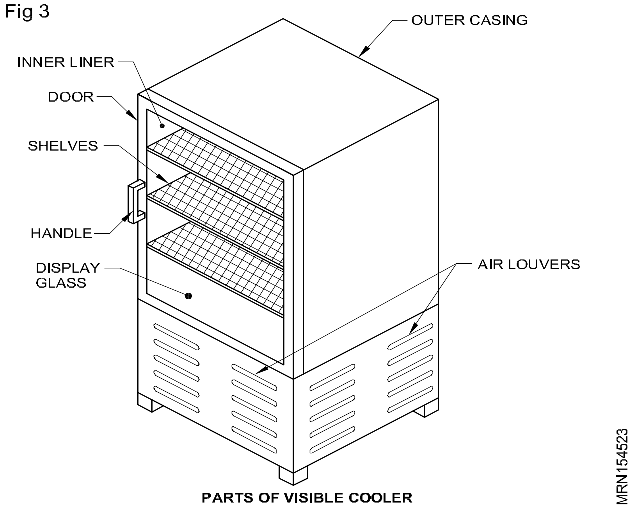
Bottle cooler: The bottle coolers are used in petty shops offices and commercial establishments. Direct expansion type bottle coolers are one in which the cooling coil is wound around the storage tank. The winding of coil in other type of bottle coolers are inside the storage tank.(Fig 2)

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 fold 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 10^0C inside (Fig 3)

Fig 3

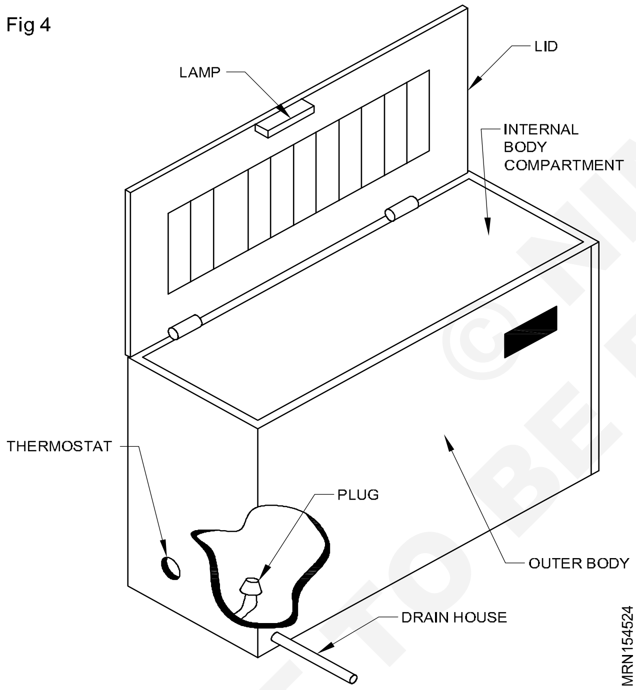


PARTS OF VISIBLE COOLER

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 (-10^0 C to 30^0 C) (Fig 4)

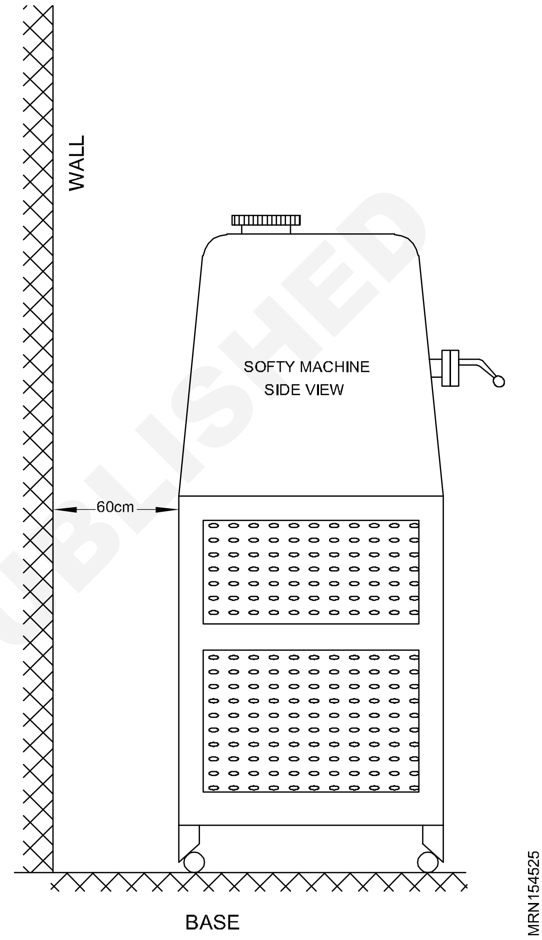
Fig 4



Softy machine

Ice cream mix containing milk cream, syrup and fruit or other flavoring 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)

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 resulting 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, absorption system, steam jet refrigeration cycle etc.

Thermo dynamic processes

When a substance, in any of the physical state 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 0^0C is heated, instead of expanding, it contracts. This contraction continues until the temperature of water reaches 4^0C(39.2^0F). Thereafter, further heating will result in expansion. Similarly, water at 5^0C when cooled contracts, but on attaining 4^0C(39.2^0F), any further cooling will make the water expand and not contract until the temperature touches 0^0C(32^0F), 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 4^0C, 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 4^0C. When the surface temperature goes below 4^0C, 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 0^0C. Thus water in a lake or ocean freezes at the surface while the water below remains at 4^0C. 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 creats 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 oly an increase in its pressure but also a lowering of its temperature is requied. 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

Pressure x Volume (P x V) = 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.,

2 Pressure varies as temperature if the volume of the gas is kept constant, i.e.,

Combining these three laws, we have the general gas law, giving the equation,

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 1^0, 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 1^0 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 at application a distance of one metre.

Power

The rate of doing work is known as power.

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 enery.

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 10^0C has more heat in it than the same substance at a temperature of 0^0C. 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 0^0C and the boiling point of water is 100^0C. The interval between these two points is divided into 100 equal divisions and each division is called one degree celsius (1^0C).

Fahrenheit Scale

The melting point, of ice is fixed as 32^0F and the boiling point of water is taken as 212^0F. The interval between the two is divided into 180 equal divisions and each division is called one degree Fahrenheit (1^0F).

Absolute Temperature (Rankin)Scale

The absolute zero on this scale (expressed as ^{0}R) is -460^0F. So to arrive at the absolute temperature of a substance expressed in ^{0}F, add 460 to the given temperature, e.g. absolute temperature of ice melting is 32^0F+460=492^0R.

Absolute Temperature (Kelvin) Scale

The absolute zero on this scale is -273^0C. So the melting point of ice on the Kelvin absolute scale is 0^0C +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

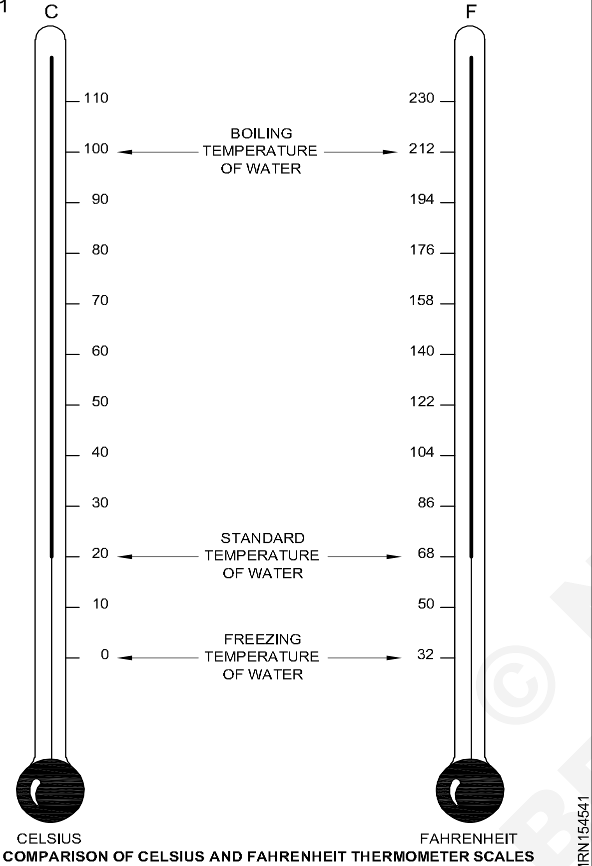
To measure the amount of heat, we have heat units-the British thermal unit (BTU) in the British system and calorie in the metric system.

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 (1^0F).

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(1^0C). 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 1^0C.

Fig 1



A COMPARISON OF CELSIUS AND FAHRENHEIT THERMOMETER SCALES

MRN154541

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 0^0C.

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 -10^0C. Ice at 10^0C when heated, rises in temperature up to 0^0C (32^0F). The heat absorbed by the ice to raise its temperature from - 10^0C to 0^0C is therefore sensible heat and it takes about 0.48 kcal of heat to raise the temperature of 1 kg of ice by 1^0C or 0.48 BTU for 1 lb of ice through 1^0F (0.48 is the specific heat of ice).

Latent Heat

Any further heat added to ice at 0^0C changes the solid ice to liquid water. During this change of state, the temperature remains constant, i.e, 0^0C (32^0F). 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 0^0C requires about 80 kcal of heat for changing its state to water at 0^0C (144 BTU per lb of ice).

The liquid water at 0^0C (32^0F) when heated rises in temperature, taking sensible heat (one kcal for one kg of water for 1^0C rise or one BTU for one lb of water for 1^0F rise in temperature). This holds true upto 100^0C (212^0F). At 100^0C (212^0F) any further addition of heat does not raise the temperature of water, but instead goes to change the liquid water to is 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 100^0C/212^0F(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 (1^0C/1^0F), 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 (1^0C/1^0F)

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 32.2^0C(90^0F).At that time the pressure would have been 11.8 kg/cm2G(168.4 PSIG)- the saturation pressure at 32.2^0C (90^0F). Any further increase in the temperature of the cylinder above 32.2^0C (90^0F) 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 through they might be having different amount of heat in them.

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: These is no area between the process diagram and the volume axis, there is no workdone 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 entalpy, h is the enthalpy of 'I' 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/16

u = the internal energy in BTU/16

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°)

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.

A skeleton 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)

$R_E = h_1 - h_4 = h_1 - h_{f3}$ (h_{f3} = Sensible heat of T_3)

$$COP = \frac{\text{Refrigeration effect}}{\text{work done}} = \frac{\text{RE}}{\text{Heat of compressor}}$$

$$= \frac{h_1 - h_{f3}}{h_2 - h_1}$$

Mass flow rate of refrigerant (m)

$$= \frac{\text{Refrigerating Capacity}}{\text{Refrigerating effect}}$$

$$m = \frac{KW}{KJ / Kg}$$

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.

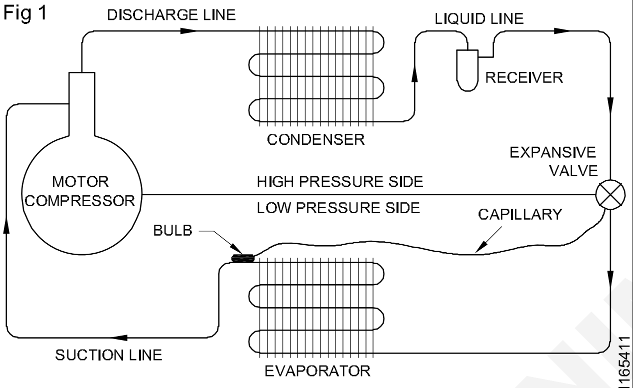
Direct cool and frost free refrigerators

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).

Fig 1



TYPICAL COMPRESSION REFRIGERATION SYSTEM

The cycle works in four phases
- compression
- condensation
- expansion
- evaporation.

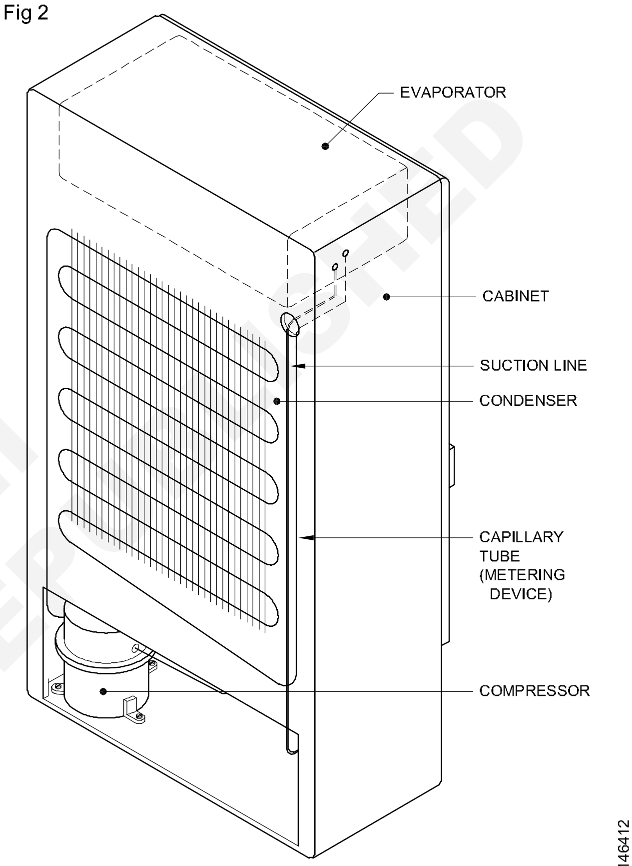
Conventional refrigeration: The important parts of the refrigerator are shown here in (Fig 2).

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 liquefied. 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 refrigeration not being in the system. The receiver should have sufficient capacity to hold the total amount of refrigerant in the system.

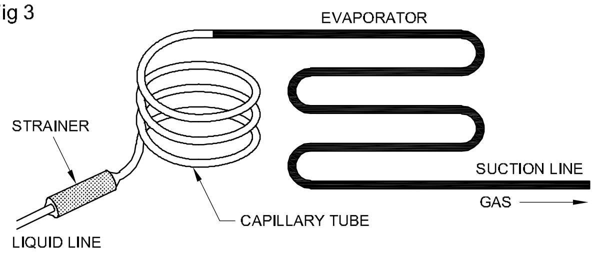
Fig 2



HOUSEHOLD REFRIGERATOR

- **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.

Fig 3



CAPILLARY TUBE AND STRAINER

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.

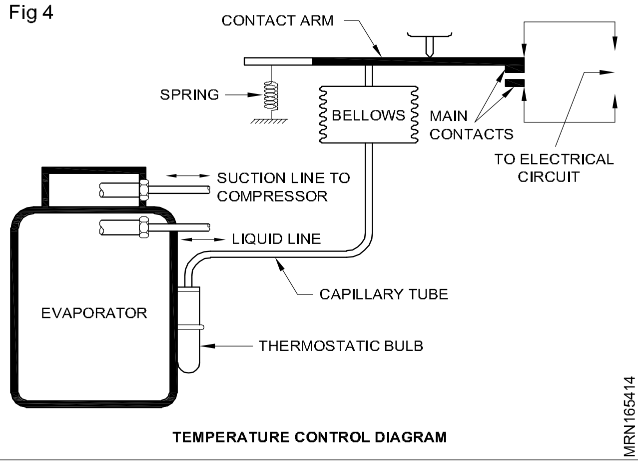
Thermostatic control: The common method of temperature control employed in house hold refrigerations units.

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.

Fig 4



TEMPERATURE CONTROL DIAGRAM

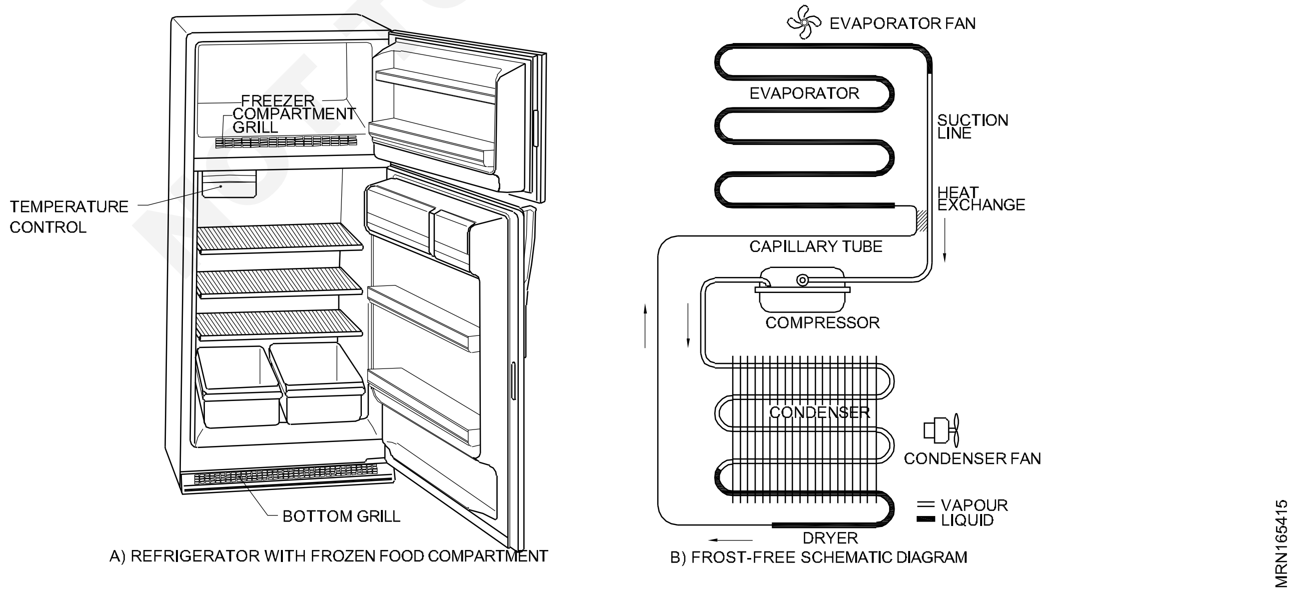
Discharge line: The line between compressor and the condenser is called discharge line, which is towards the high pressure side of the system.

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



A) REFRIGERATOR WITH FROZEN FOOD COMPARTMENT

B) FROST-FREE SCHEMATIC DIAGRAM

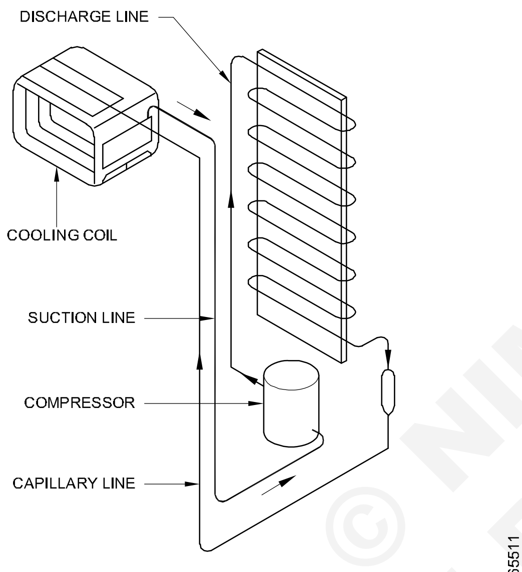
Components of Conventional type refrigerators

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).

Fig 1



REFRIGERATION SYSTEM FOR A SIMPLE HOUSEHOLD REFRIGERATOR/FREEZER.

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.

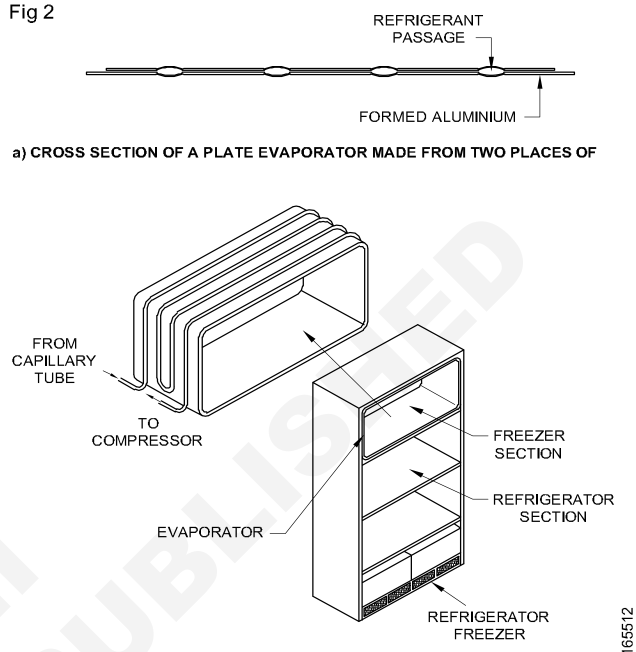
The cycle operation is the compressor, compress refrigerant vapour to a high pressure and temperature, then the vapour flows into condenser by discharge line: when it passes through the condenser, due to natural draft air cooling vapour condense to liquid.

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)

Fig 2



b) PLATE EVAPORATOR FORMED INTO A FREEZER COMPARTMENT.

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.

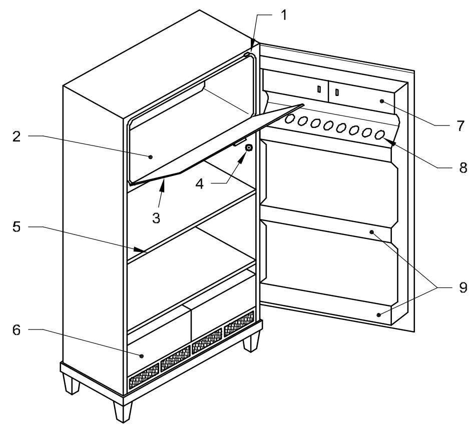
Unfrozen meat and fish should be stored at close to 0°C as possible. Fruits and vegetables should be washed and kept dry to keep in refrigerator.

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.

Fig 3



CONVENTIONAL REFRIGERATOR

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.

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, bimetallic 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 shink 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.

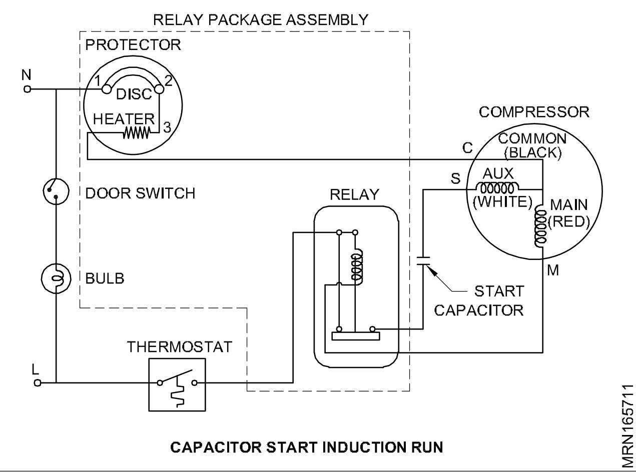
(Fig 1) shows a simple refrigeration electrical circuit. It would apply to a household refrigerators or small commercial water cooler, bottle cooler and deep freezers. The line voltage thermostat senses the cabinet temperature and closes to turn on the refrigeration system. The compressor is series with 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.

Fig 1



CAPACITOR START INDUCTION RUN

Mechanical components in refrigeration system

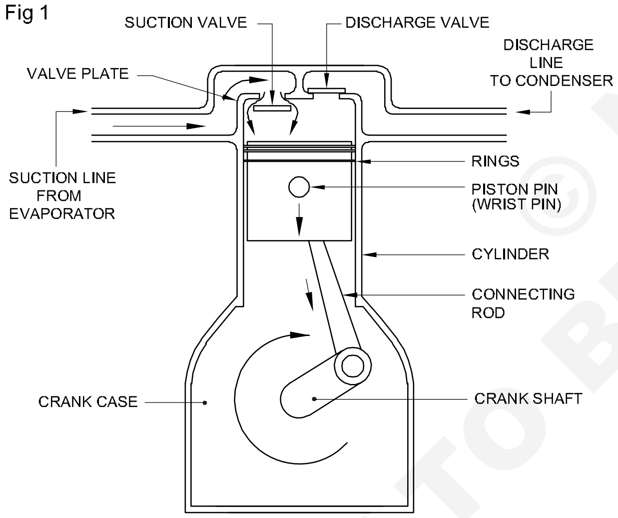
Objectives: At the end of this lesson you shall be able to
- **list the types of compressor1s**
- **study the functions of reciprocating compressor**
- **study the functions of components in reciprocating compressor**
- **study the various types of evaporators**
- **study the essential internal cleaning 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)

Fig 1



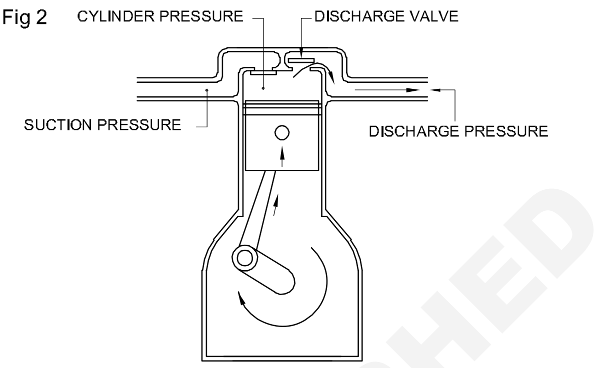
RECIPROCATING COMPRESSOR.
AS THE PISTON MOVES DOWNWARD, THE SUCTION VALVE OPENS, PULLING REFRIGERANT IN FROM THE EVAPORATOR.

Component functions of Hermetically sealed fractional horse power compressor used in Refrigerator (Fig 3)

List of components

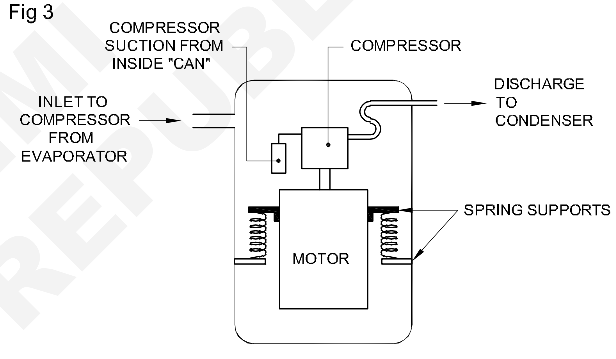
- Suction valve
- Discharge valve
- Crank shaft
- Connecting rod
- Piston pin (or) wrist pin

Fig 2



AS THE PISTON MOVES UPWARD, PRESSURE INSIDE THE CYLINDER INCREASES UNTIL IT FORCES THE DISCHARGE VALVE OFF ITS SEAT. tHE CYLINDER PRESSURE PUSHES THE SUCTION VALVE CLOSED.

Fig 3



A RECIPROCATING COMPRESSOR, SUPPORTED INSIDE A "CAN" BY SPRINGS.

- 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).

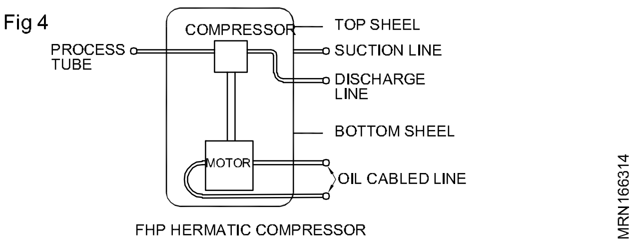
Piston pin : Couple piston and connecting rod. Refer Figs (1 & 2).

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 gas charging, 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).

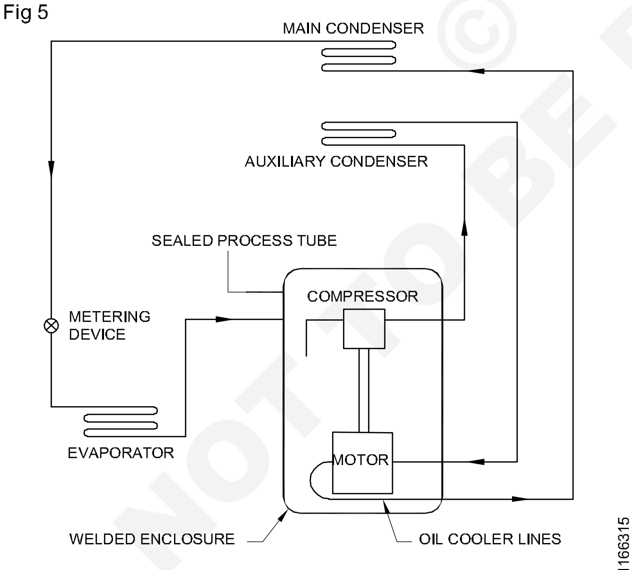
Fig 4



FHP HERMATIC COMPRESSOR

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 auxiliary condenser (Refer Fig 5). In the auxiliary condenser refrigerant lets a part of heat of condensation and then enter into oil cooled line and obsorb the heat from the oil gets heated then enter into main condenser.

Fig 5



WELDED HERMETIC COMPRESSOR WITH AN OIL COOLER.

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).

Fig 6

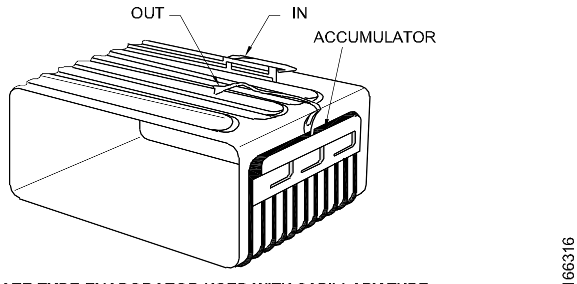
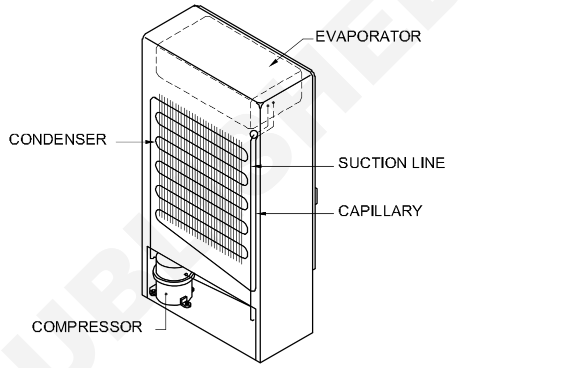


PLATE TYPE EVAPORATOR USED WITH CAPILLARY TUBE TYPE REFRIGERANT CONTROL. (HOUDAILLE-HERSEY)

Forced draft Finned tube evaporators are usually forced draft. This type of evaporator are used in frost free refrigerator Refer (Fig 7).

Fig 7



THE COMPRESSOR IS LOCATED BELOW, THE CONDENSER IS MOUNTED ON THE BACK, THE METERING DEVICE CONSISTS OF A LONG, SMALL-DIAMETER TUBE AND THE EVAPORATOR IS LOCATED INSIDE THE REFRIGERATED SPACE.

A HOUSE HOLD REFRIGERATOR

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.

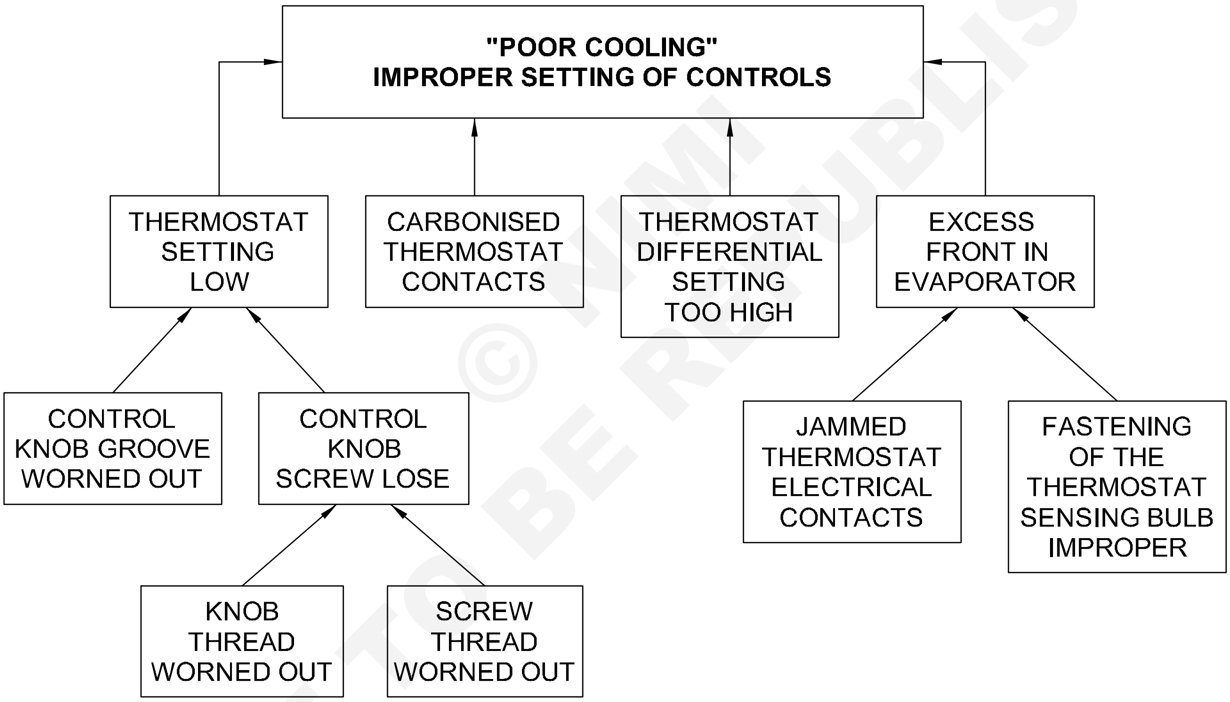
Defects in conventional type refrigerator - “More Cooling” - “Improper setting of Controls”

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”

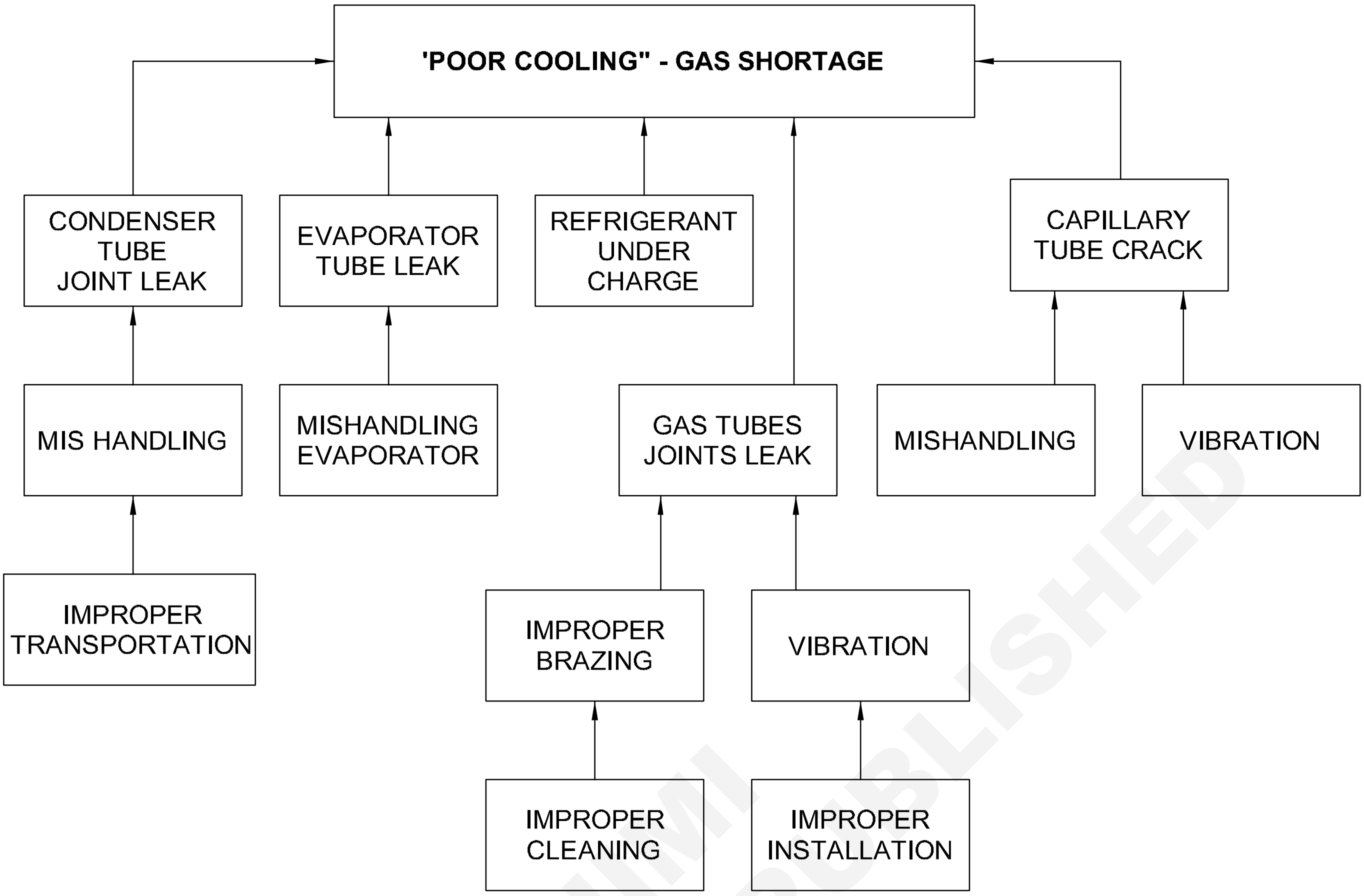
Objectives: At the end of this lesson you shall be able to
- **analyse the causes for the complaint “Poor cooling” - Gas leak with the help of Problem Tree (PT).**
- **analyse the causes for the defect leading to the complaint with the help of Trouble Shoot Chart (TSC)**
- **analyse the sequence for 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”

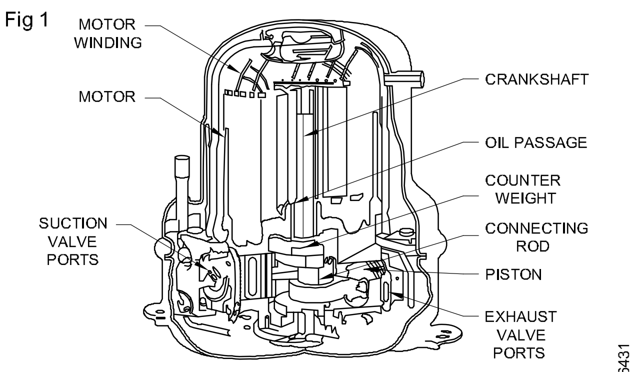
In high leak back in compressor in conventional type refrigerator results “No cooling” in the Refrigerator. Possible causes for the complaint “No cooling” is illustrated in Problem Tree given below.

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 hermatic 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 vacuming, charge refrigerant and test refrigerator performance.

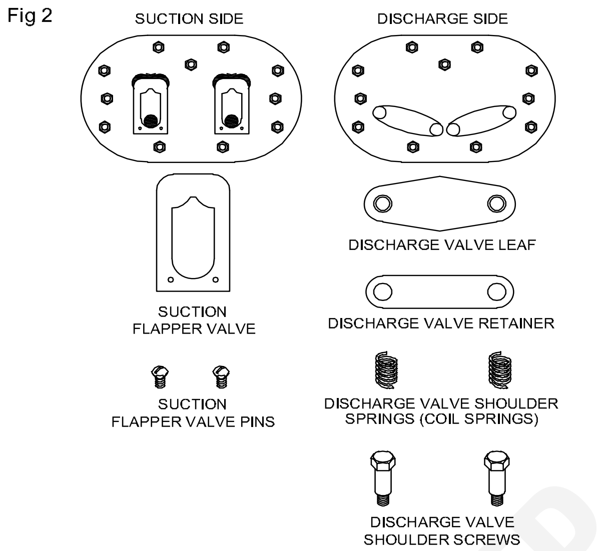
Fig 1



CUTAWAY VIEW OF A TYPICAL TWIN-CYLINDER SEALED COMPRESSOR USED IN HOUSEHOLD REFRIGERATORS

MRN166431

Fig 2



DETAIL OF A TYPICAL COMPRESSOR VALVE ASSEMBLY AND PARTS. THE SUCTION SIDE FORMS THE BOTTOM AND THE DISCHARGE SIDE THE TOP OF THE REMOVABLE VALVE PLATE.

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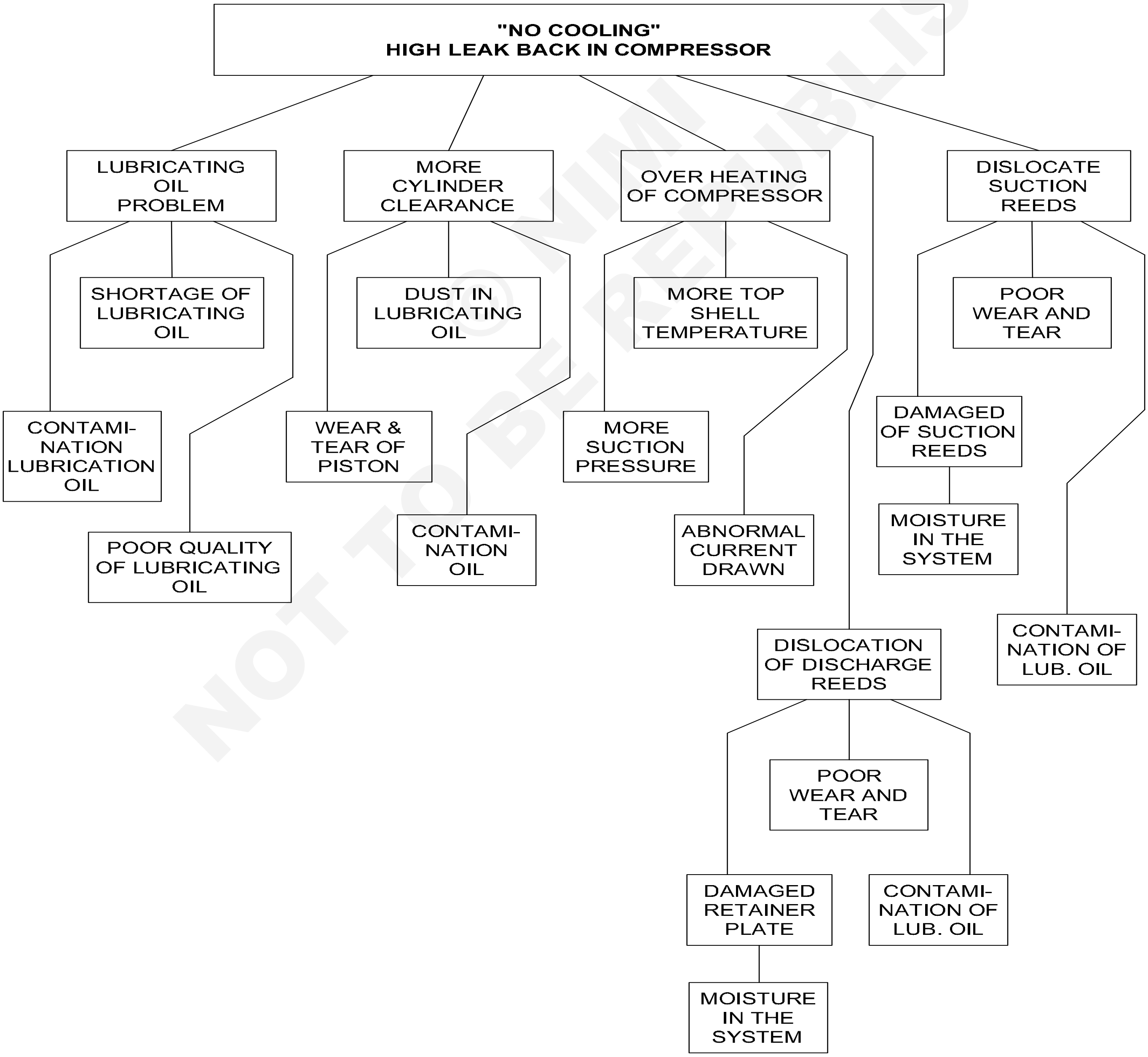
PROBLEM TREE



Defects in conventional type refrigerator - “More Cooling” - “Improper setting of Controls”

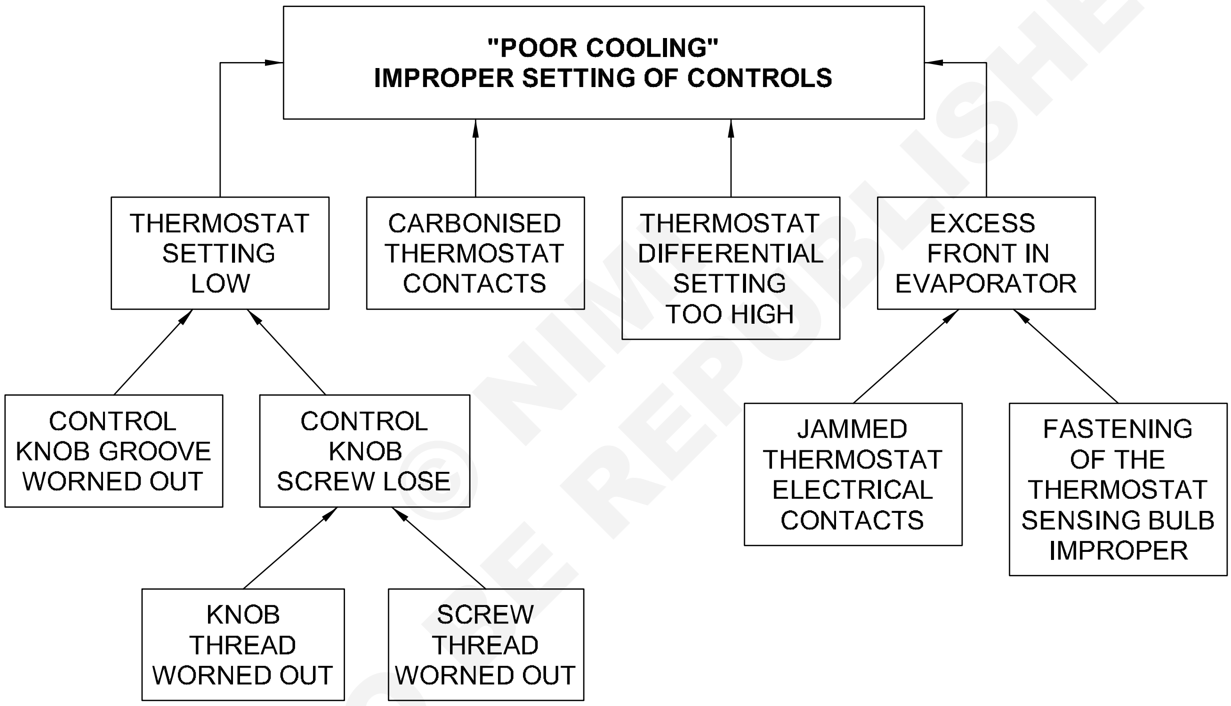
Objectives: At the end of this lesson you shall be able to
- **analyse the causes for the complaint “More cooling” - “Improper setting of controls” with the help of Problem Tree (PT)**
- **analyse the causes for the defect leading to the complaint with the help of Trouble Shoot Chart (TSC)**
- **analyse 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 (SFC) 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).**

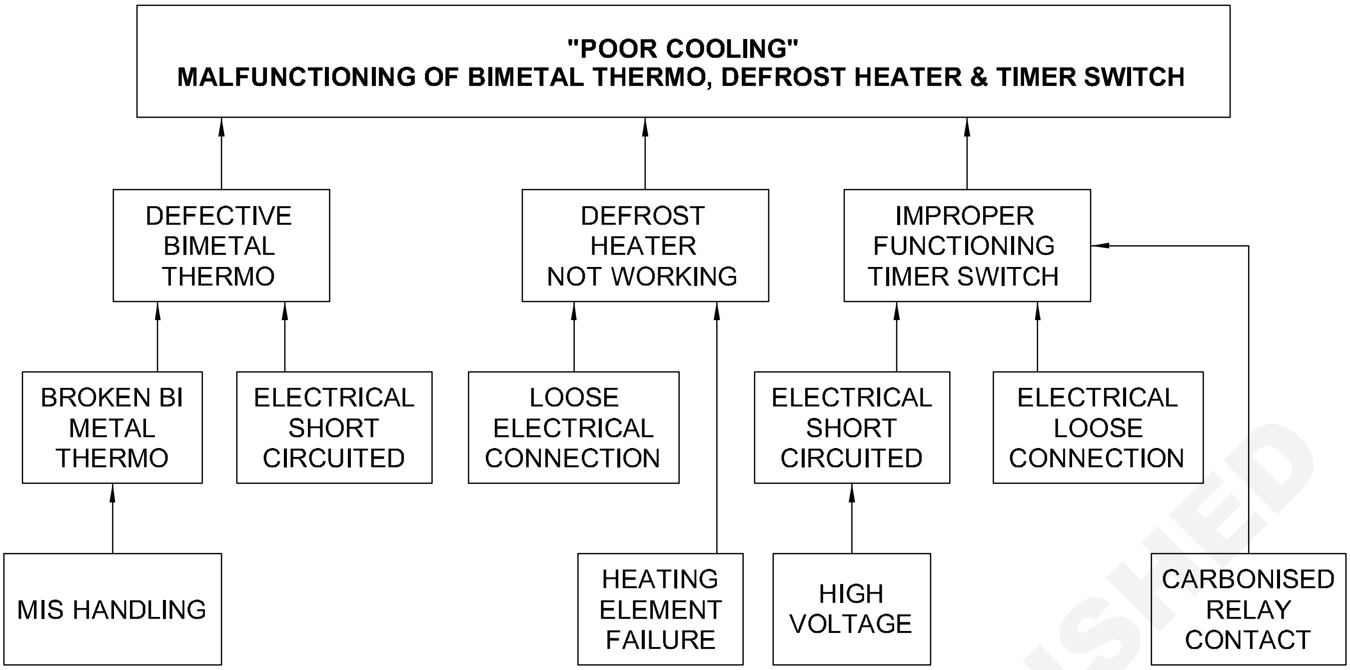
Symptom: “Excess frost”

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 Odorless
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) in 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 is 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 thermortat at medium cool position, is no load condition, note the time it takes to cut-out.
- If it is frost freeze 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.**

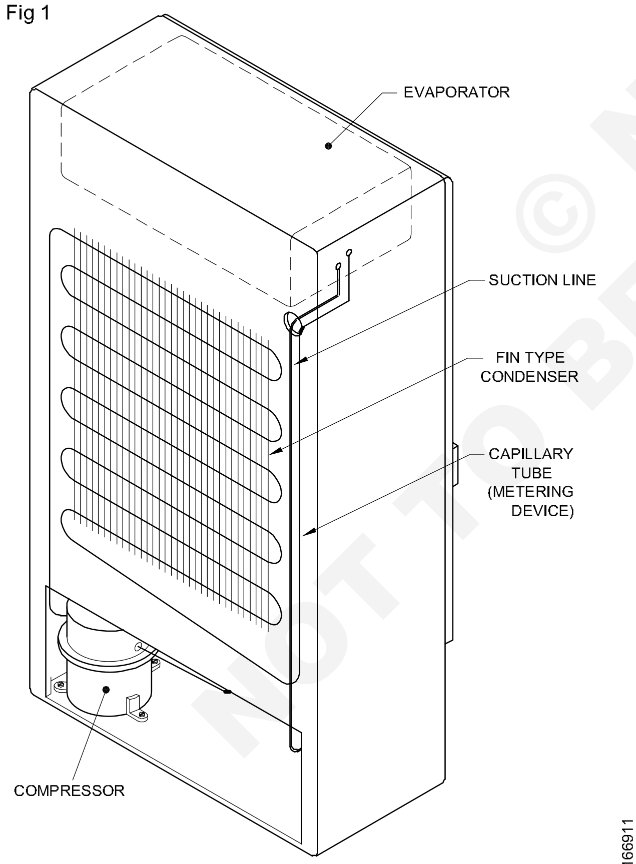
Construction: Industry technicians refer the low side of the refrigeration system, means the metering device and the evaporator. High side means the compressor and condenser. The compressor and condenser mounted together is called condensing unit.

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).

Fig 1



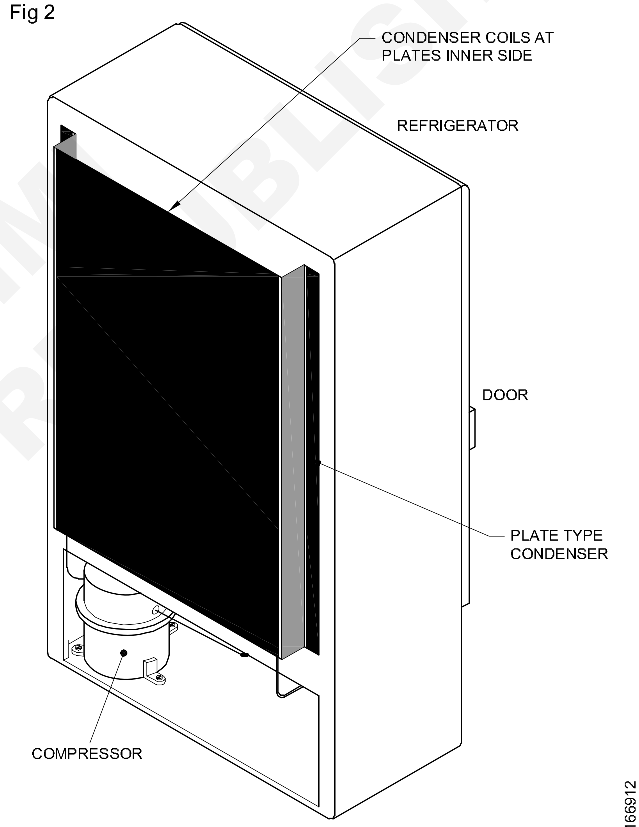
REFRIGERATOR WITH FIN TYPE CONDENSER

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 find 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)

Fig 2



REFRIGERATOR WITH PLATE TYPE CONDENSER

The condensation takes place by natural air ventilation. Condenser tubes gives up heat to the plate by conductivity and the plate surface is cooled by natural air velocity. So always its 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 need 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.

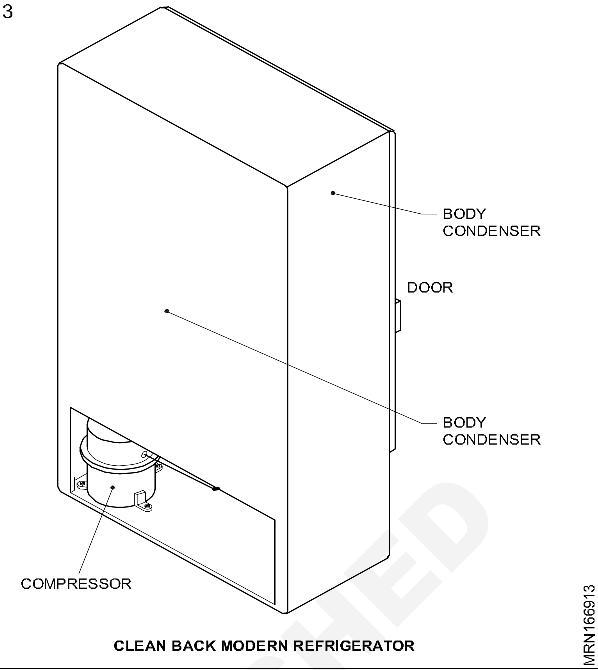
The heat of the condenser coils transmitted to the plates of the cabinets sides and it is cooled by natural air circulation. (Fig 3)

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.

Fig 3



CLEAN BACK MODERN REFRIGERATOR

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 vacuuming the system. Before gas charging contamination (carbon particle) present at the time of failure of compressor (burn out) 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 condensable 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/cm^2. 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 compresser 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, dirts, 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.

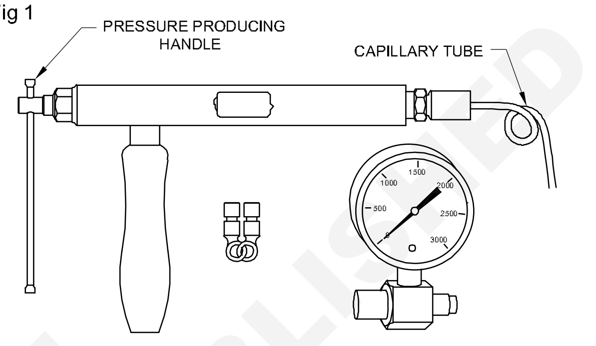
It is sometimes possible to repair capillary tube by cleaning it. Procedure is as follows:

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).

Fig 1



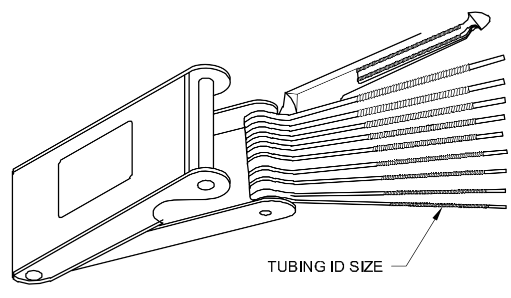
CAPILLARY TUBE CLEANER USED TO CLEAR OBSTRUCTIONS FROM CAPILLARY TUBE. IT HAS A CAPILLARY TUBE ADAPTOR FITTING. EITHER OIL OR R-11 IS USED AS PRESSURE FLUID.

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).

Fig 2



CAPILLARY TUBE SIZING KIT.
GAUGE MEASURES THE ID OF THE CAPILLARY TUBE.

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 descants.**

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)

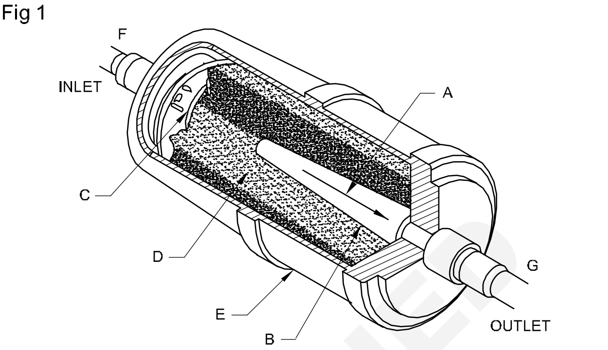
A – arrow mark -indicates the flow

B – filter element - to catch strain the particles and dirt

C – course filter - not to allow deseccant to travel

D – deseccant- drying agent silica gel

Fig 1



A - ARROW INDICATES FLOW DIRECTION
B - FILTER
C - COURSE MESH
D - DESECCANT SILICA GEL
E - DRIER - BODY (COPPER OR STEEL)
F - INLET - CONNECTION (REFRIGERANT)
G - OUTLET - CONNECTION (REFRIGERANT)

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.

Desicants:

Desicants 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 refrigerants. There are highly absorption of moisture.

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 sulphate.

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 - fluro 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 fluorocarbon 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 auditable ‘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/cm^2 gauge (180 psig) and for R 22 is 21.25 Kg/cm^2 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

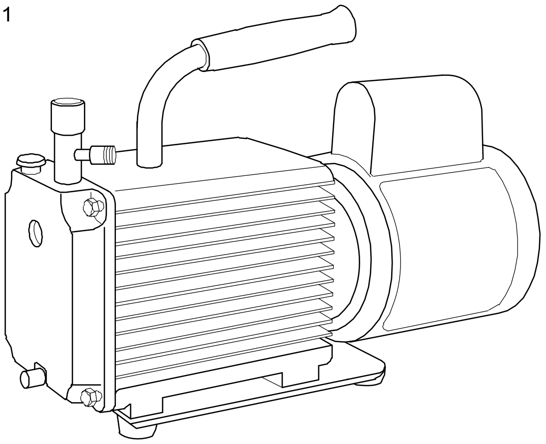
2 By high pressure side

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

Fig 1

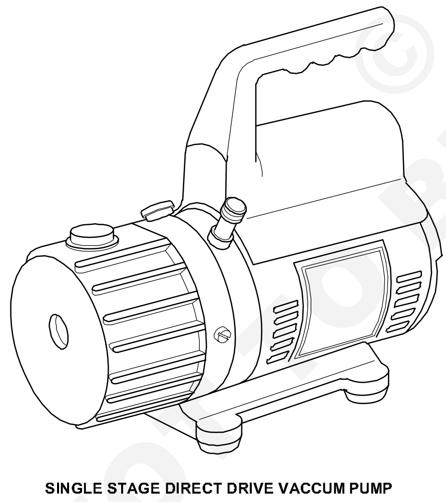


TWO STAGE DIRECT DRIVE VACCUM PUMP

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.

Fig 2



SINGLE STAGE DIRECT DRIVE VACCUM PUMP

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.

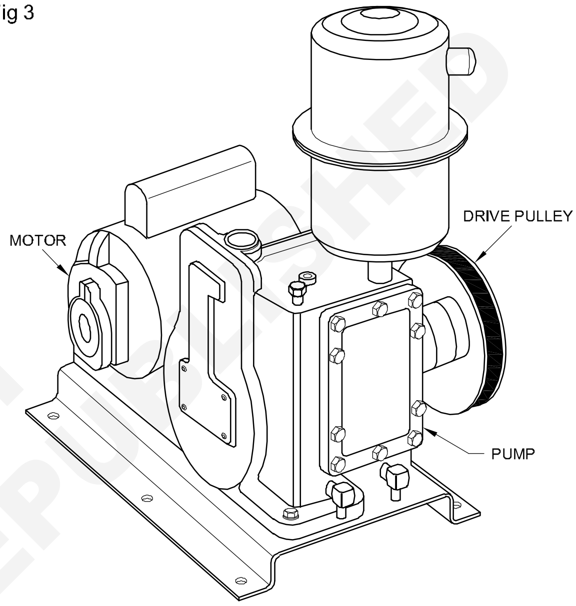
The vacuum pumps are available in two/three categories.

It is classified as under:

Vacuum pump

Direct drive		Belt drive
3 stage	2 stage	1 stage

Fig 3



TWO STAGE BELT DRIVE VACCUM PUMP

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

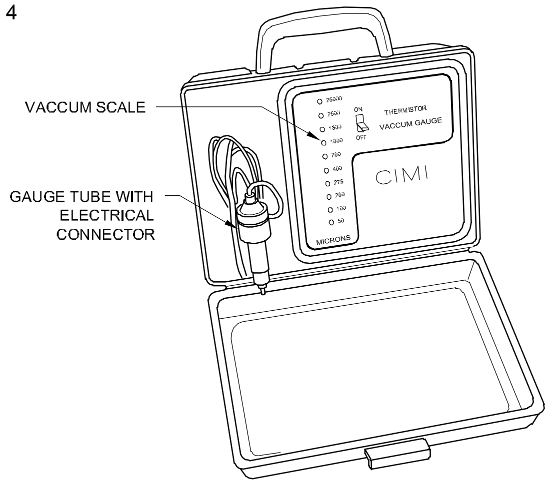
2 Micron gauge

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



MICRON GAUGE

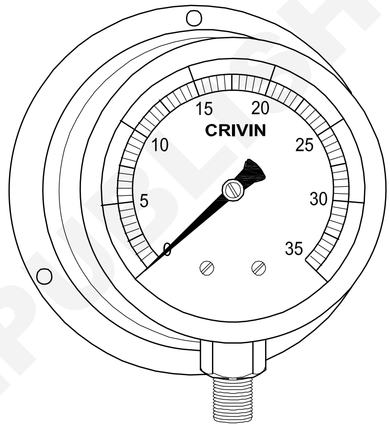
MRN165614

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



VACCUM 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.

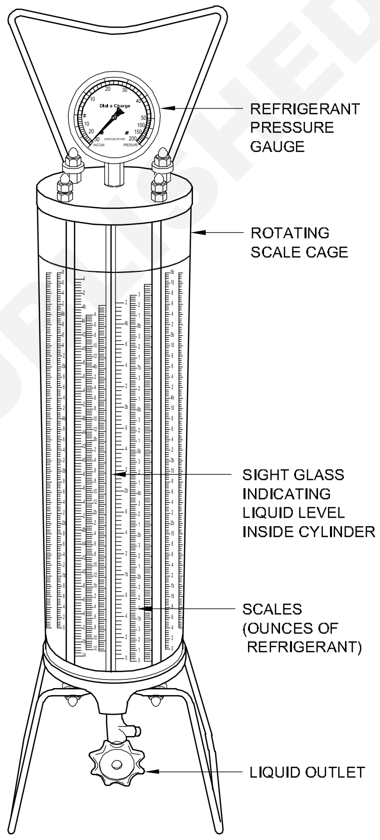
Charging cylinder

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.

Fig 1



CHARGING CYLINDER

MRN165621

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.

Table 2A

Heat rejection factors : suction cooled hermetic compressors

Evaporator	Condensing temperature (°F)					
temp. (°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	1.47	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

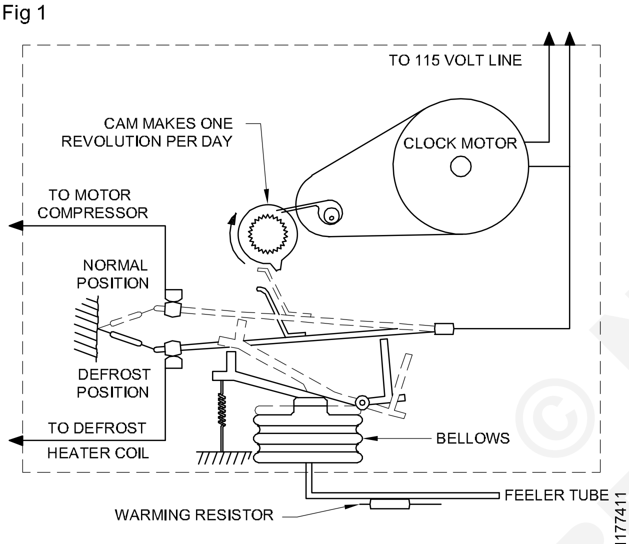
Sl. No.	Appli-cation	Refri gerent	Evaporating		Condensing				Temp ambient °C	Pressure ratio
					Air cooled		Water cooled			
			Temp °C	Press. Kg/cm³	Temp. °C	Press. Kg/cm³	Temp. °C	Press. Kg/cm³		
1	High Temp.	R-22	7	5.41	55	21.09	-	-	35	4.18
2.	High Temp	R-22	7	5.4	-	-	42	15.5	35	4.18
3.	High Temp.	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	

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 de-frost.

Fig 1



AUTO-DEFROST CONTROL OF REFRIGERATOR

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.

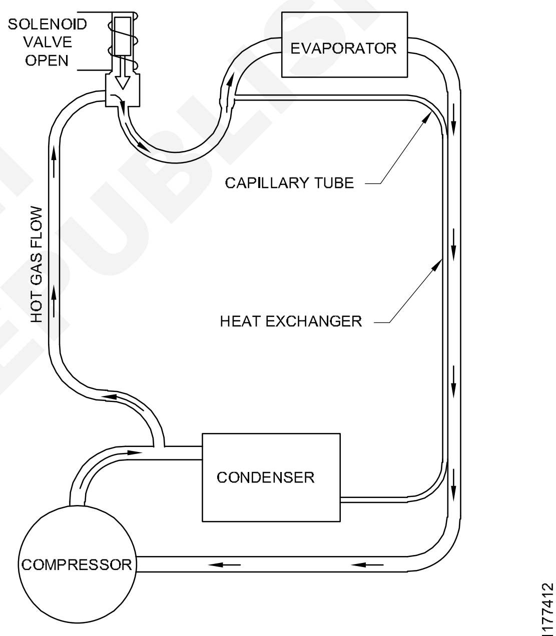
Suppose the bimetal disc fails to cut the heater, the timer switch when it closes 15 min 'off cycle', it will cut off the heater (18°C approx.)

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

Fig 2



HOT GAS DE-FROST SYSTEM

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.

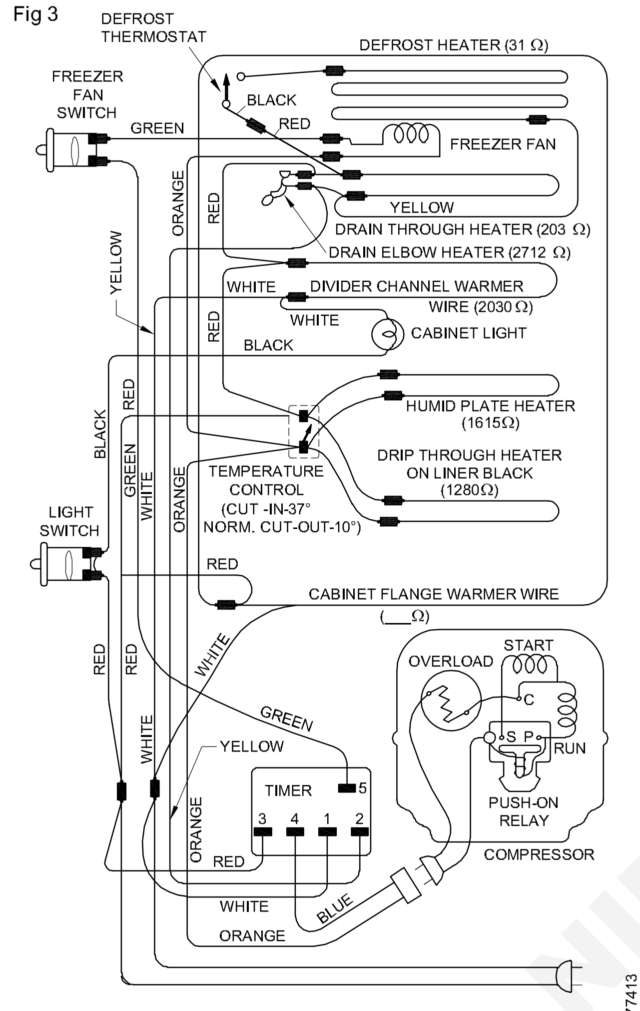
In this type defrost time also the compressor will run continuously only the discharge vapour is diverted to evaporator other than in normal condition the hot gas will flow to condenser for usual cycle.

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

Fig 3



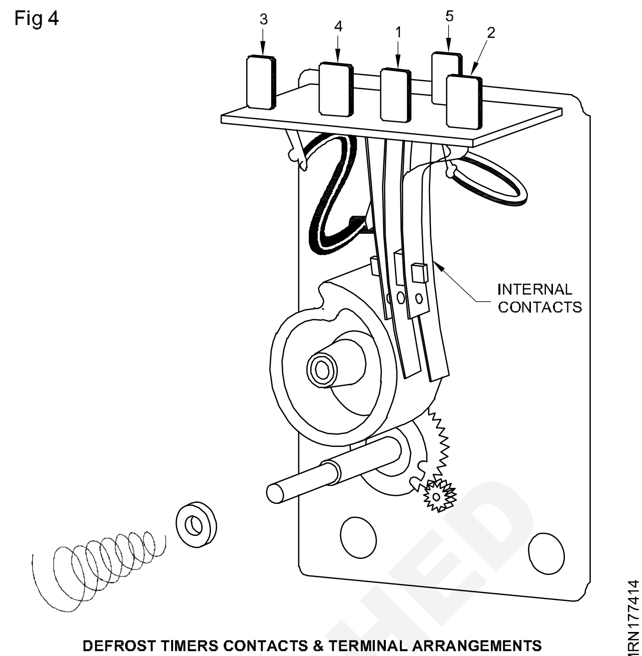
WIRING DIAGRAM OF AN ELECTRICAL CIRCUIT FOR AUTOMATIC DEFROST.

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

Fig 4



DEFROST TIMERS CONTACTS & TERMINAL ARRANGEMENTS

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.

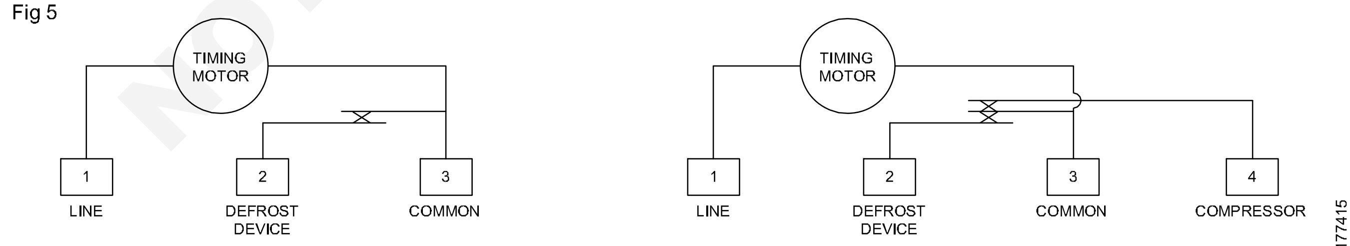
It shuts off the compressor and the evaporator fans and start the electric heater will be 'on' for about 15 min.

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.

Fig 5



a) WIRING FOR HOT GAS DEFROST SYSTEM.

b) WIRING FOR ELECTRIC DE-FROST SYSTEM.

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.

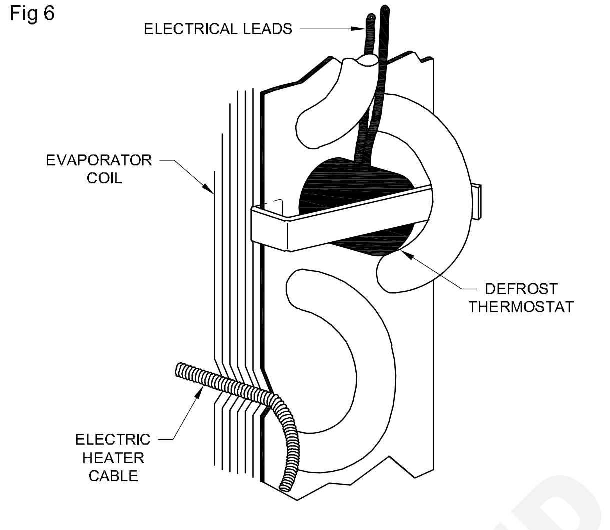
Damper control adjustment

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%

There will be 5 position in that piano type switch as A,B,C,D & 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.

Fig 6



BIMETAL DEFROST THERMOSTAT

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.

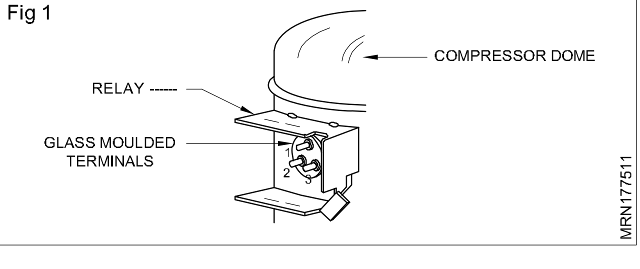
80 to 300 litres refrigerator, 1/6 H.P. compressor is used.

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.

Fig 1



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 disk 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:

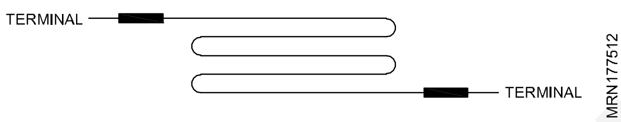
It is placed in a small P.V.C.housing. A small motor is attached with teeth wheel.

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).

Fig 2

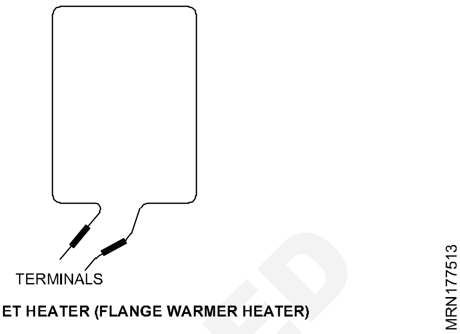


Cabinet heater and drip tray heater Refer (Figs 3 & 4). Cabinet heater (FLANGE warmer heater).

The heater protects the moisture entering inside the cabinet. This heater work very less watts, less amp.

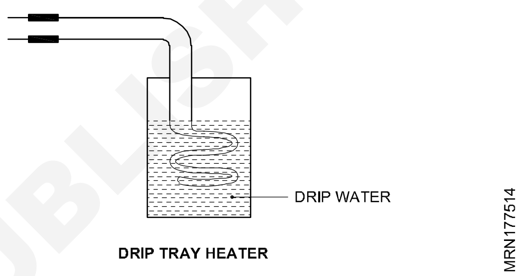
This heater evaporate the drip water and work with less power.

Fig 3



CABINET HEATER (FLANGE WARMER HEATER)

Fig 4



DRIP TRAY HEATER

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.**

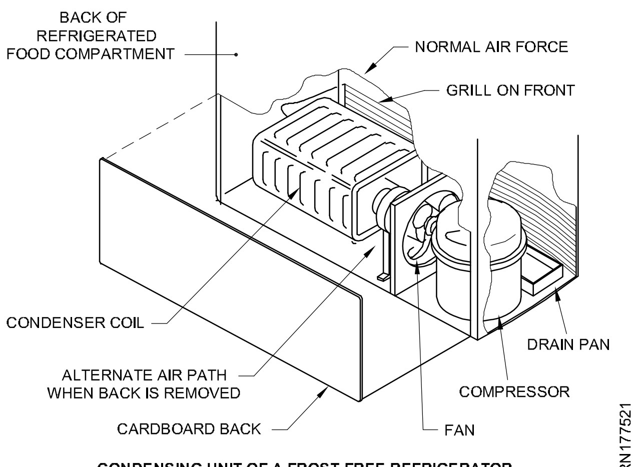
Features of the household refrigerators: There are many changes in features of refrigerators designed to create more food storage space within the same inside area of the refrigerated cabin (insulation become thinner with polyurethane material) and convenient to the users like auto defrost system.

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 fined 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)

Fig 1



CONDENSING UNIT OF A FROST-FREE REFRIGERATOR

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.

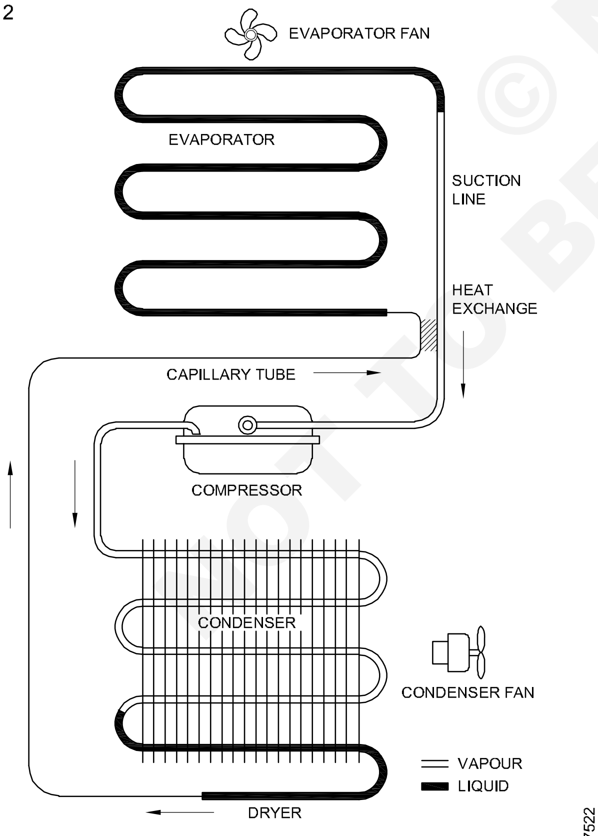
Construction of the frost free refrigerator: The arrangement of the condensing unit is already explained in the features. Usually this models have two door one on top to cover freezer cabin and the down to close the refrigerator cabinet. The light facility will be provided only for the down refrigerator 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.

Fig 2

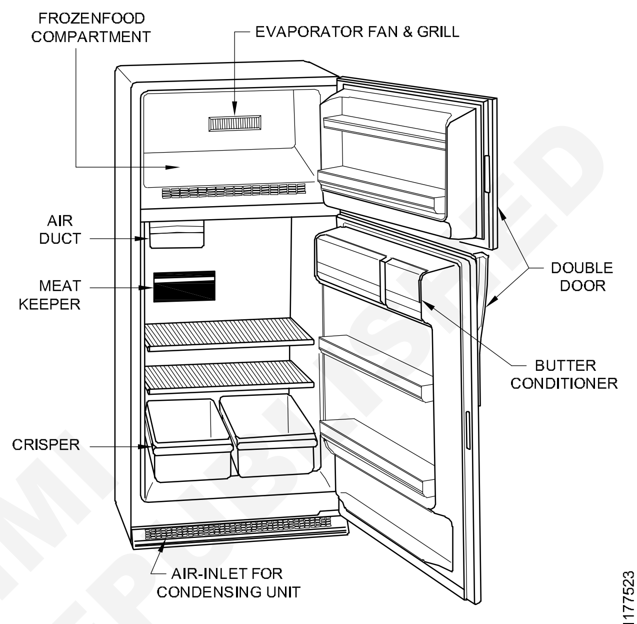


REFRIGERATOR WITH FROZEN FOOD COMPARTMENT, FROST-FREE SCHEMATIC DIAGRAM SHOWS OPERATING CYCLE.

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)

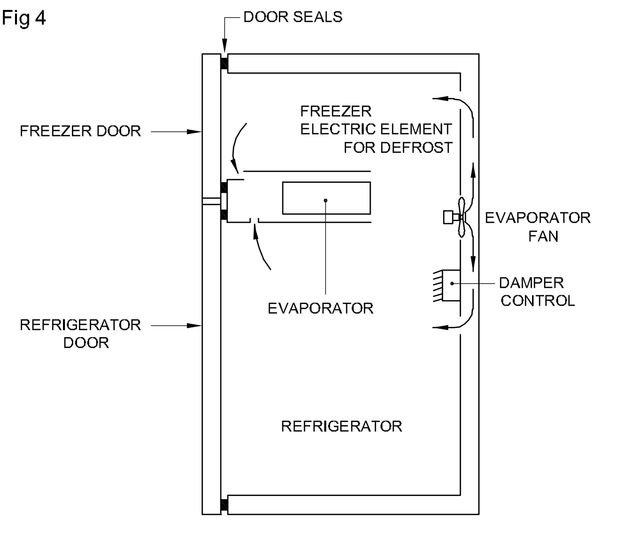
Fig 3



FROST FREE REFRIGERATOR.

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.

Fig 4



A HOUSEHOLD REFRIGERATOR WITH A FINNED TUBE EVAPORATOR AND LECTRIC DEFROST. THE AIRFLOW INTO THE FREEZER AND EVAPORATOR CAN BE ADJUSTED FOR DIFFERENT REFRIGERATOR AND FREEZER TEMPERATURES.

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)

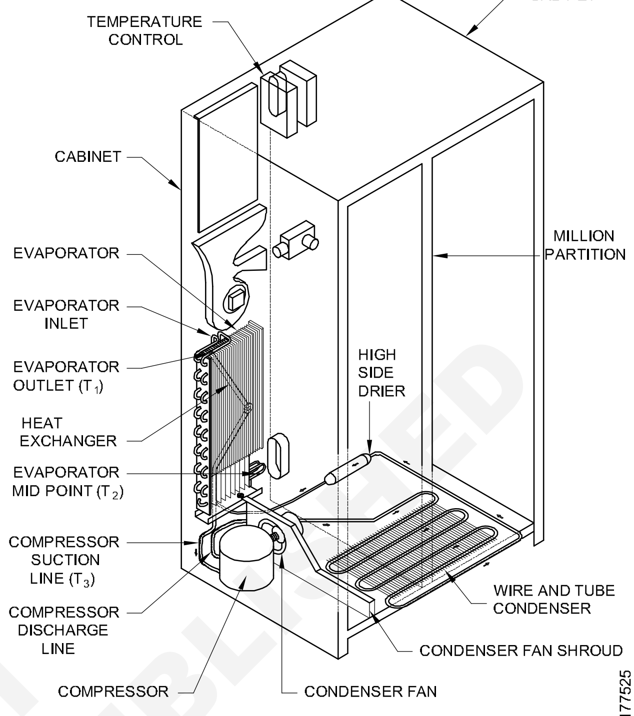
The fresh food compartment act as a return air duct from the freezing compartment back into the evaporator cabin.

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.

Fig 5



SCHEMATIC OF SIDE BY SIDE REFRIGERATOR

MRN177525

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

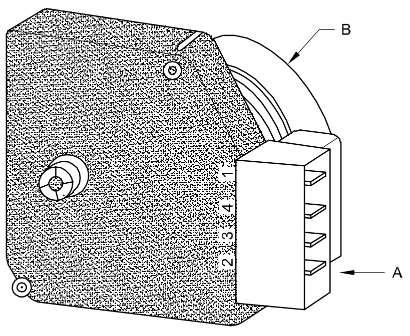
2 Gear assembly

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 activate 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 embedded 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^{0}C. Ref. (Fig 2).

Fig 1



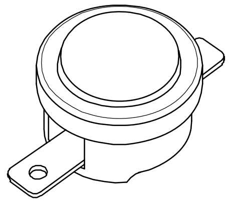
A - TIMER IS CONNECTED INTO MOTOR COMPRESSOR CIRCUIT AND PROVIDES BOTH A CLOCK MECHANISM AND SWITCHING MECHANISM. CLOCK ENERGIZES SWITCH MECHANISM IN SUCH A WAY THAT, AFTER EIGHT HOURS OF COMPRESSOR OPERATION, FAN MOTOR IS TURNED OFF AND DEFROST HEATER IS ENERGIZED.

B - TIMER MOTOR

AUTOMATIC DEFROST TIMER

MRN177531

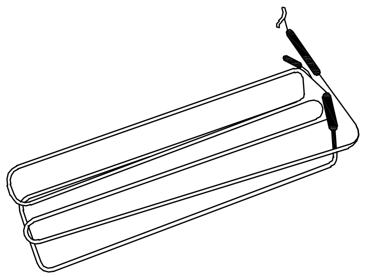
Fig 2



BIMETAL THERMOSTAT

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).

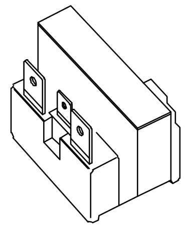
Fig 3



DEFROST HEATER

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).

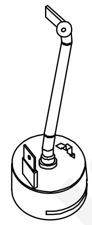
Fig 4



PTC RELAY

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).

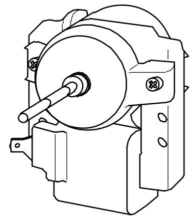
Fig 5



OVER LOAD PROTECTOR

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).

Fig 6



EVAPORATOR FAN MOTOR

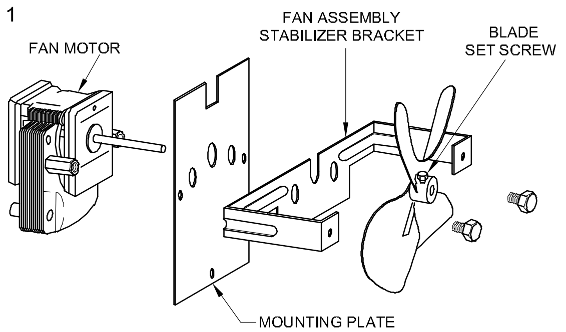
Air Distribution system in frost free refrigerator

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.

Fig 1



FAN MOTOR AND ASSEMBLY COMPONENTS.

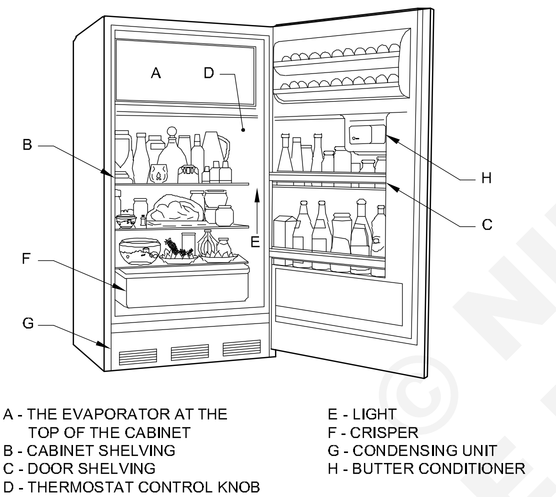
- All air contains some moisture, when air comes in contacts with an evaporator surface which is below the freezing temperature, the moisture will condense and form ice on the evaporator in the conventional manual defrost refrigerator. The frozen food cannot be preserved for long period.
- In frost free 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.

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)

Fig 1



FRESH FOOD REFRIGERATOR

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 or 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 emlpoyed 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 (bourn out) 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 - 1

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 shout 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. There kind of units are used in small restaurants.

Inverter refrigerator - 2

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 automately adjust its speed to meet cooling demand.

The speed of motor can be varied to required RPM by altering the frequency lend 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 puse 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 H2; The compressor motor speed varies according to change is frequency Fig 2 show the stages of inverter system.

Working of BLDC motor

The main thing with a brush less DC motor is that it has permanent magnet (Insulated of electro magnets) for the roles. 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 state is generate motion. The current in the starter electromagnet can be varied to change th speed of motion joint because motor generate DC magnetic field even the starter has to generator DC magnetic field this happen when the starter 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 converter 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 puses 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 form 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 advantages 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 sold 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 operate as efficiently. Their lifetimes will usually be reduced.

An inverter is usually required is 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 speed 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 & sleeplessly.
- 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 byt the torque does not vay.

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 larges 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

Fiqure 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°. Fiqure 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 Id reference is still zero, and the Iq 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. Fiqure 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 Fiqure 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.

Function of hermetic compressor

Objective: At the end of this lesson you shall be able to
- **explain the necessity of part function.**

Usually hermetic or sealed type provides compact assembly and will such require less place and noise less. The unit is completely sealed in and tested at the factory, trouble is free with compressor motor assembly. The motor located above the compressor operates horizontally. This construction method permits operation of the compressor in oil, simplifying the lubricating problem. The suction intake is placed so that suction vapour must travel through the holes in the motor rotor in order to get to the top of the shell and then to the intake tube.

Any oil or liquid refrigerant is separated from the vapour by centrifugal force due to rotation of the motor rotor as vapour passes up through the holes in the rotor. Consequently oil and liquid separation assured oil is eliminated and with it damages of valve breakage coil is picked up in a small slot on the end of the crankshaft which acts as centrifugal pump and the oil is forced into the power main bearing. From this point it follows the spiral groove in the bearing up to the crankcase where it lubricates the trust plate, connecting rod and piston coil is then pumped through a tube by vapour action up to a small reservoir beside the upper main bearing and is then fed into and spiraled up through the bearing from where it drops back to the sump. (Fig 1&2)

The main parts of reciprocating compressor are head plate valve plate and valves, piston, piston pin, connecting rod and crankshaft.

Fig 1

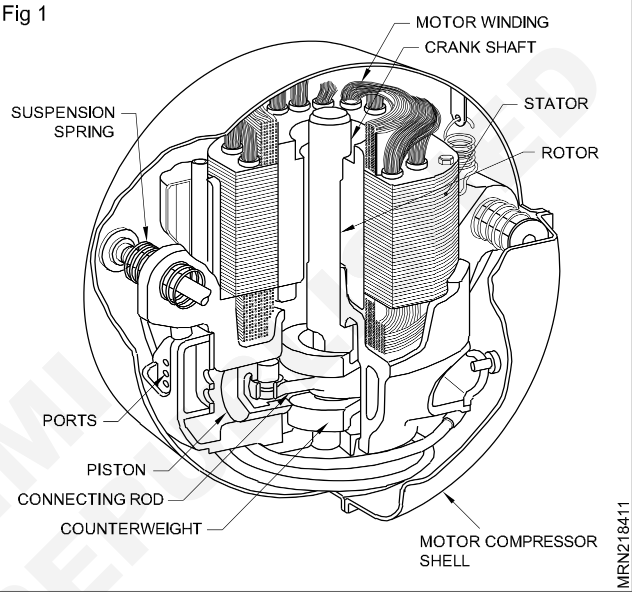
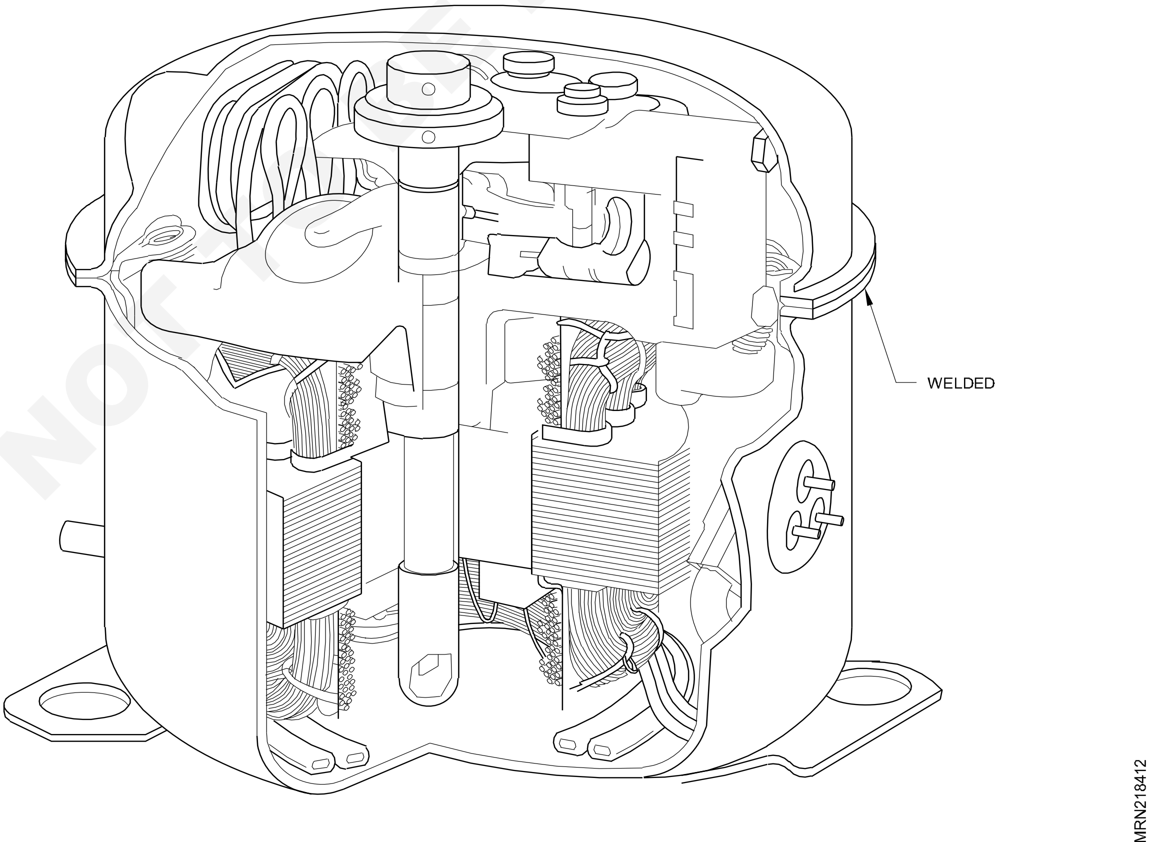


Fig 2



The reciprocating compressor are available 1/8 HP to 15 HP capacity. It is Hermetically sealed type.

Hermetically sealed type

In hermetic type there is no need for the shaft seal. The compressor and motor have a common shaft and are assembled in a single body and the whole assembled is fixed in a steel shell, the joints of which are welded.

To assemble the reciprocating compressor to check the parts and clean completely. Fix the connecting rod and piston with help of piston pin. Then piston in cylindrical and set the big end bearing of the connecting rod on the shaft and fix main bearing of the compressor and tightened the eccentric lock nut.

The following precaution to be taken while assembling the compressor.

- New gasket should be used
- The marks should be match for proper fillings
- The bolts should not be over tight
- Faulty parts should not be used

Gasket for compressor

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

- **know the need for lapping and polishing of valve plate, seal**
- **know the valve plate components and function**
- **know the causes for failure of valve plate**
- **explain the cutting gasket.**

In valve plate any scratch seat will leak the refrigerant and the system efficiency will greatly reduced.

The scratches on shaft seal will leak the refrigerant from the system. So lapping for these parts to remove scratches and improve the system efficiency.

Valve plate components & function

- Valve plate
- Suction valve plate
- Discharge valve plate

Valve plate: Both suction valve plate and discharge reed mounted on valve plate

Suction valve plate: During suction stroke through suction valve plate vapour enter into the cylinder

Discharge reed valve: During compression stroke suction valve closed and discharge valve open to the condenser.

Causes for failure of valve plate

- Uneven seatings due to the wear carbon deposit or damage.
- Valve reeds which are distorted cracked or in any other way damaged.
- Wet compression, leads damaging valve plate.

Gasket is a packing to make leak proof joint. All the joints of the compressor must be air tight and with stand the pressure and heat developed during the compression.

Gasket are generally of cork, paper composition, lead, asbestos rubber and aluminium. Mostly the lead and paper composition gasket are used in reciprocating compressor.

The size of the gasket depends upon the thickness of the gasket and common sizes are used 1.6mm, 0.8mm and 0.4mm.

When these are tightened by bolt in between two surface of joints these are previously closed and make leak proof joints.

Following properties should be suitable in gasket

- It should be compressible without expansion
- It should be able to withstand high pressure and high temperature
- It should be easily cut in proper size
- It should be made from a material which should not react chemically with air or refrigerant used in the system.

Dome welding

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

- **name all the parts and function of each**
- **explain leak test after dome welding.**

Compressor has the following parts:

- Motor winding
- Rotor
- Connecting rod
- Piston
- Gudgin pin
- Valve plate, valve reed, suction, discharge, retainer, spring, bolts
- Terminal adapter
- Crankshaft
- Discharge muffler, suction muffler,
- Compressor, top and bottom dome

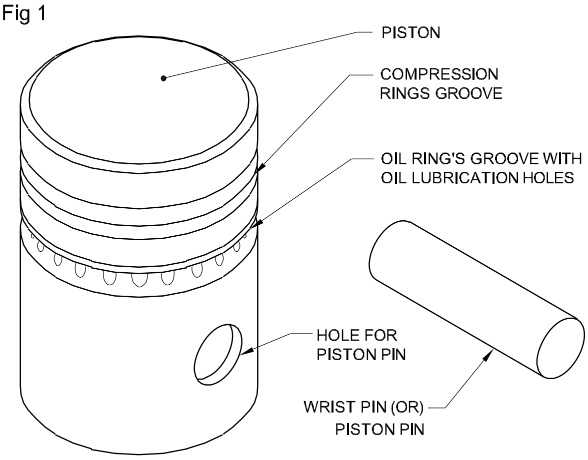
The figures of piston body, connecting rod, valve plate and reed are given in (Fig 1, Fig 2, Fig 3) and (Fig 4) respectively.

In hermetic sealed compressor motor and compressor are directly connected in a shaft and fixed in a 2 piece dome(top and bottom) with support of suspension spring for stop noise and vibration. Both motor and compressor running in a same shaft so the (RPM) will be same for motor and compressor this will give more performance for sealed compressor than open type compressor.

The total compressor inner body upto main bearing immersed in lubricating oil so in full speed motor bearing will not get wornout.

The compressor stator has got two windings (starting winding and running winding). Running the rotor got fan blade. This blade spray cool gas on winding and total dome will get cool.

Fig 1



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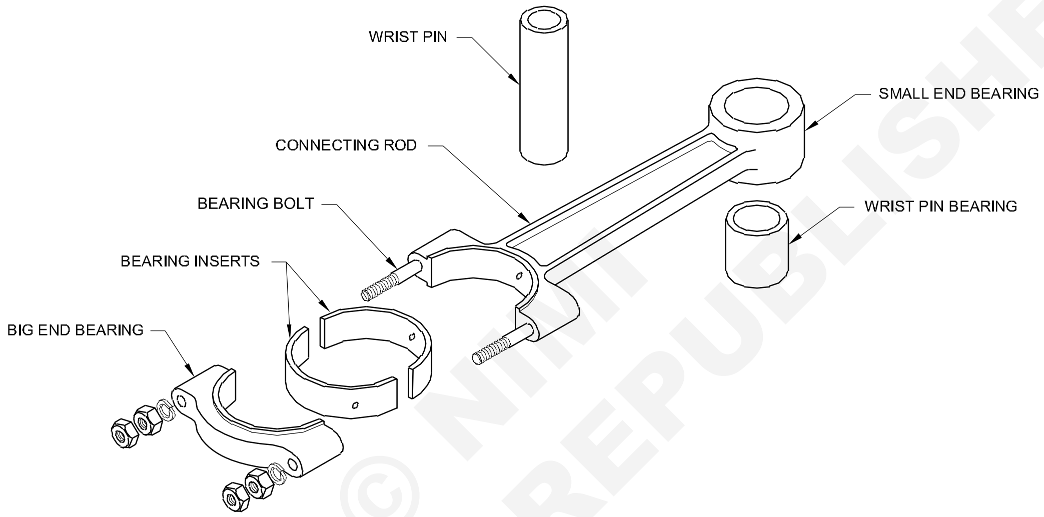
PISTON AND WRIST PIN

Fig 2



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When assembling sealed compressor should not assembled in open. Air should be assembled in AC room to avoid moisture entering in winding, compressor head and dome.

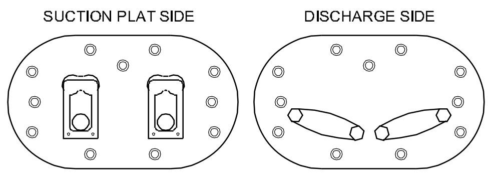
After weld compressor dome for leak test the compressor recharge pipe, suction pipe all to be sealed and through charging pipe with HP gauge 17.0 kg/cm^2 gas to be charged after charge.

Pressure total compressor to be immersed in a water tank for check minute leak.

After leak test, new oil to be charged after let out gas pressure, as recommended by manufacturer through charging pipe.

Leak testing hermetic sealed compressor is shown in (Fig 5).

Fig 3



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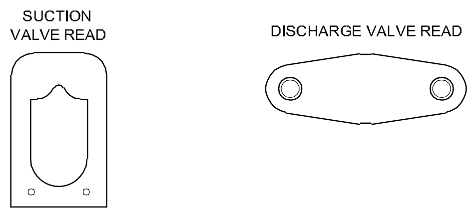
VALUE PLAT

Fig 4



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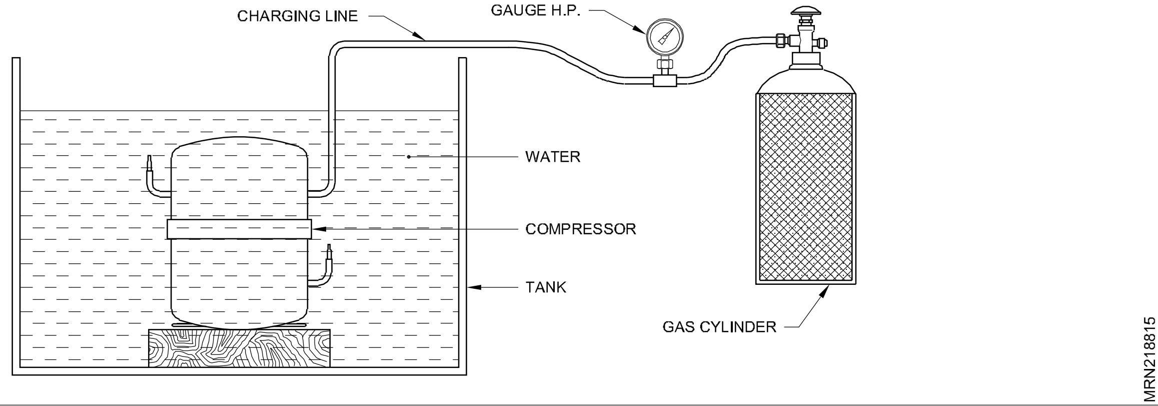
READS

Fig 5



Wet Compression:

The cmpression of wet - refrigeration vapour at the inlet of compressor to dry saturated vapour (not superheated after compression) at the outlet of compression.

Dry compression:

Dry compression means that the entry point to the compressor is from saturated vapour and outlet of the compressor is a superheated vapour.

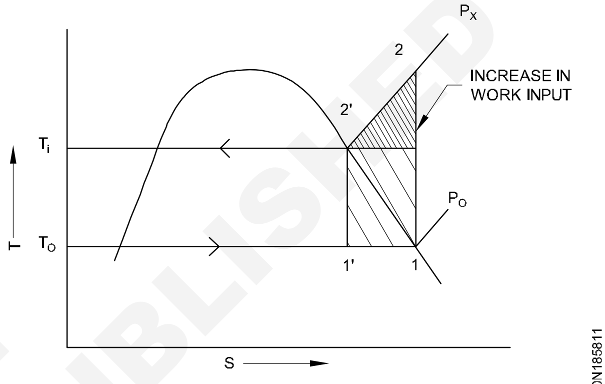
For the same pressure ratio work required for the compressor is increased in dry compression.

In the case of ammonia, the power consumption per ton refrigeration with wet compression is less by 10 percent as compared with that of dry compression.

In the TS diagram below process 1' - 2' represent wet compression of refrigerant and process 1-2 the dry compression of refrigerant on the same pressure. The area under 1'1 to 2'2 represents the increase in power consumption by the compressor in dry compression.

Hence if dry compression is replaced by a wet compression process in the refrigeration cycle then the refrigeration effect of the cycle will decrease.

Fig 1



DRY AND WET COMPRESSION PROCESSES

With a reciprocating compressor, wet compression is not found suitable due to following reasons.

Liquid refrigerant may be trapped in the head of the cylinder and may damage the compressor valves and the cylinder itself.

Liquid refrigerant droplets may wash away the lubricating oil from the walls of the compressor cylinder, thus increasing wear.

Oil to compressor

Objectives: At the end of this lesson you shall be able to
- **add oil to compressor lubrication**
- **lubricating oil properties**
- **methods of lubrication.**

Lubrication is the process by which the moving parts are kept lubricated by the film of oil. Since heat is generated in the moving parts, the oil film becomes heated and cooled by the oil level maintained in crankcase i.e., the oil should always be flowing in the bearings and moving parts, while the compressor is running.

Lubricating oils for refrigeration compressors are a special grade oil. In a refrigeration compressor oil comes in contact and mix with (such as in freon) the refrigerant.

So, it becomes necessary that the oil used in the refrigeration system should be selected to confirm to the special needs of the system.

Some of the most important properties which refrigerant oil should have

– Viscosity (as recommended by manufacturer)

– Low acidity

– Low flash point

– Low pour point

– Good dielectric strength

– Chemical stability

– Miscibility with refrigerant

Recommended quantity of oil should be used.

Viscosity	Viscosity : Viscosity is the resistance to flow of fluide and is expressed is say bolt universal (SSU)
Low acidity	Oil have a certain amount of organic acidity it's maintained below 0.05
Low flash point	At operating pressure & temperature the oil should not be flashed i.e, it should not be ignited
Pour point	Pour point is property of lubricant at the temperature oil ceases to flow
Dielectric strength	It is property of oil to resist the flow of electricity.
Chemical stability	It is the property of oil, should be chemically stable or compatible with refrigerant & others materials
Miscibility	It should be well miscibility with refrigerant.

Methods of lubrication

The methods of lubrication used for refrigeration system are divided into two main groups:

a Splash lubrication

b Forced feed lubrication

a Splash lubrication

In Splash lubrication system, the crank case acts as a sump for lubricating oil. The crank-shaft and connecting rod into oil sump. Each revolution of the crank-shaft splashes the oil on the rubbing surfaces and lubricates. This system is preferred for the compressors below 10kW capacity.

b Forced feed lubrication

In the forced feed method, the oil is forced under pressure with the help of pump through the system and the oil comes back under gravity after performing the lubricating function into the sump located in the crank case. This system is used for high capacity compressors.

Winding and pumping pressure in hermetic compressor

Objective: At the end of this lesson you shall be able to
- **check the winding in hermetic compressor.**

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.

Checking of pumping in 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.(Top 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.

Wet compression: Cycle with wet vapour refrigerant at inlet of compressor and dry saturated vapour refrigerant (Not super heated after compression) outlet of compressor

Construction and working of principle of various compressors

Objectives: At the end of this lesson you shall be able to
- **explain the construction and working of rotary compressor stationery blade type**
- **types of rotary compressor.**

Rotary compressor in that compressor in which gas is compressed in rotary motion. Generally it is used in small sealed systems like refrigerator and Air conditioner. It is also used in vacuum pump.

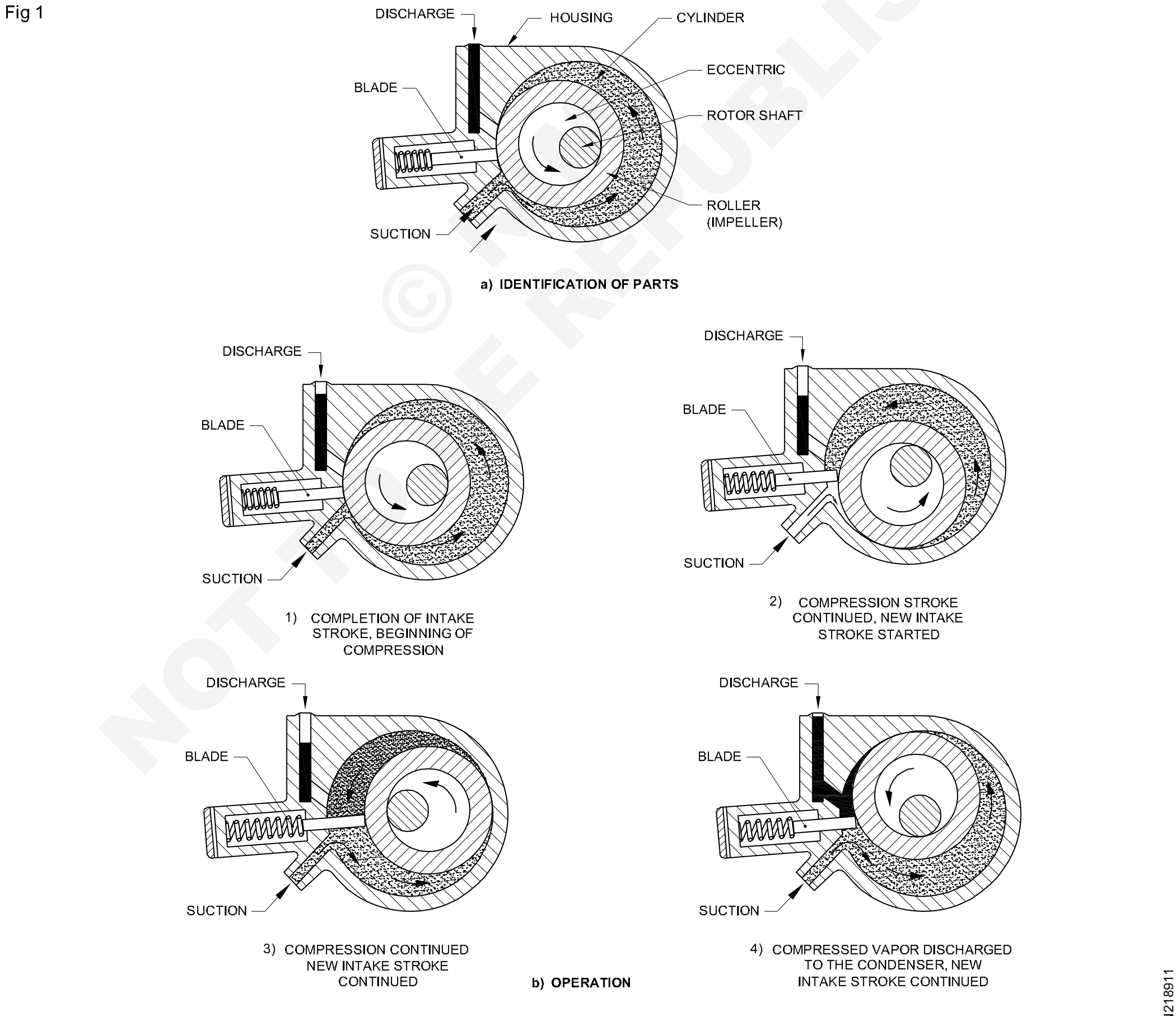
The main parts of a stationery blade type rotary compressor are roller spring and discharge valve , dividing blade is fitted on the cylinder wall. The roller is fixed on the shaft. The function of dividing blade is separate low pressure and high pressure. The oil is filled in the outcome. The oil level is maintained below the discharge tube. The shaft is connected to the motor.

When motor or the roller rotate through the surface of the cylinder. Then low pressure gas enters into the cylinder and compressed in to the outer dome. Hence oil and gas will separate. The oil will collect at the outer dome and compressed gas flows into the discharge line. (Fig 1)

Types of rotary compressor

- Stationery blade type rotary compressor
- Rotary blade type rotary compressor

Fig 1

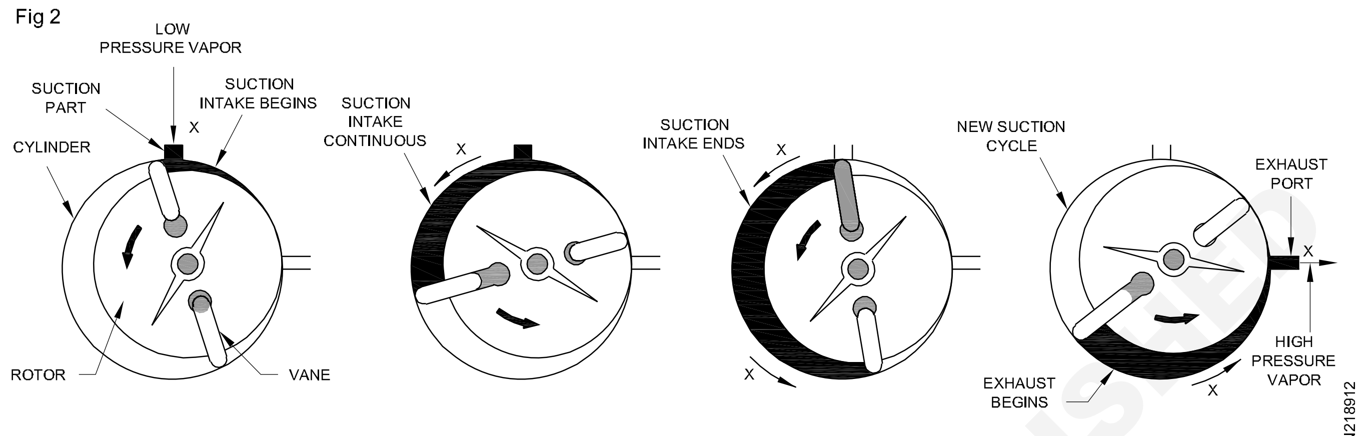


ROTARY COMPRESSOR, STATIONARY BLADE OR DIVIDER BLOCK IS IN CONTACT WITH A ROLLER (IMPELLER)

In rotary blade type rotary compressor the dividing blade is titled on the roller. Minimum two blades or multiples of two. The roller is fixed to the shaft and roller rotated through the surface of the cylinder as shown in Fig 2. As rotar rotates, roller rotated through the surface of the cylinder by centrifugal force.

The low pressure vapour coming through the suction line entres the space between two blades. As the rotar continues its rotation the volume of vapour enclosed between the blades decreases and its pressure increases. As it rotates further high pressure vapour reaches the discharge port and then discharge valve opens and vapour enters the condenser through discharge line. When these blades again reach suction port the space between them is filled with low pressure vapour again and this cycle is repeating.

Fig 2



A ROTARY BLADE COMPRESSOR BLACK ARROWS INDICATE DIRECTION OF ROTATION OR ROTOR. X ARROWS INDICATE REFRIGERANT VAPOR FLOW

Parts of rotary compressor

Objective: At the end of this lesson you shall be able to
- **identify the parts of rotary compressor.**

Stationery blade type rotary compressor

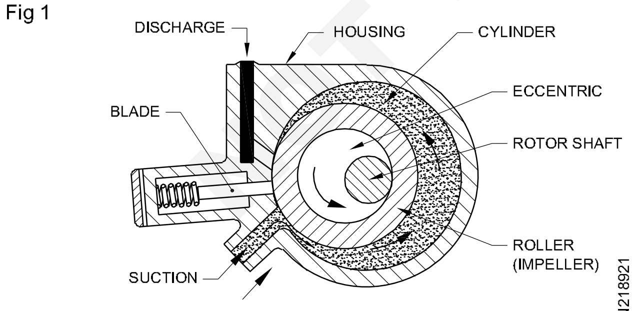
Parts of stationery blade type rotary compressor are given below (Fig 1)

- Rollar (impeller)
- Rotar shaft
- Eccentric
- Cylinder
- Housing
- Suction line
- Discharge line
- Blade

Parts of Rotary vane type rotary compressor (Fig 2)

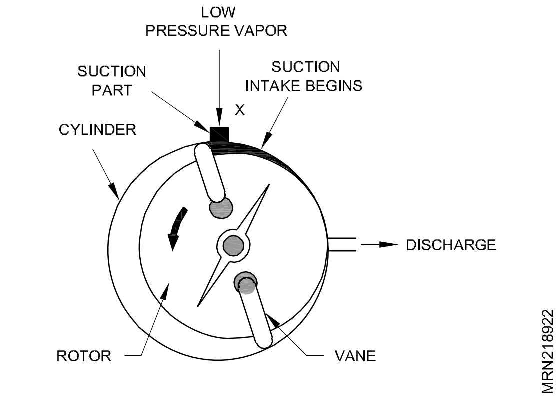
- Rollar
- Vane
- Cylinder
- Suction port
- Discharge

Fig 1



a) IDENTIFICATION OF PARTS

Fig 2



Scroll type compressor

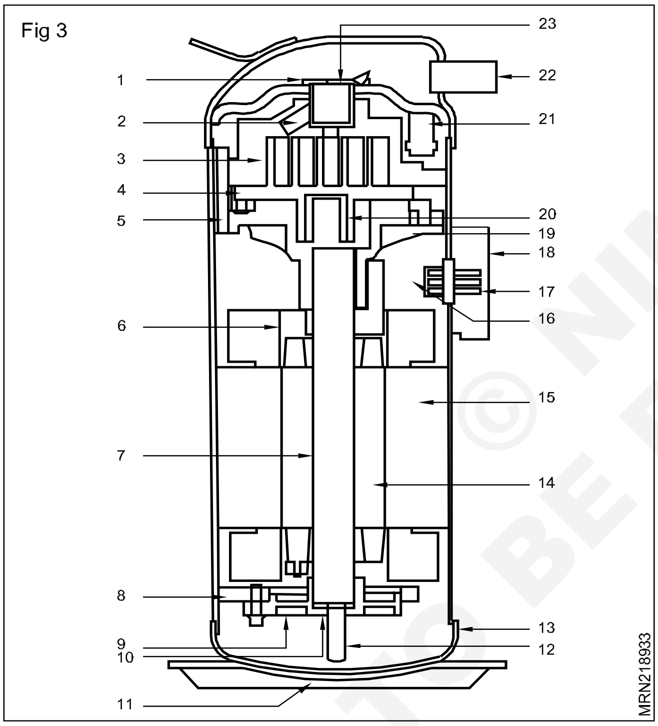
Objective: At the end of this lesson you shall be able to
- **explain scroll type compressor.**

Scroll compressor are orbital motion, positive displacement machines that compress with two inter fitting, spiral shaped scroll members. (one is fixed and another is movable)

Key components

1 Discharge plenum	2 Thermal valve
3 Fixed scroll	4 Orbiting scroll
5 Crankcase	6 Counterweight
7 Eccentric shaft	8 Lower bearing ring
9 Lower bearing	10 Thrust washer
11 Magnet	12 Oil tube
13 Shell	14 Rotor
15 Stator	16 Suction tube
17 Electric terminal	18 Terminal cover
19 Suction baffle	20 Slider block
21 Internal pressure relief valve	
22 Discharge tube	23 Check valve

(Fig 1) Scroll compressor components

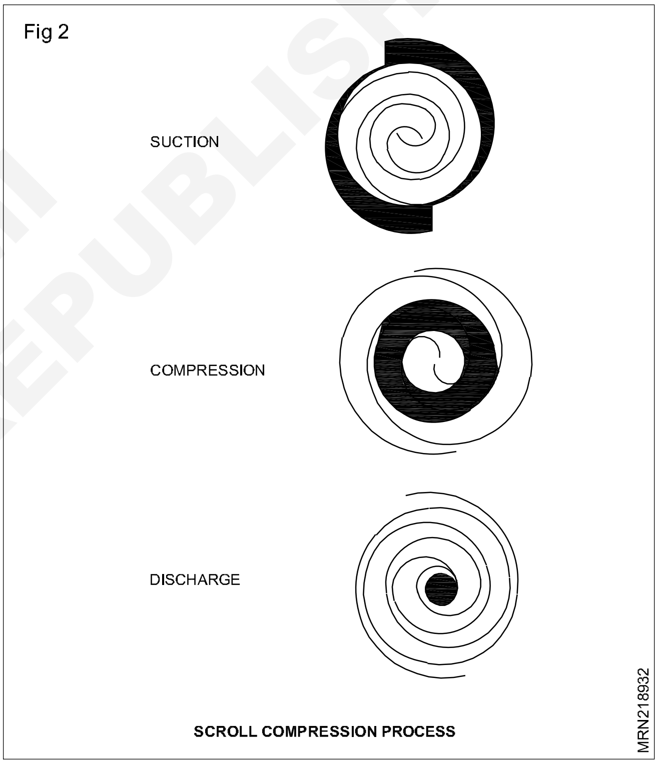


A cut away view of the scroll compressor with key components labeled in shown in fig1. The motor stator is rigidly attached to the shell. The rotor is shrink-fit onto, the eccentric shaft. The shaft is supported by two bearings, one in the crankcase and the second below the motor.

Scroll compression process

The diagram shown describes the scroll compression process. The two components shown are mating involute scrolls. One scroll is fixed in place and the other scroll orbits within this fixed scroll. On e part that is not shown in this diagram but is essential to the operation of the scroll is the anti-rotation coupling. This device maintains a fixed angular relation of 180 degrees between the fixed and orbiting scrolls. This fixed angular relation, coupled with the movement of the orbiting scroll, is the basis for the formation of gas compression pockets.

As shown here, the compression process involves three orbits of the orbiting scroll. In the first orbit, the scrolls ingest and trap-off two pockets of suction gas. During the second orbit, the two pockets of gas are compressed to an intermediate pressure. In the final orbit, the two pockets reach discharge pressure and are simulateously opened to the discharge port.



This simultaneously process of suction, intermediate compression, and discharge leads to the smooth continuous compression process of the scroll compressor.

Components of swash plate axial type compressor

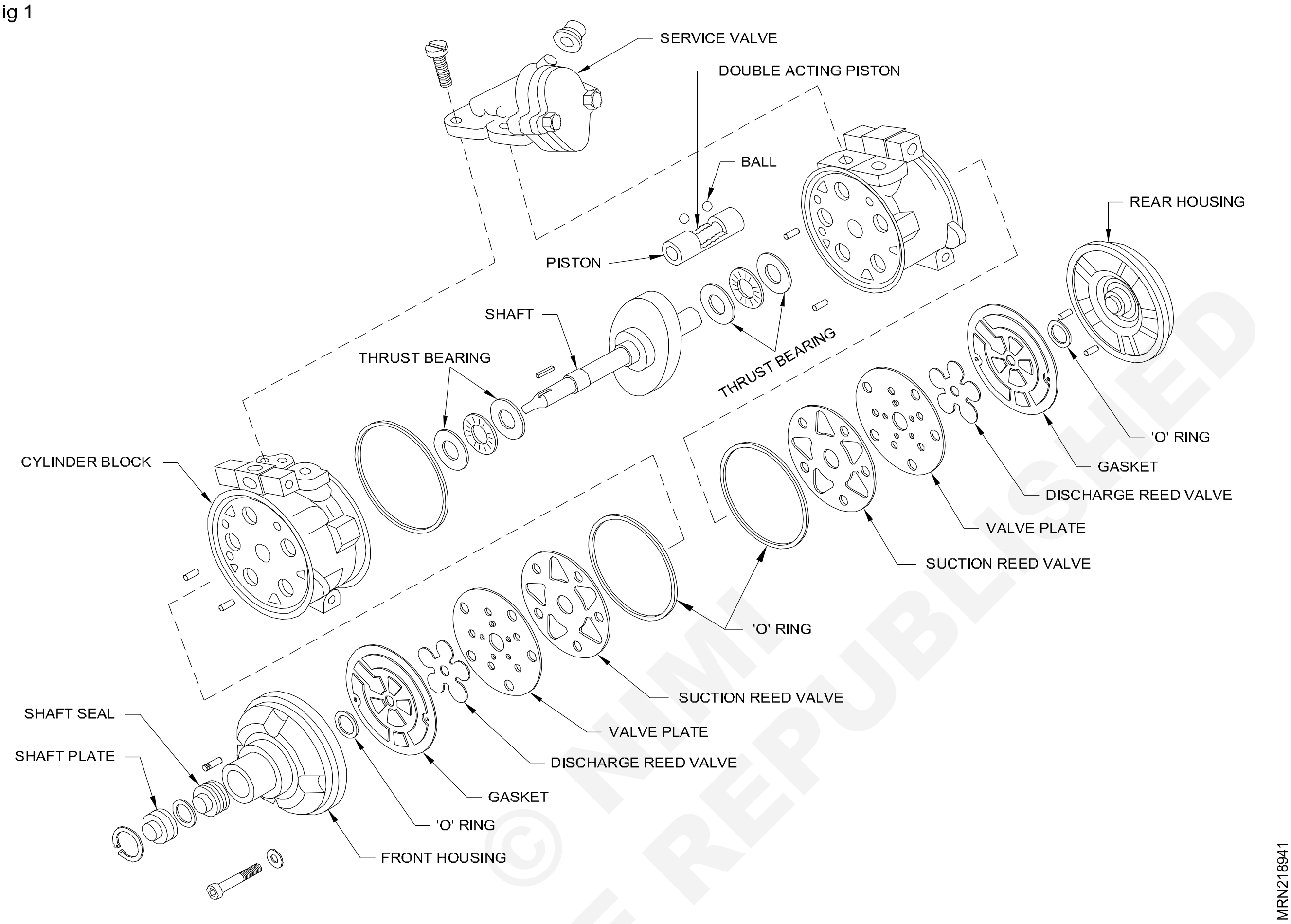
Objective: At the end of this lesson you shall be able to
- **explain briefly about swash plate axial type compressor.**

Purpose: There are numerous types of compressors in use today. Compressors may have from one to ten cylinders and may or may not have provisions to retain refrigerant oil. There is even a rotary and as scroll type design.

Regardless, all operate as the “pump” of the system to keep the refrigerant circulating and to increase the refrigerant pressure.

The pistons are operated by a swash plate which moves the pistons back and forth in the cylinders as the shaft is rotated. There are 10 separate cylinders, 5 at the front of the compressor and 5 at the near of the compressor. Reed valves are provided for each cylinder. (Fig 1)

Fig 1



The swash plate is most frequently used in car air conditioning system, it has upto ten cylinders. A swash plate mounted at an angle on a shaft moves a number of double acting pistons backwards and forward axially. (Fig 2)

This induces and compressors refrigerant. The induction and expulsion of refrigerant is controlled by metal plates with integral reed valves.

The swash plate converts the rotary movement of the compressor shaft into the reciprocating movement of pistons. Swash plate compressors can be of either fixed or variable capacity.

Fig 2

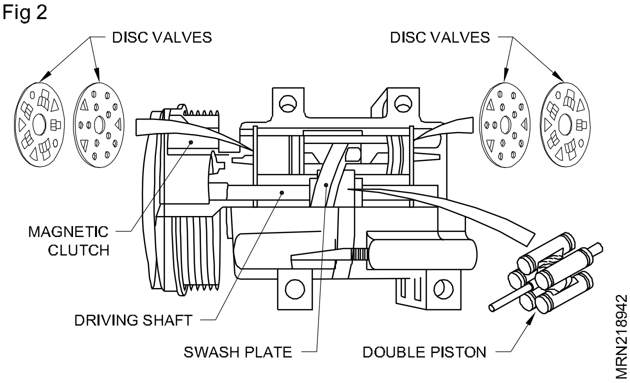


Table 1

Shows a summary of characteristics of the five compressor

Compressor types		Cost per kW	Efficiency	Vibrations	Manufacturing accuracy	Input power per unit
Positive displace ment	Reciprocating Single-acting	Low	Low	High	Easy	Low-High
	Rotary-Vane	Medium	Medium	Moderate	Difficult	Low
	Rotary-Scroll	Medium	High	Moderate	Difficult	Low
	Rotary-Screw	High	Very high	Lowest	Very difficult	High
Dynamic	Centrifugal	High	Very high	Lowest	Very difficult	High

Construction and working principle of wobble plate compressor

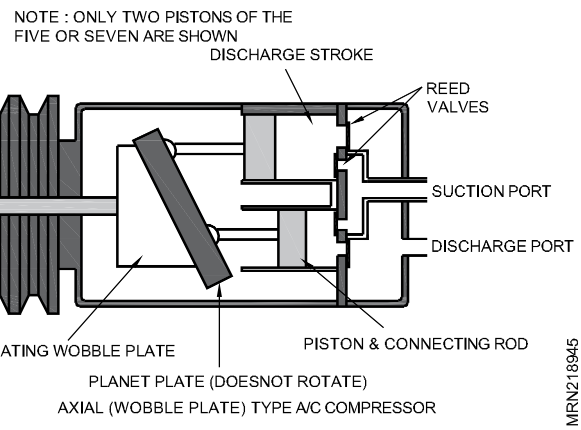
Objective: At the end of this lesson you shall be able to
- **construction and working of wobble plate compressor.**

Wobble plate compressor

A variable displacement compressor can change the angle of the wobble plate and piston stroke. This angle is changed by a control valve that senses evaporator pressure, which in turn changes wobble chamber pressure. Variable displacement A/C compressor are controlled by either a " MANUAL" or "ELECTRONIC" control valve. The manual valve consists of a diaphragm acted upon by compressor crankcase pressure. As the evaporator outlet temperature (pressure) rises and falls, the diaphragm causes the crankcase pressure to move the wobble plate in either direction. Increased wobble plate angle will increase compressor displacement and outlet and decreased wobble plate angle will decrease compressor displacement (output). MOST MANUAL VALVE VARIABLE DISPLACEMENT COMPRESSORS WILL HAVE AN ELECTRONIC CLUTCH. The electronic control valve does not have a diaphragm, but instead has a crankcase pressure control valve that is controlled by a computer (BCM or other module) based on inputs from various temperature and/or pressure sensors. It is duty-cycled to meet the needs of the outlet temperature of the evaporator. Most vehicles today use the electronic control valve. This is important to know when diagnosing a low pressure problem. The compressor may be completely capable of creating the required pressure, but the control valve or circuit is not responding to system demands. A simple pressure or temperature or other sensor could cause this problem. Never replace the compressor until all OEM diagnostic strategies are followed.

A variable displacement compressor can change the angle of the wobble plate and piston stroke. This angle is changed by a control valve that senses evaporator pressure, which in turn changes wobble chamber pressure. When the evaporator cools and low-side pressure drops, the piston stroke of a variable displacement compressor is reduced so that compressor outlet matches the cooling load. Variable displacement A/C compressors are controlled by either an internal mechanical control valve or and electronic valve that is pulse-width operated by a module. The manual valve option is shown here.

Fig 5



Identification & application of different types of single phase motors

Objectives: At the end of this lesson you shall be able to
- **description of single phase motor used in RAC fields**
- **different part of single phase motor**
- **function of different part**
- **application of the single phase motor**
- **different types of single phase motor**
- **speed/r.p.m of motors.**

Basically single phase motor driven by single phase supply i.e., 200-240 volts. Mainly induction motor used in RAC fields maximum. Induction motor receives its names because rotar has no outside source of supply. Rotating magnetic field creates in stator & that is why rotor moves by electro magnetic induction.

Motor has two parts i.e., rotor & stator

Static part is stator & revolving part is rotor. In stator two sets of winding is require to make it self starting namely, main or running winding and starting or auxiliary winding.

Main or running winding made of comparatively thick wire & starting or a auxilary winding made of thin wire, so that resistance of starting winding is more than running winding.

Types of single phase motors commonly used;

1 Split phase motor (RSIR)

2 Capacitor start (CSIR)

3 Capacitor start & run (CSR)

4 Permanent capacitor or capacitor run induction motor (PSC)

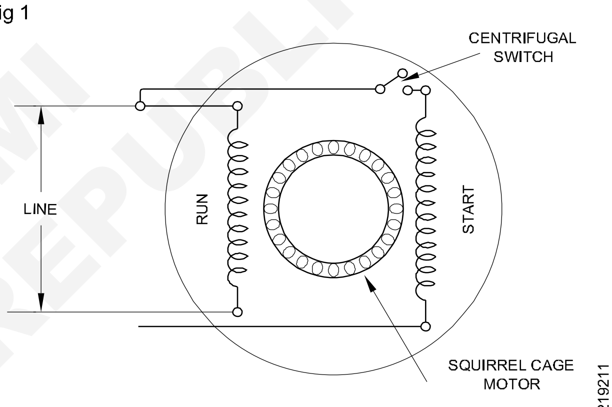
5 Resistance start capacitor run motor (RSCR)

6 Shaded pole motor

1 Split phase motor (RSIR): Basically this motor is used in small domestic freezer. Low starting torque is require to start the motor. When single phase supply is given to the stator, a rotating magnetic (field creates)in stator. The current flow in the running winding lags the current flow in the starting winding by approximately 30 electrical degrees. Since the current flowing in the two windings are 30 degree out of phase which each other the single phase is split to give the effect of two phases and a rotating field is set up in the stator which produce starting torque. When the motor speed gained about 75% of its rated speed centrifugal switch or relay disconnect the starting winding then the motor runs continuously by running winding only

2 Capacitor start (motor): The construction of capacitor start induction motor is same as that of split phase induction motor. Except that a start capacitor is installed in series with the starting winding as shown in figure. So starting torque is very high due to starting capacitor connected in series with the starting winding. When the rotor reaches 75% of its rated speed, centrifugal switch or rely disconnect the starting winding with the starting or relay disconnect the starting winding with the starting capacitor. Then motor runs only running winding. This type compressor motor mainly used in deep freezer.

Fig 1

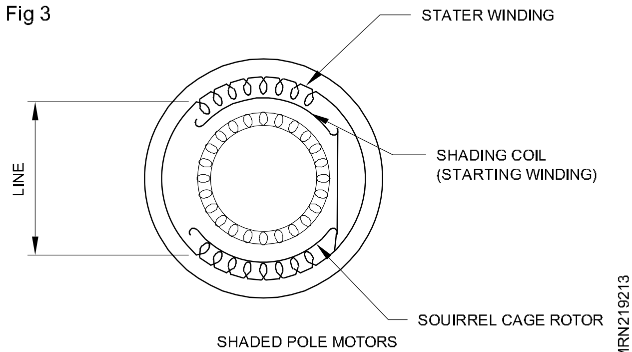


SPLIT PHASE INDUCTION MOTOR (RSIR)

3 Capacitor start & run motor (CSR): The construction of the capacitor start run induction motor is same as that of capacitor start induction motor with exception that a running capacitor is installed in series with the starting winding as shown in figure. The operation of the capacitor start run induction motor differs from that of the capacitor start and split phase induction motor is that the starting winding remains in the circuit at all times. The starting time of the motor, the starting and running capacitor are both in the circuit in series with the starting winding, So the capacity of both capacitors is utilized during the starting period. When the rotor reaches 75% of its rated speed relay disconnect the starting capacitor from the circuit. Then the motor continuous to operate with running and starting winding. The function of the running capacitor is to improve the power factor. This type compressor motor used in air conditioner.

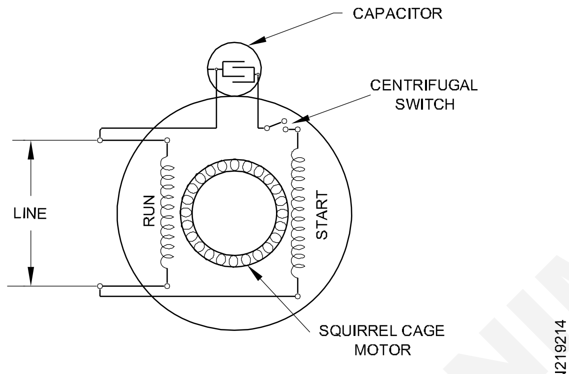
4 Capacitor run induction motor (PSC): Construction of the capacitors run induction motor is similar to that of the capacitor start run induction motor except that no starting capacitor and relay is used. The running capacitor only connected in series with the starting winding and remains in the circuit continuously. The running capacitors improved the power factor and also used for developing the starting torque during starting period of the motor. This compressor motor used in air conditioner. (Fig 3)

Fig 3



SHADED POLE MOTORS

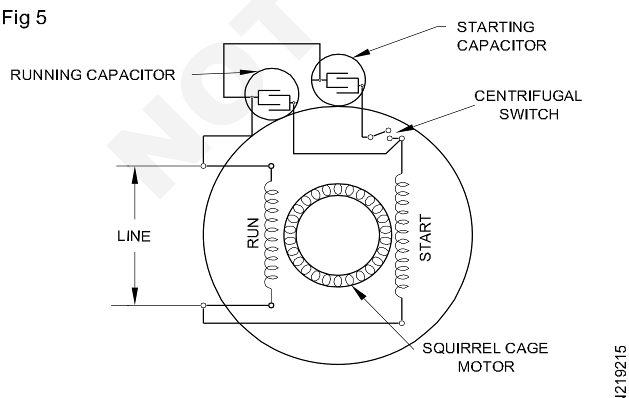
Fig 4



CAPACITOR START INDUCTION MOTOR (CSIR)

5 Resistance start capacitor run motor (RSCR): The construction of resistance start capacitor run (RSCR) motor is similar to capacitor start induction run (CSIR) motor except that running capacitor is used instead of starting capacitor. The running capacitor is connected in series of starting winding and installed before really. When motor gained 75% of this rated speed then starting winding disconnect by relay but this winding (starting winding) remains in the circuit through the running capacitor. The running capacitor improve the power factor.

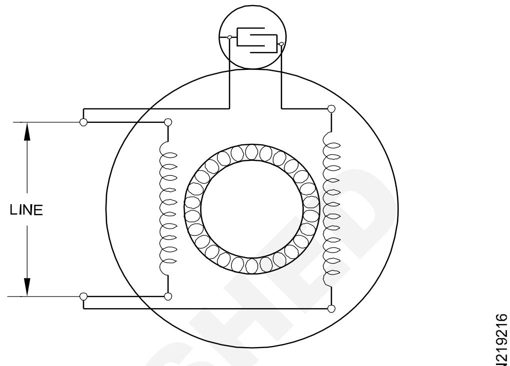
Fig 5



CAPACITOR START & RUN INDUCTION MOTOR

6 Shaded pole motor: Construction of shaded pole motor differs from the single phase motor. The auxiliary winding consists of a shading coil which surrounds a portion of one side of each stator pole. The shedding coil usually consists of a single turn of heavy copper wire which is short circuits and carries only induced current. In operation the flux produces by the induced current fields of the stator poles & there by produces a small starting torques. Shaded polemotor are widely used as drives for small fans which are mounted directly on the motor shaft (Fig 5).

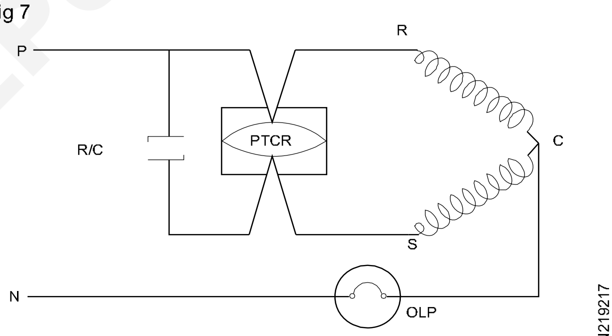
Fig 6



CAPACITOR RUN INDUCTION MOTOR (PSC)

RPM /Speed : Speed of single phase motor depends on frequently & number of electromagnetic poles forms in stator winding. If the stator winding wound or design in such a way that two magnetic poles are forms in stator then maximum speed.

Fig 7



RSCR CIRCUIT

The formula of synchronous speed

$$= \frac{2 \text{ x frequency}}{\text{Number of poles}} \text{ in seconds}$$

$$\text{For 50 cycles or } \frac{2 \times 50 \times 60}{\text{Number of poles}} \text{ in minutes}$$

$$\text{For 2 poles motor r.p.m } = \frac{120 \times 50}{2} = 300 \text{ r.p.m}$$

The speed at stator, but effective speed at rotor is tile less after decuting % of slip.

i.e. for two poles motor it may be 2850 r.p.m

For four poles motor it may be

The speed at which rotor rotates is called 1425 rpm the rotor speed of the motor.

The difference between the stator (synchronous)speed and the actual rotor speed is called Slip. Slip speed is the number of r.p.m by which rotor continuous to fall behind the revolving magnetic field.

The formula to find the slip by the equation;

of slip

$$s = \frac{Ns - Nr}{Ns} \times 100$$ given the percentage

When Ns - Rotating magnetic field speed at stator (Synchronous speed)

Nr - Rotor speed or effective speed

S - Slip

e.g. for 4 poles motor, rotor speed is 1425 r.p.m

From formula,

$$Ns = \frac{120f}{P} = \frac{120 \times 50}{4} = 1500 r.p.m$$

$$So, Slip = \frac{1500 - 1425}{1500} \times 100 = \frac{75}{1500} \times 100 = 5\%$$

Difference between AC and DC motor

Sl.No	AC motor	DC motor
1	AC motor can be defined as an electric motor which is driven by an AC current	DC motor is also rotatory electric motor that convert DC current to mechanical energy.
2	AC motors are mainly two types a Synchronous motor b Induction motor	DC motors also two types a DC motor with brushes b DC motor with out brushes
3	Commutators and brushes are absent in AC motors.	DC motors will only run when DC supply is given, in the case of DC series motor the motor might run with AC supply but for shunt motors never runs on AC motor
4	AC motors can run on both single phase and three phase supply.	Commutators and carbon brushes are present in DC motors.
5	A three phase AC motor is self starting but single phase AC motor require a starting mechanism.	DC motors are always self starting in nature.
6	In AC motors the armature is station any while the magnetic field rotates.	DC motors the armature rotates while the magnetic field remains stationary.
7	In AC motors three input terminals (RYB) is present.	In DC motor two input terminals (+ve and –ve) are present.
8	The speed of an AC motor can be changed by varying the frequency	In case of DC motor speed can be controlled by changing the armature winding current.
9	AC motors show a slow response to the change in load.	DC motors show a quick response to the change in load.
10	Since AC motor do not have brushes and commutators, they are very rigged and have a high life expectancy	Brushes and commutator in DC motors limit the speed and reduce the life expectancy of the motor.
11	Due to induction current lose and motor slip, the efficiency of AC motor is less.	The efficiency of DC motor is high as there is no slip and induction current loss.
12	AC motor require less maintenance as brushes and commutators are absent.	DC motor require excessive maintenance due to presenter of commutator and brushes.
13	AC motors are required where there is a need for high speed and variable torque.	DC motors are required where there is a read for variable speed and high torque.

Terminal of a sealed compressor motor

Objectives: At the end of this lesson you shall be able to
- **description of compressor motor terminals**
- **checking procedure of unknown terminals by different methods.**

Basically hermetically sealed compressor motor & compressor assembly inside a sealed housing only terminals of motor outside the steel casing. So it is difficult to identify the terminals from outside without testing.

So make wiring with the controls & run the compressor motor is difficult & without knowing the terminals identify.

So far identify the terminals of the motor, the resistance in between terminals should be measured. At first mark the terminals of hermetic unit like XYZ and then measure the resistance by ohmmeter.

Maximum resistance (Ω) will be in between main & starting terminals so remaining terminal is common identified. Again minimum resistance is between running (main) &common terminals so starting terminals is identified

Instead of ohm meter we can check by series lamp (200 watts) as per the resistance of pair of terminals, the bulb glow more bright with less resistance & glow comparative dim (for high resistance). It require more experience to identify the terminals correctly, so by checking ohm is avoid confusion and identify the terminals more correctly.

X & Y more Ω identified two terminals are running & starting.

So Z is common minimum Ω identified two terminals are running & common.

So 'Y' is starting.

Compressor motor check out

Identifying the compressor terminals

Using an ohmmeter

Compressor terminals can be identified either by markings on the protective terminal cover, the wiring diagram or with a ohmmeter.To identify the Run, Start and Common terminals with an ohmmeter, do the following:

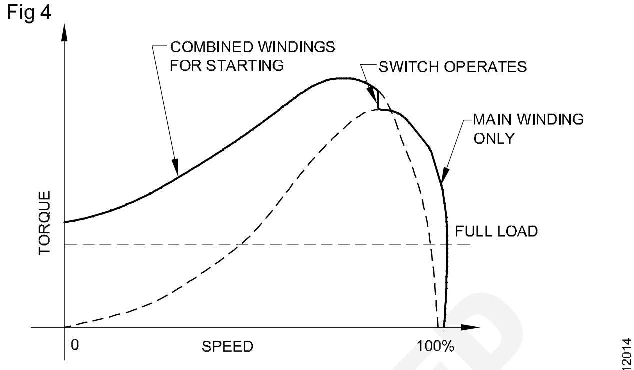
1. Determine the highest reading between any two terminals and write it down. The remaining terminal is the common terminal.
2. Determine the highest reading between common and the other two terminals. This terminal will be the Start terminal.
3. The lowest reading is the Run terminal.

X More Ω

Y

Z Minimum Ω

Fig 4

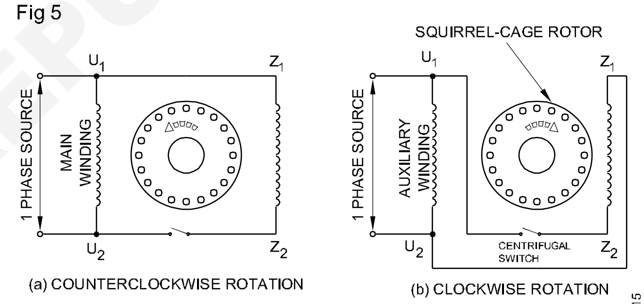


TORQUE SPEED CHARACTERISTIC OF SPLIT PHASE MOTOR

joined to U1, 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.

Fig 5



METHOD OF CHANGING THE DIRECTION OF ROTATION OF RESISTANCE START INDUCTION RUN MOTOR

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.

Fig 1

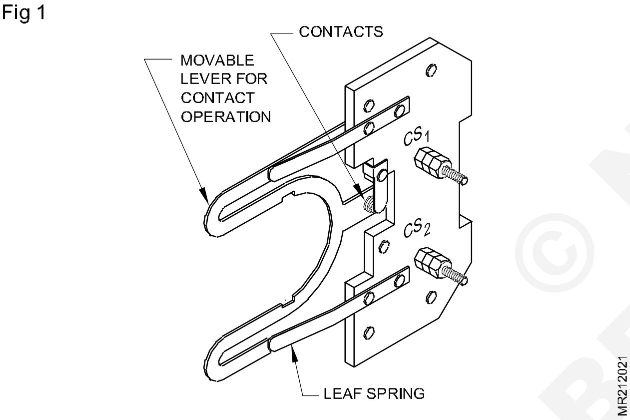
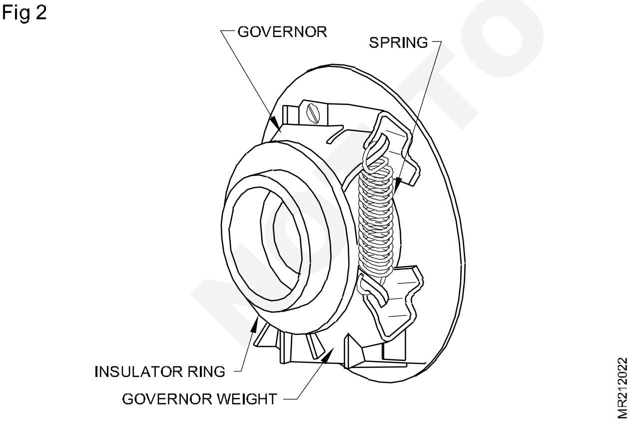


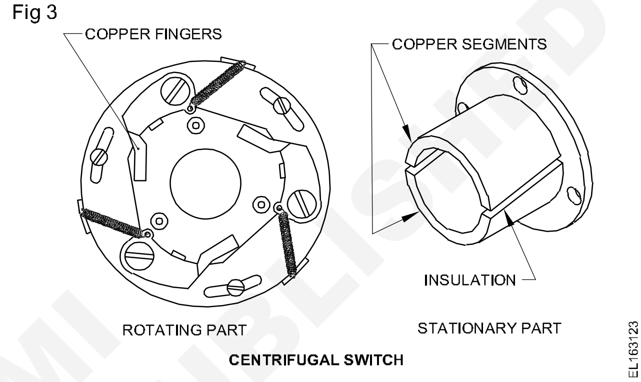
Fig 2



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 CS1 and CS2 open the starting winding.

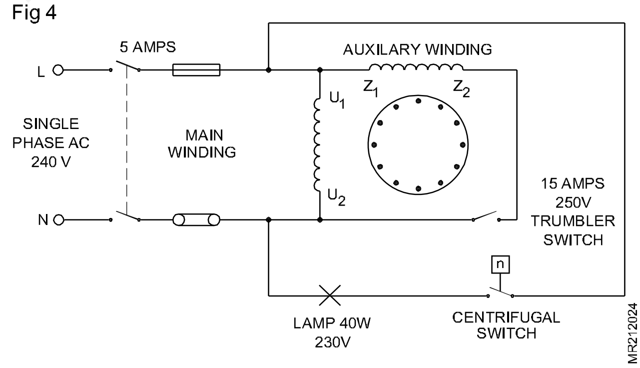
In older types of centrifugal switches, the stationary part consists of two copper, semicircular segments. These are insulated from each other and mounted inside the front-end plate. The centrifugal switch connections are given to these segments. The rotating part is composed of three copper fingers 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.

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.

Fig 4



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 atleast once in six months to ensure their proper operation. Look for broken or weak springs, for improper movement, for dirt or corrosion or pitting 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 trumbler 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 5

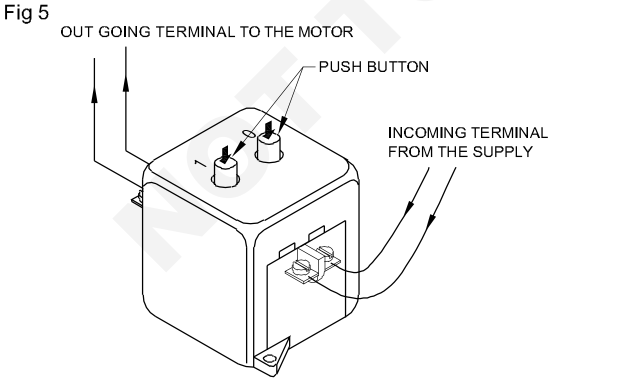
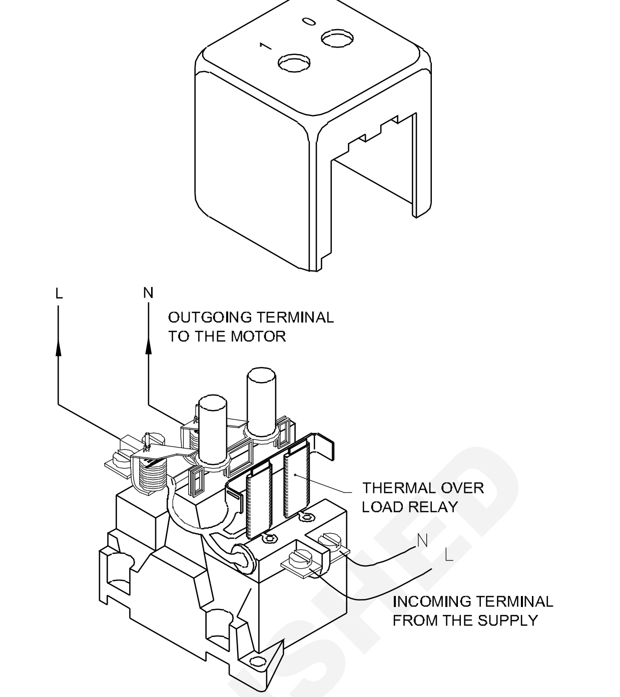


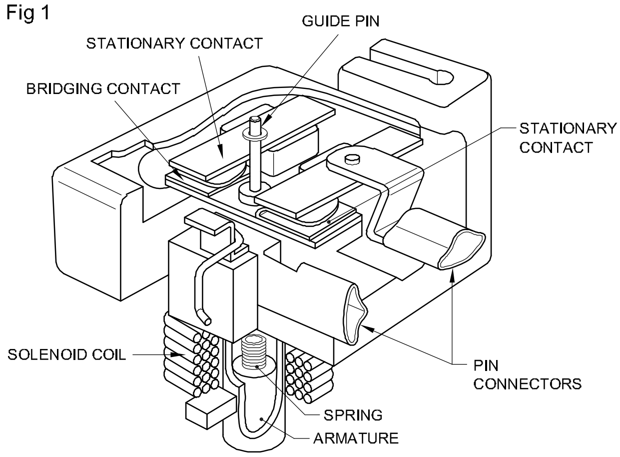
Fig 6



OPEN VIEW OF MANUAL D.O.L STARTER

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 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)

Fig 1



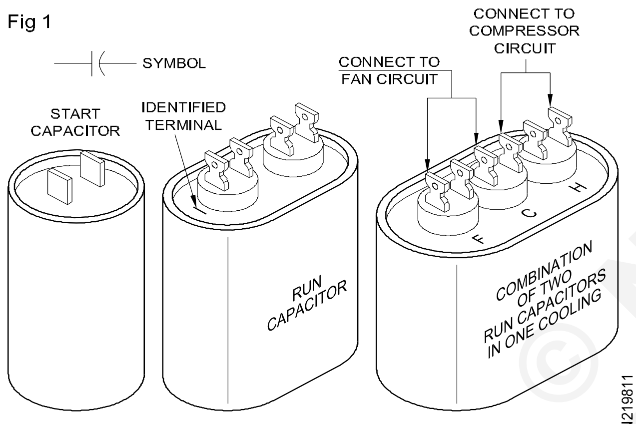
CURRENT TYPE STARTING RELAY

Capacitors, relays, over load protector, thermostat and selector switch

Objectives: At the end of this lesson you shall be able to
- **explain capacitors and functioning of start capacitor and run capacitor**
- **explain types of relays and functioning**
- **explain overload protector**
- **explain compressor winding and their uses.**

Capacitors: A capacitor (Fig 1) consists of two conducting plates separated by a dielectric (insulating) materials. When a voltage is applied to a capacitor electrons build up on one plate charging the capacitor. When the charge builds up on one plate, electrons are moved from the other plate. When a capacitor is used in an alternating current circuit, the build up of charge can be used to amplify the voltage as it build in the opposite direction. Capacitors are of two types and used for two different purposes.

Fig 1



TYPES OF CAPACITORS

Start capacitors are commonly round in cross section and designed to amplify a voltage to increase the starting torque of a motor. Start capacitors are designed to be used for only a few seconds at a time (during the startup of a motor). After this time, a switch wired in series must open or disconnect starting capacitor from the circuit.

Run capacitors are commonly oval or rectangular in cross section shape and designed to align the voltage and amperage cycles that have been separated by the back e.m.f generated by a motor winding. This improves the power factor reduces the running current of the motor.

The unit of capacitance is the Farad. A farad however is a very large unit of capacitance. In order to avoid using very small numbers, capacitors are rated in Microfarad (mfd). Run capacitors are usually lower Microfarad rating (2-40 mfd) than start capacitors.

There are testers available that can test the capacitance rating of capacitors. Field checks can be performed using only ohmsmeter. First discharge any stored charge on the capacitor by shorting across the terminal with (15000 to 20000 ohms). Technician commonly discharge the capacitor with an insulated screw driver but this method not recommended by capacitor manufacturers as it may cause failure of the capacitor.

If there is already a bleed resistor installed across the capacitor terminals, it will need to be disconnected to test the capacitor. Then with the ohmmeter set on a high resistance scale (Rx10000) measure the resistance across the terminals. If the capacitor is good, the needle will swing towards zero and then slowly return to a high resistance reading. The capacitor resistance is increasing as it stores the charge being furnished by the battery in the ohmmeter. A second check is required to determine whether the capacitor is shorted to the metal casing. Still using Rx10000 scale, measure resistance from each terminal to the casing. The needle should not move (infinitive resistance).

Run capacitors have one terminal identified with either dot, a dash, an arrow or a red dot. This is the terminal that is more likely to ground to the casing.

The running capacitor is a permanent. Capacitor it will remain the circuit until stop the motor. Starting capacitor is a temporary capacitor, it should be disconnected after giving starting torque & start the motor by CF switch or relay.

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 sometimes called amperage relay. Since it is the ampere draw on the circuit that operates the relay.

> **The relay coil series with the running coil of the motor.**
>
> **The running capacitor is a permanent.**
>
> **Capacitor it will remain the circuit until stop the motor.**
>
> **Starting capacitor is a temporary capacitor, it should be disconnected after giving starting torque & start the motor by cf switch or 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 with in a few seconds, the start winding current that is passing through the relay causes the relay to set quite hot. This counts its resistance to increase dramatically at it than 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.

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 with in one or two minutes and will try to start the compressor again.

Compressor winding: Any single phase induction motor is not self starting. It require additional torque to rotate the rotor. To provide additional torque starting winding is necessary.

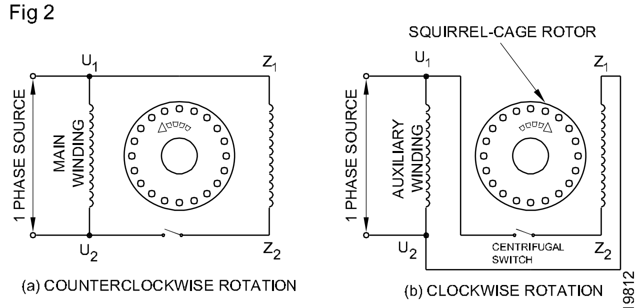
For self starting single phase compressor have two motor windings. The start winding and the run winding. These two windings are wired together in series inside the compressor shaft. Three wires are attached to these winding. One at each end and one at the common junction of the two winding. These three 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 this 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.

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 2a. 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 2b.

Fig 2

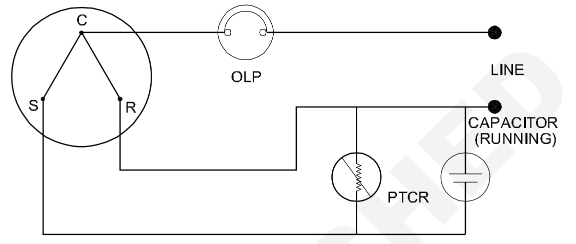


METHOD OF CHANGING THE DIRECTION OF ROTATION OF RESISTANCE START INDUCTION RUN MOTOR

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.

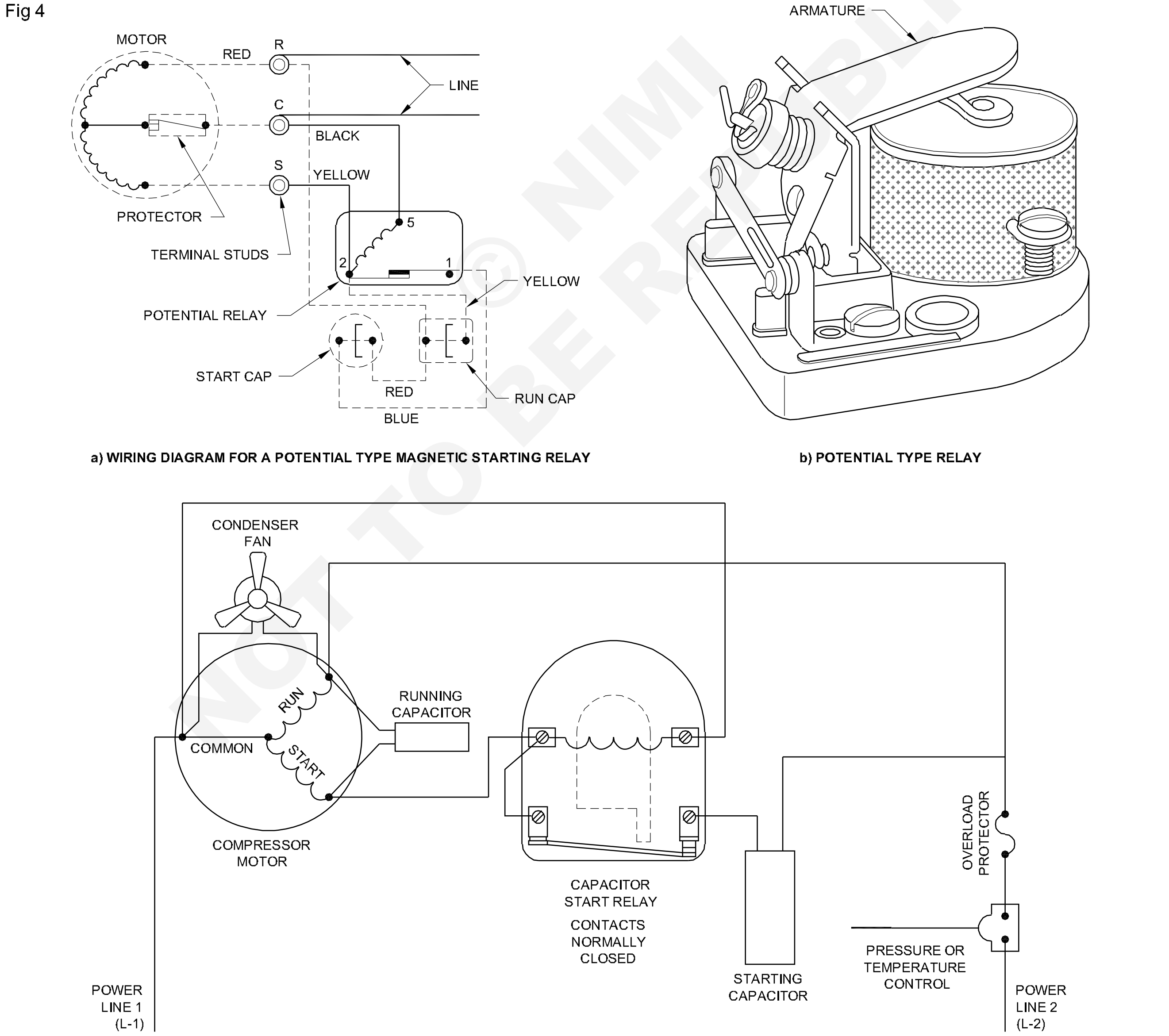
Induction start, induction run motor: Instead of resistance start, inductance can be used to start the motor through a highly inductive starting winding. In such a case, the starting winding will have more number of turns, and will be imbedded in the inner areas of the stator slots so as to have high 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.

Fig 3



RSCR CIRCUIT

Fig 4



a) WIRING DIAGRAM FOR A POTENTIAL TYPE MAGNETIC STARTING RELAY

b) POTENTIAL TYPE RELAY

c) WIRING DIAGRAM FOR POTENTIAL RELAY

Basic working principle of inverter AC

Objectives: At the end of this lesson you shall be able to
- **introduction & overview split & multi split**
- **describe inverter technology.**

Daikin's split and multi-split type air conditioning systems offer superior performance, energy-efficiency, and comfort in stylish solutions conforming to all interior spaces and lifestyles. An extensive product lineup utilizes Daikin technology for lower costs and environmental impact.

OVERVIEW

Split

Connects one indoor unit to an outdoor unit. Installs simply and unobtrusively to buildings with no need for ductwork.

Delivers a sophisticated air conditioning solution to single zone interior spaces at an affordable price. Provides a simple solution for one-room additions.

Multi-split

Connects up to nine indoor units to a single outdoor unit.

Installs a complete air conditioning system to multiple zone interior spaces with no need for ductwork.

Provides individual control of room temperature settings.

Enables indoor units of different styles and capacities in one system for customized solutions unique to each residential setting.

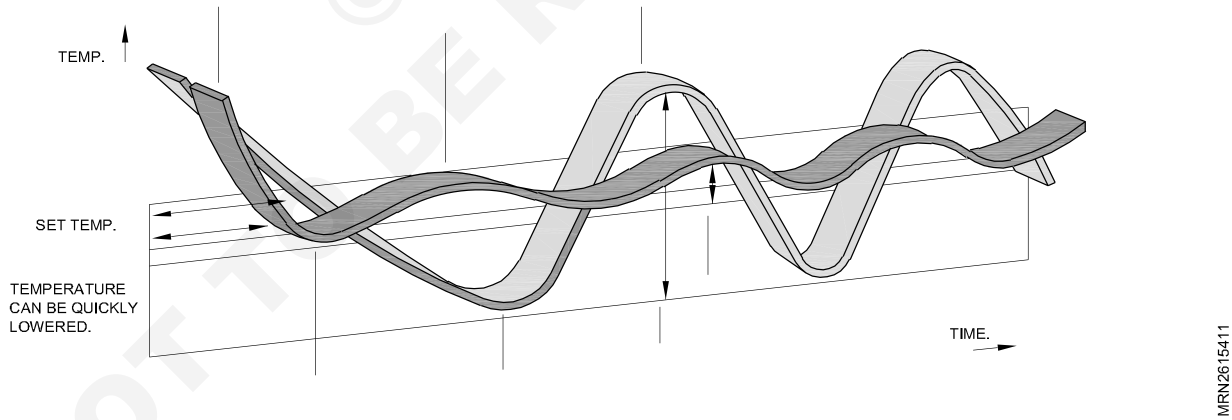
Inverter Technology

Air conditioning compressors are driven by motor, and motor rotation speed depends on power supply frequency. An inverter modulates power supply frequency to control motor rotation speed. Inverters stabilize temperature by adjusting compressor operation according to load to eliminate waste and save energy.

Even adopting an inverter to the fan motors of the indoor and outdoor units provides more precise control and contribution to energy savings.

Temperature control by inverter/non-inverter compressors (cooling)

Fig 1



Air Conditioner inverter

An inverter in an air conditioner is used to control the speed of the compressor motor to drive variable refrigerant flow in an air conditioning system to regulate the conditioned space temperature. By contrast, traditional air conditioner regulate temperature by using a compressor that is periodically either working at maximum capacity or switched off entirely. Inverter-equipped air conditioners have a variable-frequency drive that incorporate an adjustable electrical inverter to control the speed of the motor and thus the compressor and cooling output.

The variable-frequency drive uses a rectifier to convert the incoming alternating current(AC) to direct current(DC) and then uses pulse-width modulation in an electrical inverter to produce AC of a desired frequency. The variable frequency AC drives a brushless motor or an induction motor. As the speed of an induction motor is proportional to the frequency of the AC, the compressor can now run at different speeds (icitation needed) A micro controller can then sample the current ambient air temperature and adjust the speed of the compressor appropriately. The additional electronics and system hardware adds cost to the equipment installation but can result in substantial saving in operating costs.[1]

Difference between a standard and inverter split systems

Inverter of Air conditioning

Through new, advanced technology, Inverter air conditioner are more economical to operate and quieter to run than conventional units. They can handle greater extremes in temperature, we are smoother and more stable in operation, and reach the desired temperature more quickly than conventional air conditioners.

Split Systems

Split systems are where the compressor and outdoor heat exchanger are located outside, some distance from the indoor air-handling unit. They are joined together by refrigerant lines. You need to get the systems installed by a professional installer.

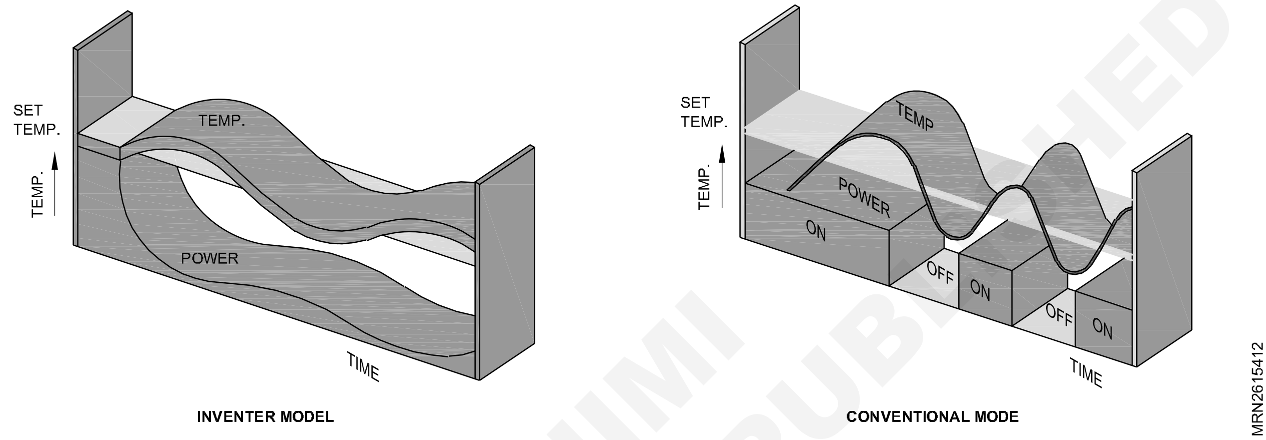
The indoor units can be floor-mounted, wall mounting ceiling mounting or as cassette units. Outdoor units are usually located externally-on the roof, on a balcony or at ground level.

Temperature for efficient use of air conditioner

The queensland government (Australia) promotes 24 degrees celsius as being the recommended temperature for the efficient use of an air conditioner when cooling.

This is supposedly a temperature that keeps you comfortable and does not use undue power to the unit.

Fig 2



Air cooled condenser of domestic refrigerators

Objectives: At the end of this lesson you shall be able to
- **function of the condenser**
- **description about construction**
- **state flushing & cleaning procedure**
- **explain types of condensers used in household refrigerators**
- **state body condenser in modern fridges**
- **describe the problem in air-cooled condenser.**

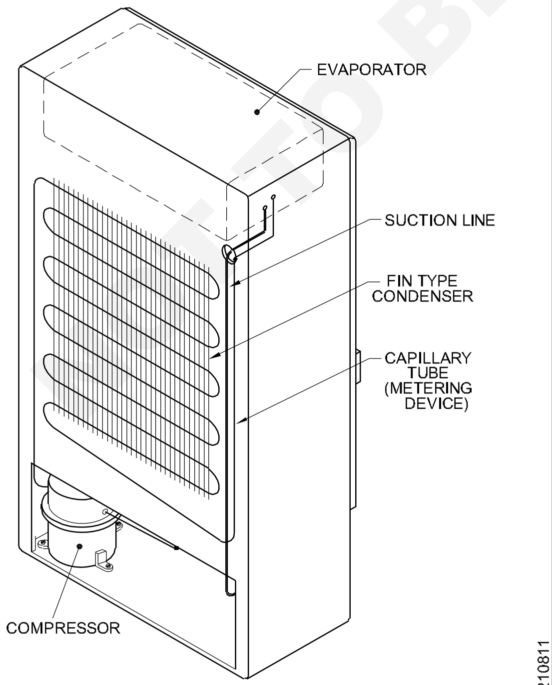
Function of condenser: The function of the condenser is to remove heat from the super heated high pressure refrigerant vapour and to condense the vapour into a sub cooled high pressure refrigerant liquid. This is accomplished by passing atmosphere air sucked by the fan and thrown or sucked through the condenser. This air picks up the heat from the heated refrigerant and cools the refrigerant and it gets liquefied.

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 wiremesh type and the other is plate type. For wiremesh type refer Fig 1.

Fig 1



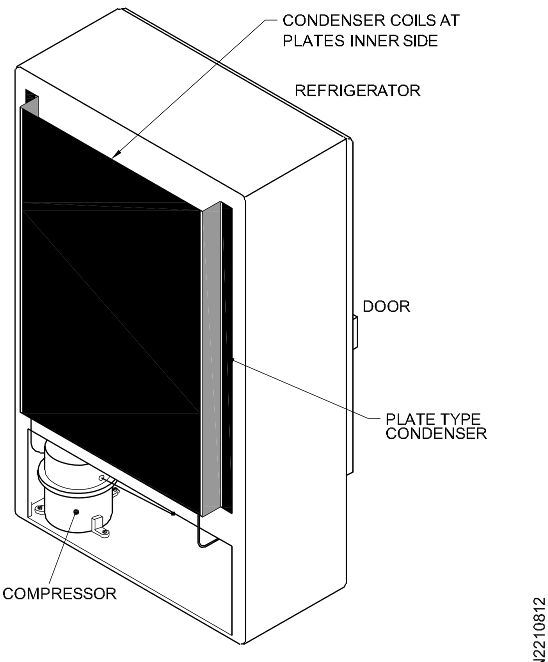
REFRIGERATOR WITH FIN TYPE CONDENSER

Wiremesh type: In this type the wiremesh are provided vertical on a frame. The fins are like a thin rod (2mm dia) evenly welded in proper interval to the frame. The condenser coils will be clamped & 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) & the condenser coils get cool. The pollution of air, the condenser wiremesh will get a coating of find 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)

Fig 2



REFRIGERATOR WITH PLATE TYPE CONDENSER

The condensation takes place by natural air ventilation. Condenser tubes gives up heat to the plate by conductivity and the plate surface is cooled by natural air velocity. So always its 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 need 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.

It may be propular back clean condenser by name

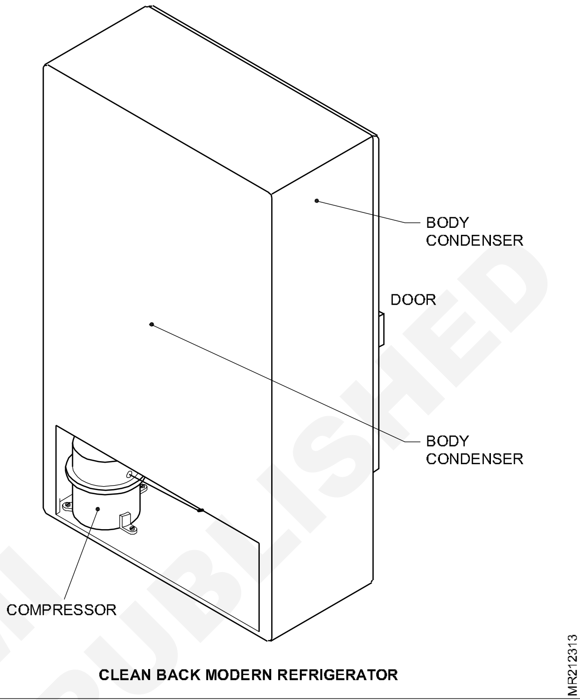
It also advantageous no extra anti condensation neater or any arrangement is to be provided. As it is little bit warm, so no dew point. So that no sweeting problem arises.

Disadvantages

Service difficult if there is any leakage or blockage the entire condenser into be replaced by external condenser.

Running period of compressor is more as the condenser closer to refrigerator cabinet, so that heat description will be more.

Fig 3



CLEAN BACK MODERN REFRIGERATOR

Air cooled condenser in Window Air conditioners

Objectives: At the end of this lesson you shall be able to
- **explain window air conditioners**
- **explain room units air flows**
- **explain fin type air cooled condensers**
- **explain tips while servicing and repairs of air cooled condensers.**

Window air conditioners: In window air conditioner all the components are located with in a box. This box is divided into an outdoor section and an indoor section. One motor is used to drive both the outdoor condenser fan and the in door evaporator blower. The window air condition unit mounts on a window side of the wall and installation is too easy.

Window units are available in several types. One type cools and filters the air and has a fresh air intake also. Most of the hospitals patients rooms which has to be pollution free there these kinds of units are recommended.

The another type same kind of arrangements will be in addition has an electrical resistance heating unit, to furnish heat in winter season. One more type uses a reverse cycle system of air flow to permit the use of refrigeration unit both for comfort cooling and heating purpose.

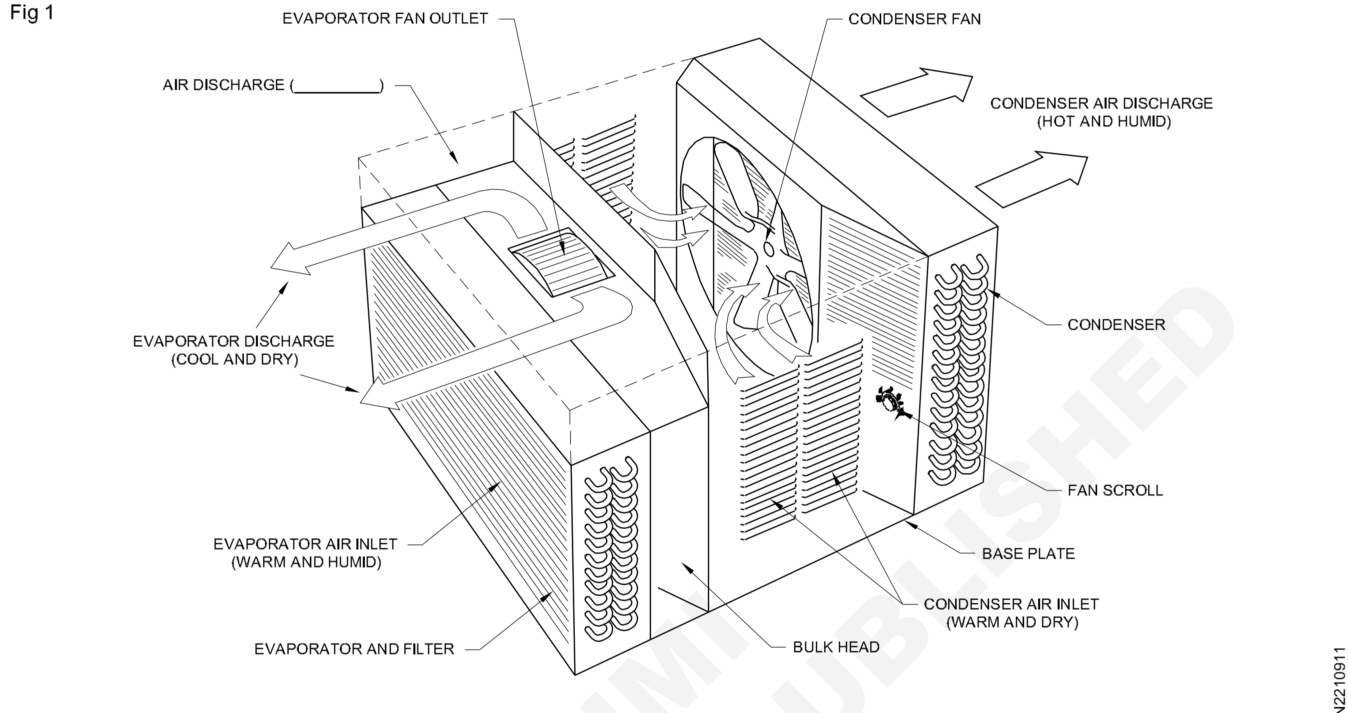
Room units air flows: In room window air condition units the outside air is forced over the condenser by a fan inside room the evaporator blower draws air in through a filter and forces it over the evaporator. (Fig 1) This picture shows the complete air flows in room unit.

In comfort cooling type which is commonly used in window air conditioner will produce cooling in the room. These window air conditioner is provided with air cooled condenser. The rooms related humidity is not controlled in window air conditioners. Only space temperature being sensed by the controls. But normally 50% to 70% relative humidity, fluctuating with latent heat of load variation will be maintaining inside the room.

Fin type air cooled condenser: The condenser coils will be covered with the section of fins externally with equal gap to distribute the air flow on the coils. The fan is provided facing the condenser to deliver air for cooling the coils, (Fig 2). The fan will be made with slinger arrangement that will splash the condensate water accumulates on the base, throw it on the condenser for easy cool.

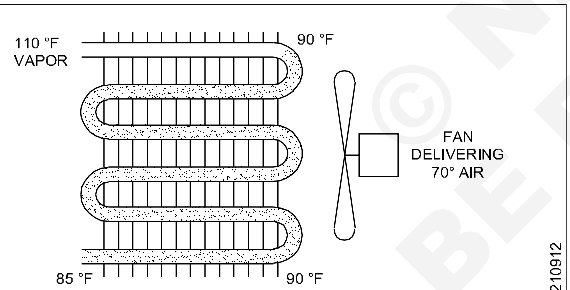
The hot vapour from the condenser enters the top of the condenser. In first small section this vapour is cooled to the condensing temperature for the pressure prevailing in condenser. From here the heat is extracted and the vapour is condensed. The refrigeration circuit for window air conditioner (Fig 3) is shown below.

Fig 1



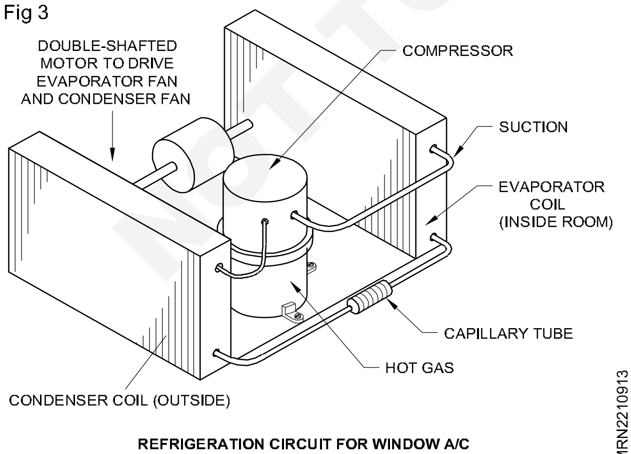
ROOM UNITS AIR FLOW

Fig 2



SCHEMATIC AIR COOLED CONDENSER.

Fig 3

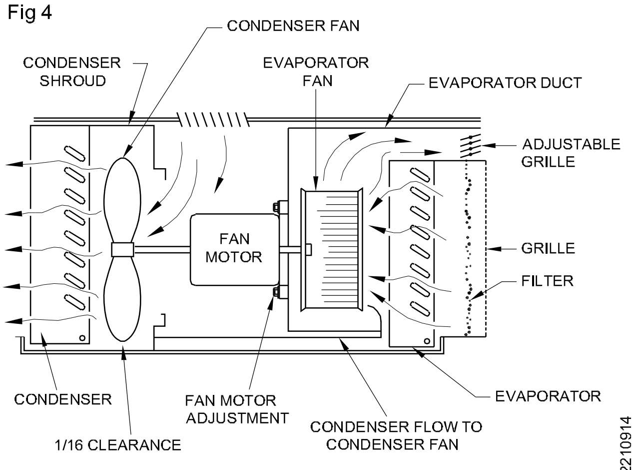


REFRIGERATION CIRCUIT FOR WINDOW A/C

The vapour gets condensed in the form of liquid droplets, collect and run after filling the entire tube. To keep this heat extraction going on, a fan forces a blast of air over the outside of the condenser.

The basic arrangement of the components are shown (Fig 4). These window air conditioner units refrigerant R-22 for the maximum cooling effect for the small size compressor. A single phase double end shafted motor is used to turn both the evaporator and condenser fan. A thermostat cycles the compressor to satisfy the room temperature demand.

Fig 4

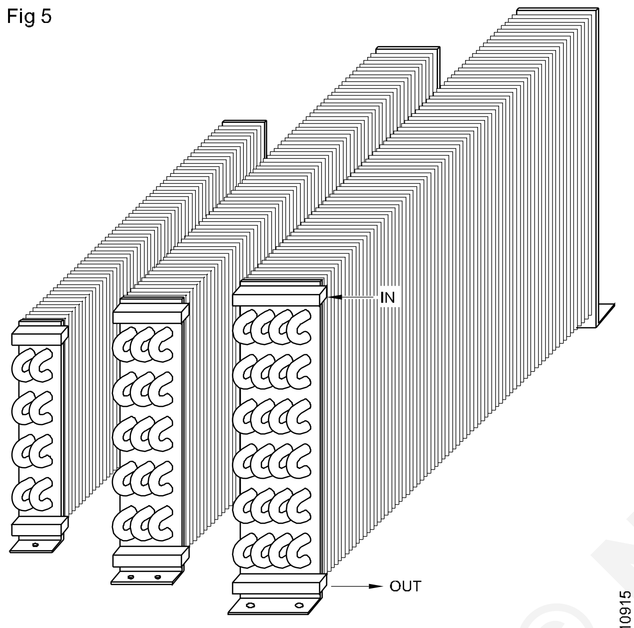


BASIC ARRANGEMENTS OF COMPONENTS IN WINDOW AIR-CONDITIONS.

There are various size of air cooled condensers are available depends on the capacity of the units. The double row single pass has two rows of tubes to give greater surface but all the refrigerant must pass through all the tubing before escaping.

In the case of the double row double pass, half the refrigerant goes through each coil. Since half the liquid is then condensed in each coil the liquid will not fill the coil so quickly. As per the heat load calculations of the space the number of rows will be increased in design (Fig 5). The fins which are arranged on the condenser tubes will distribute the air velocity evenly on the tubes.

Fig 5



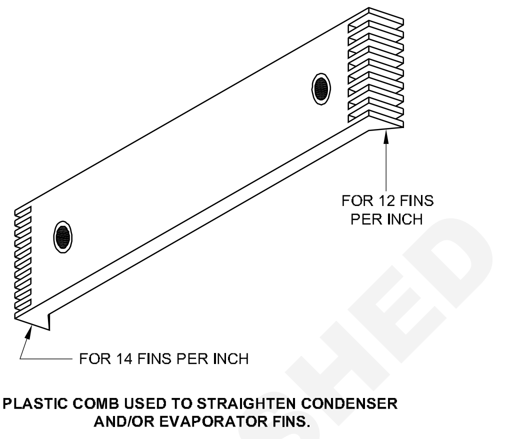
DOUBLE ROW DOUBLE PASS, THREE ROW THREE PASS AND FOUR ROW FOUR PASS AIR COOLED CONDENSERS.

Service and repair of air cooled condensers: Since the fins are arranged with narrow gap, the dust in the air will be accumulating on the fins and affect the air flow through the condenser. This can be cleaned by air blowers pressure.

Moisture in the air causes rusty formation on the Aluminium fins and it can be cleared by spraying rust removing chemical when the unit is under service.

Fins are made up of thin sheets and so there are possibilities for it to bend and jam. These fins may be straightened by using a fin comb (Fig 6). It is one model of the fin comb.

Fig 6



PLASTIC COMB USED TO STRAIGHTEN CONDENSER AND/OR EVAPORATOR FINS.

All these servicing are illustrated.

Important notes while servicing window air conditioners, air cooled condenser.

Lubricate the fan motor on every service and wipe the excess oil. Avoid bending the fan blades if rubbing with the condenser shroud or cabinet wall since the fan blade may break soon.

Check the condensate water passes correctly to the base drain by level adjusting. Inspect the base drain it must be kept clean. Check all the bolts & nuts screws for tightness to avoid vibration.

Effects of a chocked condenser in split AC

Objectives: At the end of this lesson you shall be able to explain the
- **effects of a chocked condenser.**

Effects of a chocked condenser: When the fins get chocked in a air cooled condenser it restricts the air flow due to lack of air flow condensation from gas to liquid will not take place fully. Hence only the quantity of condensed liquid will carry out the refrigeration effect. Where as the gas will flow in the useless evaporator not doing any jobs.

Due to this lack of condensation, not only lack of refrigeration takes place but also the running current increases and if the condenser is chocked severely the compressor will trip on overload. If it trips on overload very often, the motor windings will get heated which will result in a winding failure.

Hence the condenser should be checked physically and the period of cleaning should be decided according to the area it is located.

Effect of internal checked:

Condenser & capillary strainer may be fully or partly checked due to contaminated refrigerant lubricant or very old capillary & filter formation copper oxide, inside in presents of very little quantity of moisture. So for clean the condenser coils, flush the coil by dry nitrogen thorough. For more contaminated coir chemical cleaning is require. Trichloro ethylene is used for chemical cleaning.

Adequate care should be taken to remove the chemical by flushing otherwise compressor winding and lubricant may be damaged. After clean the coil, capillary & strainer/drier should be replaced.

Receiver, liquid line sight glass and strainer

Objectives: At the end of this lesson you shall be able to
- **explain the liquid line connected to receiver**
- **explain the position and function of sight glass**
- **explain the location and use of liquid line strainer and liquid line shut off (solenoid valve) valve.**

Liquid receiver: The liquid receiver is a steel tank of welded construction. The main function of this part in open type refrigeration system is to receive and store the liquid refrigerant from condenser outlet, after condensation and also to distribute as per quantity to flow control, when the machine is in running condition. When the machine is in 'OFF' condition, it will store the excess refrigerant liquid.

According to construction of fitting, liquid receiver is classified into two types.

Vertical type: This type of liquid receiver is commonly in smaller capacity open units and it is very rare in use.

Horizontal type: The receiver is constructed horizontally and it is usually equipped with two service valves.

One is a liquid receiver service valve mounted between the liquid receiver and the condenser. The other is located at the outlet of the receiver on the liquid line (King valve). These two valves enable to service technical to disconnect the liquid receiver from the system separately.

Since receiver is a refrigerant container, the pressure may vary, during pump down, shut down, fire or extreme temperature conditions - faulty electrical controls, high pressure could come to some part of the system to explode.

To prevent extreme dangerous pressures, relief valves are mounted on the units, usually on the liquid receiver. In water cooled condensers provided in large commercial plants, the shell of the condenser is designed to act as a receiver. The receiver should be large enough to hold all the refrigerant in the system. Fig 3.

In commercial plant liquid receivers, there are some additional fittings provided.

Charging port: Through this charging port refrigerant gas can be charged, bulk quantity in the system.

Purging port: This is intended to purge (remove) non-condensable gases (air, carbon-di-oxide etc.) from the system during off condition. In addition to this sight glass (Reflex) is provided to check the level of the liquid receiver, while the plant is idle.

Sight glasses: Sight glasses are usually installed in liquid lines of commercial installations. The sight glass will show bubbles if the system is low on refrigerant. Fig1.

These types of sight glass designed for soldered or brazed connections. The cap is to protect the sight glass from damage and keep it externally clean.

Pump down system in the split AC

Objectives: At the end of this lesson you shall be able to
- **explain the pump down the system**
- **explain the types of split A/C system.**

As you all know split A/C system in the combination of the indoor unit and outdoor unit connected through refrigerant line (upper) are duly insulated.

The Outdoor unit is mounted at the top of the (floor) building, balcony, even mounted on the angle frames duly grounded in the wall. Out door unit consists of condenser, service valves (inlet and outlet) fan motor and propeller (for air throw). Some outdoor units mounted along with compressor, discharge line mounting frame. Outdoor units provided with fan motor(s) (two) according to the capacity of the unit.

The Indoor unit is always mounted inside the insulated room where cold air is needed. It comes of with cooling coil (evaporator), fan motor with blower (s) (scroll assembly) differs in air throw (top throw, side throw) and filter provision is made before the cooling coil to prevent moisture/dirt from the air which is drawn through.

Before removal of both the units, gas must be saved through storing at one of the unit by pump down the system. The main advantage of the pump down system is savage of refrigerant and also can be used the same refrigerant lines (copper) if possible.

Pump down system is the simple work by closing the outlet of condenser (provided with condenser outlet service valve) and run the unit. No possibility of gas (rest) passing over the condenser outlet all the refrigerant stand with in the condenser.

The pump down system can be checked by measuring through compound gauge mounted on the service valve. After completion of the pump down (to the satisfaction of the technician) stop the unit lines from the service valve connections by removing clamps (if any) for easy removal of pipes.

Cleaning and removing the copper lines will be an advantage of using the same for the installation (possibly). This removal of units (explained brief) is to reinstall or to use at some other position without much cost. Improper removal of indoor unit/outdoor units will create major problems in reinstallation also to change of electrical aspects.

During installing the unit, always maintain the distance between the indoor unit and outdoor units as follows,

Horizontal distance	40ft.	(12 mts.)
Vertical	20ft.	(6 mts.)

The oil charged is sufficient to operate up to the rated level (above). If the tubing is longer, compressor has to be charged with extra oil (i.e. 90ml. of every extra 3 ft.).

Now-a-days split A/C units becomes popular and comes out in many types as follows,

A Direct room mounted split unit

The evaporator unit of this type is available in three patterns suitable for:

i) Floor mounting

ii) Wall mounting

iii) Ceiling mounting

B Ductable split unit

In this type the evaporator is concealed and normally mounted above false ceiling and the cold air is supplied through ducting (G.I.) and delivered through the outlets (diffuser's in various models) located at the selected places.

C Multi split unit

This system offers the features of having individual room temperature controls. Now-a-days it is developed to maintain cool temperature at different (2 or 3) rooms simultaneously by having as many individual compressor and separate refrigerant circuits with single condenser at the outdoor unit (single),

Separate thermostat(s) is used to control the room temperature and is connected to the respective circuits for cutout, cut in operation.

Pump down process

Pumping down is a process to store the refrigerant in the liquid receiver or condenser from entire system. It is done in open type and split air-conditioners only.

In open type, the refrigerant stores in liquid receiver.

In split air-conditioner the refrigerant stores in condenser.

1 If there is any repairs in low side, we will have to pump down the system.

2 If we want to shut down the unit, we will have to pump down the system.

3 If we transfer the system from one place to another place, we will have to pump down the system.

If the split air-conditioner have any repairs in low side or shift the unit from one place to another place we will have to pump down the system to avoid refrigerant. It can be done in running units only, not in break down units.

Dehydrators (filter drier)

Objectives: At the end of this lesson you shall be able to
- **explain replace of dehydrator (filter drier)**
- **describe the purpose of dehydrator (filter drier)**

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 desecant (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

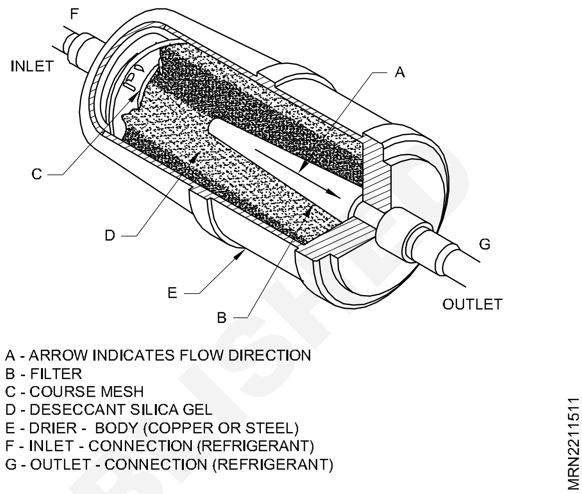
C – course filter - not to allow deseccant to travel

D – deseccant- drying agent silica gel

E – drier body - made of copper or steel holds the internal

F – inlet connection flare or brazed - refrigerant

Fig 1



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.

Filter drier used in different application are various types

Such as pencil type double mouth type filter drier generally used in refrigerator. It is made of copper with fine wiremesh. Screen filter accommodated inside filter at inlet. One end for braze the capillary & other end double mouth for providing 1/4" or 3/4" ϕ copper tube for connect the liquid line & extra line generally used for both side vacuum & test the pressure of high side during running after gas charged. After test the performance the extra mouth should be pinch off & brazed.

Desicants: May be used adsorbant or absorbant drying agent like silicaged, activated alumina, molecular sieves etc

Types: Available use & throw or replace type or desicants may be replaced in old housing.

Capillary tube for the hermetic type compressor

Objectives: At the end of this lesson you shall be able to
- **explain about capillary tubes application and function**
- **describe the handling of capillary tube**
- **explain the advantages of capillary tube**
- **state 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.

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.

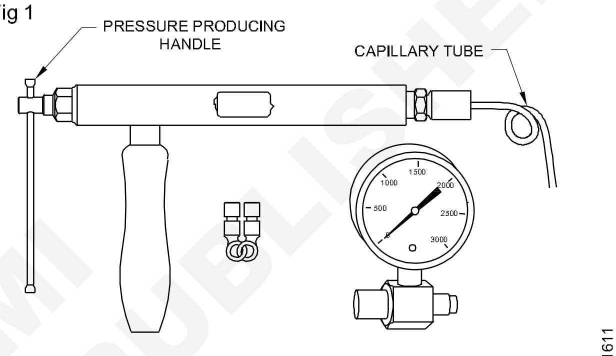
Servicing procedure of capillary tube: Debraze the capillary joints along with the filter dryer.

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 dry nitrogen.

Attach the capillary tube cleaner to the outlet end of the tube.

Fig 1



CAPILLARY TUBE CLEANER USED TO CLEAR OBSTRUCTIONS FROM CAPILLARY TUBE. IT HAS A CAPILLARY TUBE ADAPTOR FITTING. EITHER OIL OR R-11 IS USED AS PRESSURE FLUID.

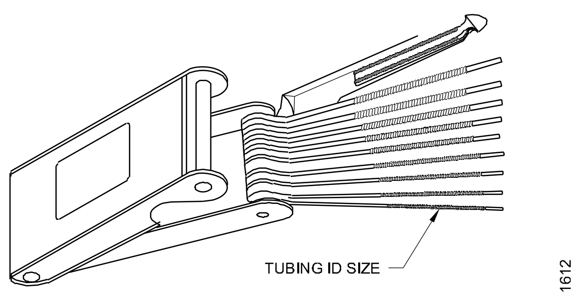
Build up pressure on the tube by tightening pressure producing handle to force the wax or dirt out as in Fig1.

After the capillary tube has been cleaned continue to flush out the tube thoroughly. Use either dry nitrogen 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)

Fig 2



CAPILLARY TUBE SIZING KIT.
GAUGE MEASURES THE ID OF THE CAPILLARY TUBE.

Clogged capillary tubes

Objectives: At the end of this lesson you shall be able to
- **explain how to locate capillary tube**
- **state causes for blockages in capillary tube**
- **proper selection of capillary tube depends on**
- **location of capillary tube.**

The capillary tube is a metering device it is located in between the condenser and evaporator. The condenser outlet is connected to the filter inlet, the filter outlet is connected to the capillary inlet and capillary outlet is connected to the evaporator inlet as shown in Fig 1.

Window model air conditioner consists of three basic parts.

– Hermetic compressor

– Condenser

– Evaporator

Using a capillary refrigerant control in the schematic diagram (Fig 1).

C to D indicates high pressure liquid refrigerant in liquid line

D to E indicates low pressure liquid refrigerant

E to F indicates low pressure vapour in suction line

A to B indicates high pressure vapour in condenser.

Liquid refrigerant collects in the lower coils of the condenser and flows through the capillary tube refrigerant control into the evaporator when the unit is in operation. This is under low pressure. The liquid refrigerant rapidly boils and picks up heat from inside the room through a filter and forces it over the evaporator. Here it is cooled and goes back into the room. Arrows in (Fig 1) shows the air flow pattern.

Low pressure vapour is drawn from the evaporator through the suction line back to the compressor compressed to the high side pressure it is forced into the condenser to be cooled and condensed to a liquid. The cycle repeats.

Causes of blockage in refrigeration system.

Moisture in the refrigerant and wax forms oil which causes blocking in the capillary tube.

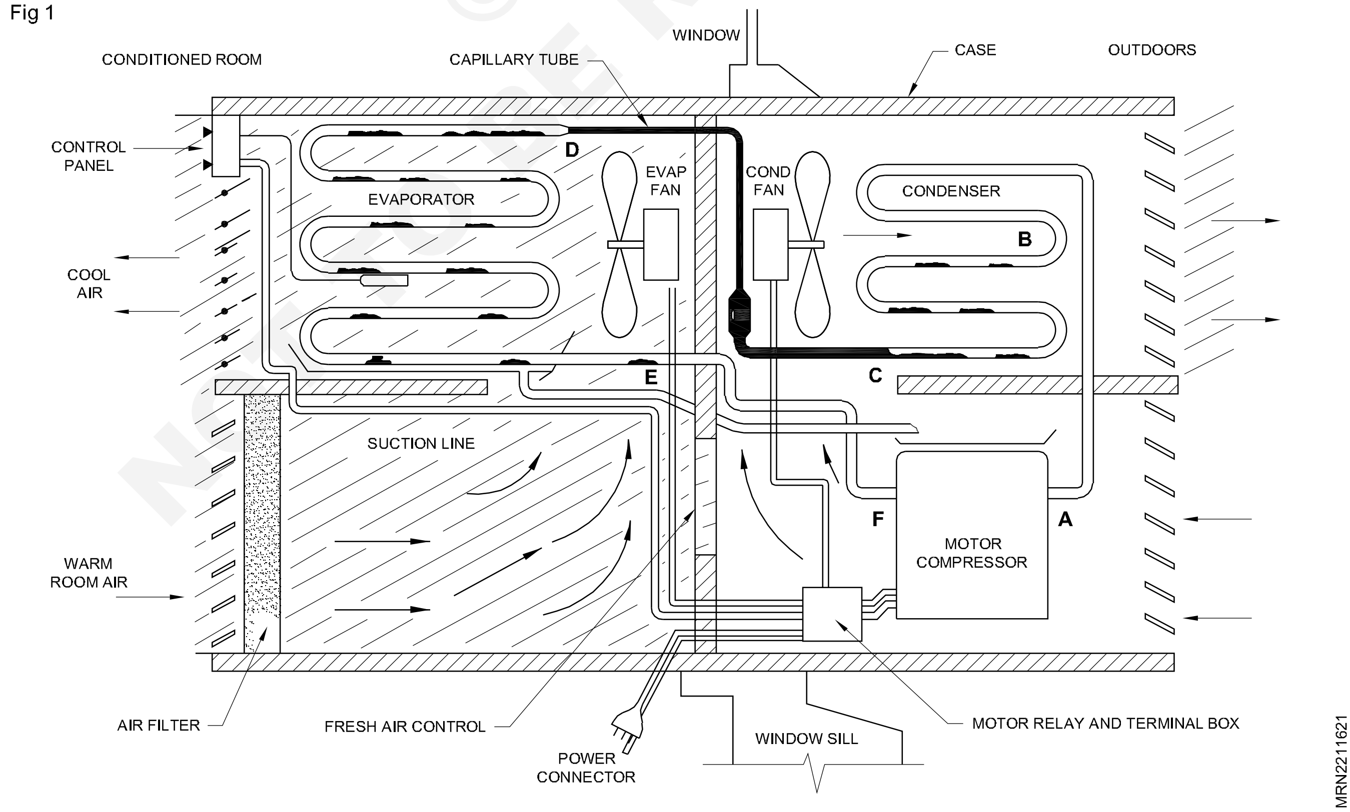
Moisture in the refrigerant system will cause the unit to malfunction. The moisture forms ice in the refrigerant control (capillary tube).

This is at the point where it is expanding into the evaporator being closed, the opening blocking flow into the evaporator.

This condition can be recognised by several observations.

The system will completely defrost.

Fig 1



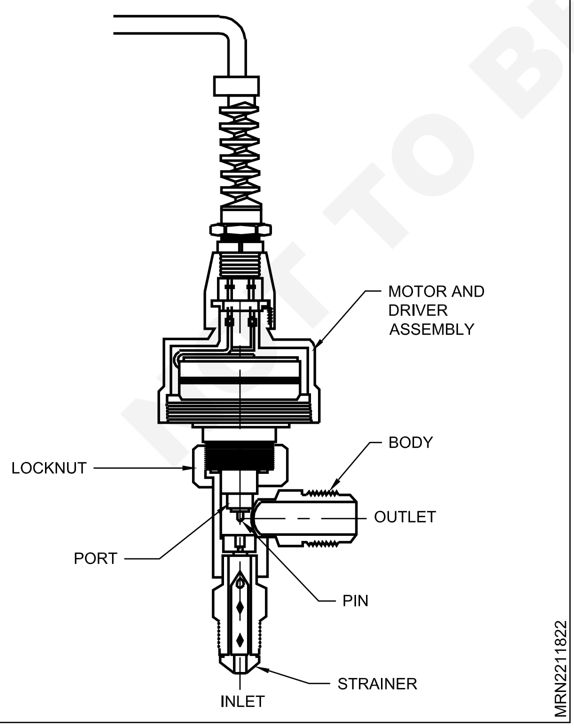
Electronic Expansion Valve (EEVs)

The electronic expansion valve (EEV) operates with a much more sophisticated design. EEVs control the flow of refrigerant entering a direct expansion evaporator. They do this response to signals sent to them by an electronic motor. Step motors do not rotate continuously. They are controlled by an electronic controller and rotate a fraction of a revolution for each signal sent to them by the electronic controller. The step motor is driven by a gear train, which positions a pin in a port in which refrigerant flows. A cut away of an EEV with step motor and drive assembly is shown in Figure 4.

Fig 4

Step motors can run at 200 steps per second and can return to their exact position very quickly. The controller to return the valve to any previous position at any time. This gives the valve very accurate control of refrigerant that flows through it. Most of these EEVs have 1,596 steps of control and each step is 0.0000783 inches. (Fig 5) A cut away of an electronic expansion valve (EEV) with step motor and drive assembly sensors.

Fig 5

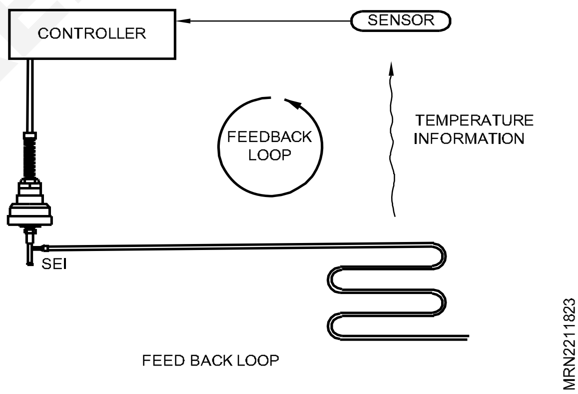


The electronic signals sent by the controller to the EEV are usually done by a thermistor connected to discharge airflow in the refrigerated case. A thermistor is nothing but a resistor that changes its resistance as its temperature changes. Other sensors are often located at the evaporator inlet and outlet to sense evaporator superheat. This protects the compressor from any liquid flood back under low super heat conditions.

Pressure transducers can also be wired to the controller for pressure/temperature and super heat control. Pressure transducers generally have three wires. Two wires supply power and the third is an output signal. Generally, as system pressure increases, the voltage sent out by the signal wire will increase. The controller uses this voltage to calculate the temperature of the refrigerant with the use of a pressure/temperature table programmed into the controller.

A combination of compressor flood back protection and the ability to maintain refrigerator case discharge air temperature set point control makes the EEV useful in many diverse applications. Some EEV controllers can also be programmed for custom control applications. (Fig 3) The feed back loop. The controller may open the EEV too much and cause an overcooling condition. The sensors connected to the refrigeration system and wired to the controller will sense this overcooling condition and feed this information to the electronic controller and the EEV. This will cause the step motor to move in the closing direction and close the valve more.

Fig 6



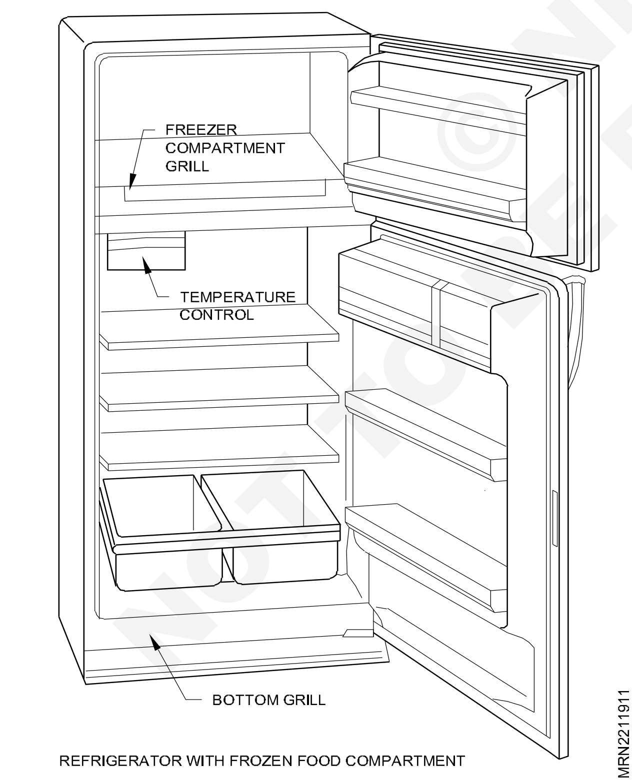
Evaporator in refrigerator

Objectives: At the end of this lesson you shall be able to
- **explain about evaporator**
- **state the different types evaporator**
- **describe about super heating in evaporator.**

Evaporator

The process of heat removal from the substance to be cooled or refrigerated is done in the evaporator. The liquid refrigerant is vaporized inside the evaporator (coil or shell) in order to remove heat from a fluid such as air, water or brine. The fluid to be cooled can be made to pass over the evaporator surface inside which the refrigerant is boiling, such as a system is called the direct-expansion system. In certain cases, such as in big air conditioning systems or in industrial processing, water or brine is chilled in the evaporator. The chilled fluid is circulated through copper or steel coils over which the air or substance to be cooled is passed. Such a system is called the indirect system. The coil (copper or steel) generally called cooling coils act as heat exchangers. (Fig 1)

Fig 1



REFRIGERATOR WITH FROZEN FOOD COMPARTMENT

Evaporators are manufactured in different shapes, types and designs to suit a diverse nature of cooling requirements. Thus, we have a variety of types of evaporators, such as the prime surface type, finned tube or extended surface type, shell and tube liquid chillers, etc.

Evaporators are classified into two general categories the dry-expansion evaporator and flooded evaporator.

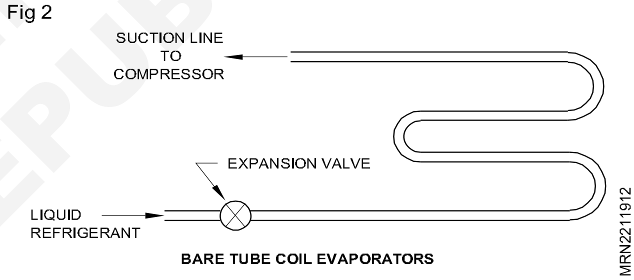
Plate Evaporators

A common type of plate evaporator is shown in Fig in this type of evaporator, the coils are either welded on one side of a plate or between the two plates which are welded together at the edges. The plate evaporators are generally used in household refrigerators, home freezers, beverage coolers, ice cream cabinets, locker plants etc.

Bare tube coil evaporators

The simplest type of evaporators is the bare tube coil evaporator, as shown in Fig 2.

Fig 2



BARE TUBE COIL EVAPORATORS

The bare tube coil evaporators are also known as prime-surface evaporators. Because of its simple construction the bare tube coil is easy to clean and defrost. A little consideration will show the this type of evaporator offers relatively little surface contact area as compared to other types of coils. The amount of surface area may be increased by simply extending the length of the tube, but there are disadvantages of excessive tube length. The effective length of the tube is limited by the capacity of expansion valve. If the tube is too long for the valve's capacity, the liquid refrigerants will tend to completely vaporise early in its progress through the tube, thus leading to excessive superheating at the outlet. The long tubes will also cause considerably greater pressure drop between the inlet and outlet of the evaporator. This results in a reduced suction line pressure.

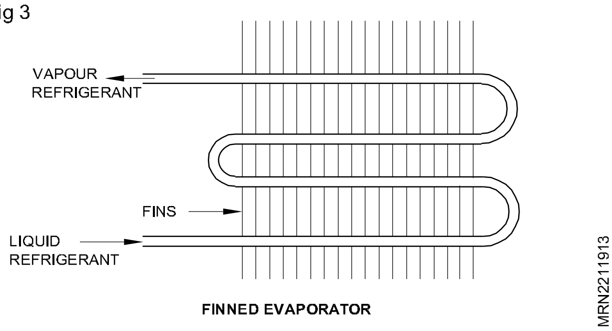
The diameter of the tube in relation to tube length may also be critical. If the tube diameter is too large, the refrigerant velocity will be too low and the volume of refrigerant will be too great in relation to the surface area of the tube to allow complete vaporisation. This, in turn may allow liquid refrigerant to enter the suction line with possible damage to the compressor (i.e. slugging). On the other hand, if the diameter is too small, the pressure drop due to friction may be too high and will reduce the system efficiency.

The bare tube coil evaporators may be used for any type of refrigeration requirement. Its use is however, limited to application where the box temperatures are under 0°C and in liquid filling, because the accumulation of ice or frost on these evaporators has less effect on the heat transfer than on those equipped with fins. The bare tube coil evaporators are also extensively used in household refrigerators because they are easier to keep clean.

Finned Evaporators

The finned evaporators as shown in Fig 3. consists of bare tubes or coils over which the total plates or fins are fastened.

Fig 3



FINNED EVAPORATOR

The metal fins are constructed of thin sheets of metal having good thermal conductivity. The shape, size or spacing of the fins can be adapted to provide best rate of heat transfer for a given application. Since the fins greatly increase the contact surfaces for heat transfer, therefore the finned evaporators are also called extended surface evaporators.

The finned evaporators are primarily designed for air conditioning applications where the refrigerator temperature is above 0°C. Because of the rapid heat transfer of the finned evaporator, it will defrost itself on the off cycle when the temperature of the coil is near 0°C. A finned coil should never be allowed to frost because the accumulation of frost between the fins reduces the capacity. The air conditioning coils, which operate at suction temperature which are high enough so that frosting never occurs, have fin spacing as small as 3 mm. The finned coils which frost on the on cycle and defrost on the off cycle have wider fin spacing.

Super heating in evaporators

The liquid refrigerant is completely vaporized just before the end of the evaporator. There after, the cold vapour continues to absorb heat and gets super heated in the last portion of the evaporator and in the suction line. Due to friction between its moving parts, the compressor gets heated up in operation. The refrigerant vapour, therefore, gets further superheated in passing through the heated suction passages in the compressor. Therefore, by the time it reaches the compressor cylinder, the suction vapour gets superheated much above its saturation temperature.

Fig 4

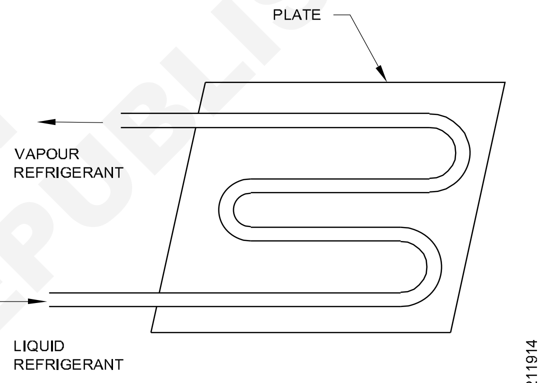


PLATE EVAPORATOR

Direct cooled evaporator

Objectives: At the end of this lesson you shall be able to
- **describe the function of evaporator in a refrigerator**
- **specify the need for changing evaporator coil in conventional**
- **explain the service of direct cooled HFC 134a refrigerator.**

Describe the function of evaporator in a refrigerator

It is the most important part of refrigerator. The refrigerator from the capillary tubes comes to evaporator below, and the temperature is required to maintain the evaporator and carries heat from evaporator. The evaporator can also be termed as freezer.

The pressure of refrigerant when it leaves capillary is maintained above atmosphere. Whereas the temperature of refrigerant will be corresponding to the saturation temperature to be maintained in the cabinet of refrigerator, so that when this vapour flows through the evaporator (placed in the cabinet of the refrigerator also termed as freezer) it is capable of absorbing heat.

Specify the need for changing evaporator coil in conventional as well as frost free refrigerator

In conventional refrigerator evaporator defrost is carried out by manual defrost. In this process refrigerator is totally switched off or defrost button pressed to stop compressor. In this process consumer when handling refrigerator damage the evaporator by using sharp instruments to pull out ice trays or when removing shelves or other vessels from the cabinet, damage the evaporator coils, and even make dents in evaporator. Also evaporator coils internally gets contaminated by mixing with oil by internal wear and tear of the compressor. The overall performance of the evaporator thus gets lowered and need arises to change evaporator for good performance of evaporator.

In frost free refrigerator, where the evaporator is kept at the back a fan sucks cold air from evaporator and delivers to freezer and fresh food compartment and return back to evaporator to complete air flow in a continuous manner. In the long run of refrigerator very minute food particles (degraded) or contaminated gets collected in the fins of the evaporator along with water particle. This will starts corroding the fins and gets accumulated on the evaporator surface and thus blocks the air flow thereby reducing the cooling efficiency of the refrigerator. Hence there is a need of changing evaporator in frost-free evaporator.

How to service direct cooled HFC 134a refrigerator?

When servicing HFC 134a filled refrigerator, take care to ventilate the area well. Do not service or open the system for repair in outside place. Since HFC 134a refrigerant are sensitive to moisture and the system opened for repair should be assembled carefully not to leave any trace of moisture dust or dirt and the oil used in the system is POE oil is again is sensitive to moisture (100% moisture absorbent). And when mixed with different vapour HFC 134a may be may be flammable. Do not breathe HFC 134a in high concentration, as it will suffocate and will create environment imbalance, it can pollute the air. When working with HFC 134a care taken to wear goggles, gloves to cover the body when contacted to bare skin HFC 134a can be given frostbit. In whole it will contaminate the work area.

Also do not vent HFC 134a to atmosphere as it has high GWP.

Now switch off the refrigerator, now by using clean soap solution clean refrigerator system, body and inner liner of door assembly and make it dirt and moisture free. Now check evaporator, condenser and compressor suction and discharge for leaks, kinks. If you find major defects change evaporator, condenser, compressor, whichever is necessary. If the damage is minor, recover HFC 134a by using recovery equipments and note down its weight. While assembling system use new dryer filter of molecular sieve and new capillary tube.

Now braze the leaky joints (while or before brazing purge out the little HFC 134a left out in the system. As HFC 134a when burnt will pollute the air.)

Pressurize the system using dry nitrogen of 13.5kg/sq.cm. leak test using soap solution. Purge out dry nitrogen to the air.

Evacuate system using 2 stage rotary vacuum pump to acquire 100 microns of Hg, break the vaccum by closing shut off valve in the manifold valves of the vaccum pump. Hold the vacuum for an hour.

Charge the system with HFC 134a by using electronic weighing scale and record the weight of refrigerant charged. Seal the process tube twice and close it by brazing. Now leak test the system for any leaks.

Frost free evaporator

Objectives: At the end of this lesson you shall be able to
- **explain basic principle of frost free evaporator**
- **specify the parts of frost free evaporator**
- **describe defrost problem symptoms.**

Basic principle of frost free evaporator

In a normal freezer, the evaporator i.e. the parts on which the frost forms, is exposed, these are the pipes you can see that often actually form the shelves. The frost builds up on these and, if left, will completely take over the space where you should be able to place your food. When defrosted, usually just by switching the appliance off, the ice melts and drips all over the base of the freezer hence the need for towels etc. In a frost free appliance, the cooling evaporator is concealed, often behind the cover at the back of the inside of the freezer or in a compartment at the top. The evaporator is formed of pipes, similar to a normal freezer, but with fins attached. An electric fan draws air from the cavity (i.e. the food stored inside), through the finned evaporator and then back into the cavity again for the process to continue. Frost will therefore still build up on the evaporator but, due to its compact nature, it can be carefully monitored and defrosted by a small heater with the water running neatly down a drainage hole onto a tray mounted above the compressor from where it will evaporate. If the appliance is a fridge freezer then the fridge compartment may have no working parts in it at all, refrigeration will take place by simply opening a mechanical flap from the freezer which will close once the temperature is correct.

Part of a frost free evaporator

In frost refrigerator normally used following components

Defrost timer, Defrost heater, Defrost controls (Thermostat Timer and Heater, Damper controls) Refer first semester book.

As mentioned above, most will have a fan which may be visible from inside the freezer and will be heard running. If your fan is not running, don't automatically assume it is faculty as they may switch off when the door is opened and when the correct temperature is reached. In general, evaporator fans don't cause a lot of problems and rarely fail although often they become noisier than they should be and changed for that reason.

Evaporator in water cooler

Objectives: At the end of this lesson you shall be able to
- **explain the general detail of water cooler**
- **explain the function of evaporator/cooling chamber-storage type.**

General details of water cooler: Water coolers are used for cooling water for beverage purposes previously. Now-a-days it becomes an important aspect to quench thirst of human people at various centre's such as restaurants, theatres, offices, commercial complexes, etc.

The temperature of water should be around 42°F- 45°F (drinking level). Water coolers were used/provided according to the person's capacity of people using it. Regarding this a separate table is given in this exercise.

Types of water cooler: Water coolers of various type/ models have come around by the different manufacturers maintain the temperature of the water. All units were provided with thermostat.

The main types of water coolers are as follows:

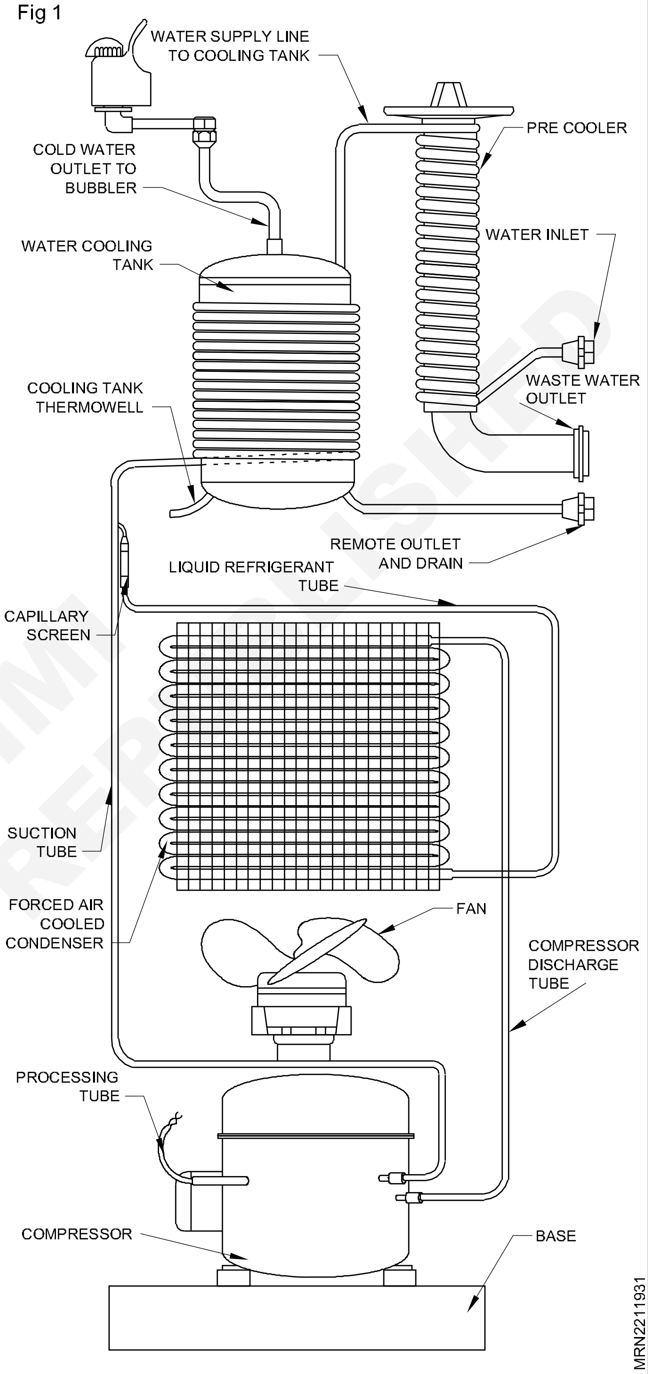
– Instantaneous type water cooler/pressure type water cooler.

– Storage type water cooler

Evaporator/cooling chamber - Storage type: Evaporator tank when it is soldered with cooling coil outside the tank (touching the body with lead soldering). Normally 2/3 height only be covered. Also minimum of some distance will be maintained at the start of the coil from the bottom of the capacity of the water tank is 80 lts., then the coil round area will cover only 40 lts. from the bottom remaining will be called as storage area, when the water clears (old) from the bottom. Simultaneously water is filled up.

The cold effect will be more in the coil soldered area. At the top of the tank there will be water inlet duly connected with water line and another hole nearby is kept to drain out excess water, if any. Water inlet line (at the tank) is fired up with float assembly to maintain the water level. In case float system fails excess water will be drained out through over flow line. Also drain plug is provided at the bottom to clean the tank when necessary. (Fig 1)

Fig 1



Evaporator in window AC

Objectives: At the end of this lesson you shall be able to
- **explain main components of window AC**
- **describe the finned evaporator**
- **describe the capacity of an evaporator**
- **explain factors affecting the heat transfer capacity of an evaporator**
- **describe about heat transfer in evaporators.**

Air conditioner

Air conditioner is defined as the process of treating air so as to control simultaneously its temperature, humidity, cleanliness an distributing to meet the requirements of the conditions space.

Main components of window A/C

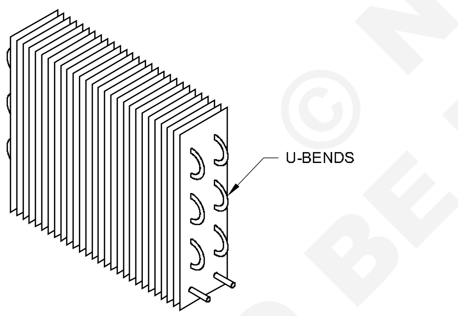
Room Air conditioner: Room air conditioner is designed and assembled by a manufacturing company as a unit for mounting in a window through wall. It delivers conditioned air to an enclosed space without any ducts.

The main components of window A/C are as follows:

- Compressor
- Condenser
- Filter drier
- Capillary tube
- Evaporator

Evaporator: Any heat transfer surfaces area in which a refrigerant vapourizing for the purpose of removing heat from the medium being cooled. (Fig 1)

Fig 1

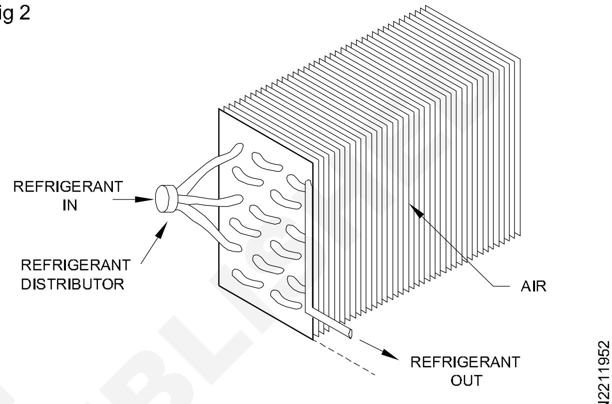


EVAPORATOR

Finned Evaporators

The heat transfer efficiency is less in the case of air to the refrigerant in the evaporator than when the substance to be cooled is a liquid such as water or brine. Therefore, for air-cooling applications 'finned evaporators' are used (Fig 2). Fins are thin metallic plates, usually of aluminium or copper, securely attached or bonded to the evaporator tubes. With bare-tube evaporators, much of the air (to be cooled) does not come in contact with the evaporator tubes but passes through the spaces between the evaporator tubes or 'bypasses' the coil surface. The fins on the tubes extend the area of heat absorption and the effect of by-pass is considerably reduced. Thus a finned coil with its effect of increasing the overall surface area delivers more capacity than a bare-tube evaporator. The heat transfer from the fins to the main evaporator tube is by conduction. Therefore, the bonding between the tube and fins must be good. When fins become loose on the tube, the evaporator capacity falls down substantially, i.e., the evaporator will not have sufficient area to transfer heat for vaporizing the refrigerant in the evaporator and even liquid flood back to the compressor can occur.

Fig 2



FINNED EVAPORATOR COIL

Fins are slipped over the tube and positioned at a definite pitch and the tube is expanded (i.e. its diameter is increased), thus making the fins sit tight or get bonded to the tube surface and obtain good thermal contact. The expansion of the tube is accomplished by filling the tube with oil and building up high hydraulic pressure. Another method is to force an oversized (properly finished) rod (called bullet) through the pipe, which will expand the tube.

Because of the increase in surface area for the same capacity, a finned coil will be much smaller than a bare-tube or plate type evaporator.

The fin pitch or spacing varies from 3 to 14 fins per inch, depending on the operating temperature of the coil. For applications such as for air conditioning where the coil operates at temperatures much higher than the water-freezing point, coils with 12 to 14 fins per inch are used. In air-cooling applications, where the operation is at temperatures.

than the freezing point of water, frost accumulation on the evaporator cannot be avoided. Frost accumulation on the coil between the fins tends to restrict the air passages and thus retard air circulation. Therefore coils for low-temperature applications should have a wide fin spacing. Coils with 61/2 fins per inch are used for cold-storage jobs and coils with three to four fins per inch are used for still lower temperature jobs.

The frost on coils acts as an insulation and retards the heat flow. As the thickness of frost increases, the heat-transfer is very much affected. Further, too much frost accumulation on finned coils can make the fins move and thus loosen the bond on the evaporator tubes. Therefore, defrosting the coil at regular intervals is absolutely necessary.

Capacity of an evaporator

The capacity of an evaporator is defined as the amount of heat absorbed by it over a given period of time. The heat absorbed or heat transfer capacity of an evaporator is given by

where

Q = $UA(T_2-T_1)$W or J/s

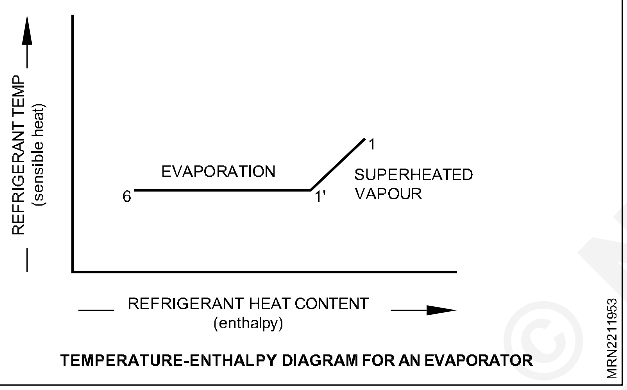
U= Overall heat transfer coefficient in W/m2 °C,

A= Area of evaporator surface in m²,

T_2= Temperature of medium to be cooled (or temperature outside the evaporator) in °C, and

T_1= Saturation temperature of refrigerant at evaporator pressure (or temperature inside the evaporator) in °C.

Fig 3



TEMPERATURE-ENTHALPY DIAGRAM FOR AN EVAPORATOR

Factors Affecting the Heat Transfer capacity of an evaporator.

Though there are many factors upon which the heat transfer capacity of an evaporator depends, yet then following are important from the subject point of view:

Material: In order to have rapid heat transfer in an evaporator, the material used for the construction of an evaporator coil should be a good conductor of heat. The material which is not affected by the refrigerant must also be selected. Since metals are best conductors of heat, therefore they are always used for evaporators. Iron and steel can be used with all common refrigerants. Brass and copper are used with all refrigerants except ammonia. Aluminium should not be used with freon.

Temperature difference: The temperature difference between the refrigerant within the evaporator and the product to be cooled plays an important role in the heat transfer capacity of an evaporator.

Velocity of refrigerant: The velocity of refrigerant also affect the heat transfer capacity of an evaporator. If the velocity of refrigerant flowing through the evaporator increases, the overall heat transfer co-efficient also increases. But this increased velocity will cause greater pressure .... in the evaporator. Thus the only recommended velocities for different refrigerants which give high heat transfer rates and allowable pressure loss should be used.

Thickness of the evaporator coil wall: The thickness of the evaporator coil wall also affects the heat transfer capacity of the evaporator. In general, the thicker the wall, the slower is the rate of heat, transfer. Since the refrigerant in the evaporator coils is under pressure, therefore the evaporator walls must be thick enough to withstand the effects of that pressure. It may be noted that the thickness has only a slight effect on total heat transfer capacity because the evaporator are usually made from highly conductivity materials.

Contact surface area: An important factor affecting the evaporator capacity is the contact surface available between the walls of evaporator coil and the medium being cooled. The amount of contact surface, in turn, depends basically on the physical size and shape of the evaporator coil.

Heat transfer in evaporators

The heat transfer in evaporators has the following three resistance in its path:

The resistance of medium being cooled. This may be air, water, brine or any other fluid or a wetted surface of a cooling and dehumidifying coil.

The resistance of metallic wall of tube liquid.

The resistance of cooling medium i.e., refrigerant film which gets heat from solid metallic walls.

Evaporators in split A/C

Objectives: At the end of this lesson you shall be able to
- **explain the features of outdoor unit of split A/C**
- **list the specification of indoor unit**
- **list the sizes of indoor unit (room unit).**

Indoor unit is the part of the split A/c system which consists of low side system. Indoor unit is placed inside the room where the area to be cooled.

Indoor units comes in various types depends on its positioning.

i) Wall mounted

ii) Floor mounted

iii) Ceiling type

All the indoor units are provided with fan having 2 or more speeds such as low, medium, high, three levels differentiate the speeds of increase in revolution of fan motor. Mostly all the indoor unit provided with blower(s).

Indoor unit works as recycling of air inside the room. It also controls the humidity contents of air. All the indoor units will be mounted where the air throw will not go out of the room (i.e. facing the door/entrance area).

Filters were placed in the front side of the unit covering the evaporator. This will be in easily movable position to clean it up/change periodically.

The air inside the room was sucked through the evaporator fan motor and thrown back to the room depending on the throw of the model differs.

Indoor unit will be mounted inside the room at the corner near to wall or window so that the drainage line can be provided easily. Also the refrigerant line both suction/ liquid will be clamped on the wall. Suction line will be insulated for better refrigeration.

The motor inside the unit will be suspected and lubricated properly. Also the fan blower's cleaned/ serviced properly.

Rubber pads will have to be provided to avoid vibration of overall unit. If the unit runs with vibration, it will lead to pipe crack and leakage of refrigerant.

All the places should be insulated well to avoid air leak at the indoor unit.

The I.D.unit should be installed in slight slope towards drain line side to facilitate the disposal of dehumidified water.

Clean the external surface of the evaporator coil with detergent water and insulate. If the refrigerant line connecting outdoor unit and indoor unit exceeds 40 ft, Add 90 ml.of oil extra to the compressor.

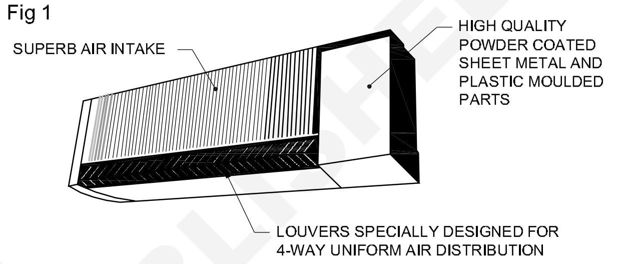
Thermostat will be positioned properly at the evaporator coil which will sense and cut the compressor after the unit reaches sufficient temperature.

Insulating the room will have advantage of the unit working for shorter period.

Specification of Indoor unit

Indoor unit is shown in the Fig 1.

Fig 1



MODEL	BTU/HR	Cooling coil size	Impeller	Blower motor	Apl.No. of DLF	R.P.M.	Air flow CFM	Suitable capacity	Size of unit L. H. D.
WM120	12,000 2 Row	26"x 10" 2 Nos	9"x4"	1/30 HP 3 speed	CO41	900/1000/1100	400	1.0 ton	34"x14"x 8.1/2" 864x356x216 mm
WM180	18,000 3 Row	26"x10" 2 Nos	9"x4"	1/30 HP 3 speed	CO41	900/1000/1100	450	1.5 ton	34"x14"x 8.1/2" 864x356x216 mm
WM200	20,000 2 Row	37"x10" 2 Nos	15"x4"	1/30 HP 3 speed	CO40	1000/1100/1200	500	1.75 ton	46"x14"x 8.1/2" 1169x356x216 mm
WM240	24,000 3 Row	37"x10" 2 Nos	15"x4"	1/30 HP 3 speed	CO40	1000/1100/1200	550	2.0 ton	46"x14"x 8.1/2" 1169x356x216 mm

All specifications are approximate and are subject to change without notice due to a continuous R&D program.

Room unit sizes

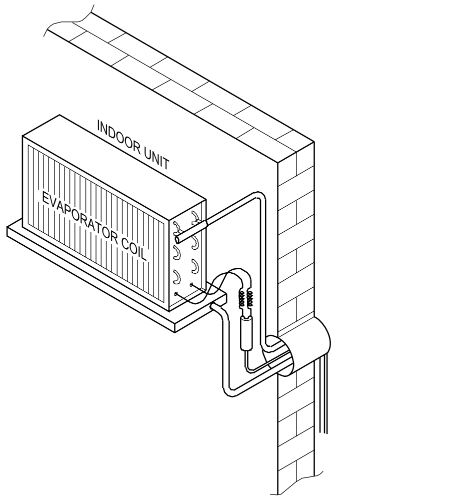
	1.5 TR	3 TR
L (mm)	600	936
D (mm)	388	440
H (mm)	574	580
W (mm)	33	48

View of installed indoor unit is shown in Fig 2.

Some of the unit details (Indoor unit) are given below:

	1.5 ton	2 ton
Capacity	18,000 BTU/Hr. 4,500 Kcal/Hr.	24000 BTU/Hr. 6,000 KCal/Hr.
Power supply	230V/50Hz/1 ph.	2301/50Hz/1 ph.
Power consumption	65 W	90 W

Fig 2



INSTALLED INDOOR UNIT

Fan motor	3 speed	3 speed
Current	0.3 amp	0.4 amps.
Air flow Ft/mm	450	550
M^2/hrs	765	950

The wall mounted indoor unit is shown in the Fig 3.

Effect of suction superheating

So far we have assumed a saturated refrigerant gas at the inlet of the compressor, without any pressure drop in the suction line and the compressor body. In actual practice, however the suction gas gets superheated in the suction line and also to a great extent in the compressor body. So by the time the gas reaches the compressor body. So by the time the gas reaches the compressor cylinder, it is superheated to a great extent.

We have seen in chapter 6 that the section gas superheating affects the cycle efficiency.

In a direct-expansion system, the expansion valve is adjusted to maintain a superheat of 5.56°C (10°F) in the suction gas at the outlet of the evaporator. The gas also picks up some heat in the suction line and the compressor body. i.e more superheat is added to the suction gas. Let us examine the effect of the super heating on the compressor capacity.

In our example of the 40-tonne plant, the evaporator temperature is at 4.4°C (40°F) [4.85kg/cm^{2}G (169 PSIG) for R-22]. With the expansion valve maintaining 5.56°C (10°F) superheat and a temperature rise of 5.56°C (10°F) in the suction line and compressor, the gas entering the compressor will be at 15.56°C (60°F) (i.e. superheated by 11.1°C (20°F) from its saturation temperature of 4.4°C (40°F) in the evaporator.) Assuming that there is no pressure drop in the suction line, the gas will be at 15.56°C (60°F) and 4.85 kg/cm^{2}G (69 PSIG) pressure when it reaches the compressor cylinder. Since the gas is warmed up, it becomes lighter, i.e. its density becomes less than its density of 24.43kg/m^3 at 4.4°C (40°F) saturation. From thermodynamic charts/tables, it can be seen that the density drops down to about 23.48kg/m^3 (1.466lb/cu.ft.) So the volume of gas the compressor now will have to pump, to achieve 40 tonne refrigeration is:

$$\frac{55.17}{23.48} = 2.35\text{m3/min.(82.95 cfm)}$$

as against 2.26m^3/min. (79.74 cfm) without superheating.

Again, if the gas is superheated by 11.1°C (20°F) in the suction line and compressor as against 5.56°C (10°F) assumed earlier, the gas will be at 21.1°C (70°F) when it reaches the compressor cylinder (4.4°C saturation temperature +5.56°C superheat in evaporator +11.11°C temperature rise in the suction line and compressor body). Working the same way, the volume of the 55.17kg (121.6lb) of superheated gas at 21.1°C (70°F) will be about

$$\frac{55.17}{23.04} = 2.39\text{m}^3\text{/min.(84.56fm)}$$

We have examined three conditions (all cases without pressure drop):

1 Suction vapour reaching the compressor cylinder in a saturated condition, without any superheating (purely a hypothetical situation).

2 Vapour superheating by 5.56°C (10°F) in the evaporator and superheating in the suction line and compressor body by another 5.56°C (10°F), thereby the gas reaching the compressor cylinder at 15.56°C (60°F).

3 Suction vapour superheating by 5.56°C (10°F) in the evaporator and by 11.1°C (20°F) in the suction line and compressor body, the gas thus reaching the cylinder at 21.1°C (70°F). (Super-heating in the suction line will be comparatively less and much pronounced in the compressor body.)

Since it is assumed that there is no pressure drop in the suction line and the compressor, the compression ratio in all the three cases will be same and hence the volumetric efficiency will be the same, i.e. 82%

Table 10.1 shows the summary of the results. the last step in the table is arrived at as follows: To obtain 40 tons refrigeration, the refrigerant will have to be vaporized in the evaporator at the rate of 55.17kg/min. (121.6 lb/min). The compressor will have to pump the refrigerant to the same rate to enable the evaporator to give the capacity of 40 tonne refrigeration. As the actual displacement of the compressor is fixed, the weight of the refrigerant handled by the compressor per minute will depend upon the density of the gas in the cylinder. On superheating, the density of gas comes down and so the capacity of the compressor comes down as superheating increases.

Function of accumulator

Objectives: At the end of this lesson you shall be able to
- **explain the function of accumulator**
- **describe the parts of the accumulator.**

Accumulator

The accumulator is fitted between the evaporator and the compressor. The function of the accumulator.

1 To ensure that the refrigerant leaves the accumulator as a vapour and not a liquid state for the compressor to induce.

2 To ensure it is free from dart, to stop any excessive wear premature failure to components.

3 To act as a temporary reservoir to supply the system under varying load condition.

Fig 1

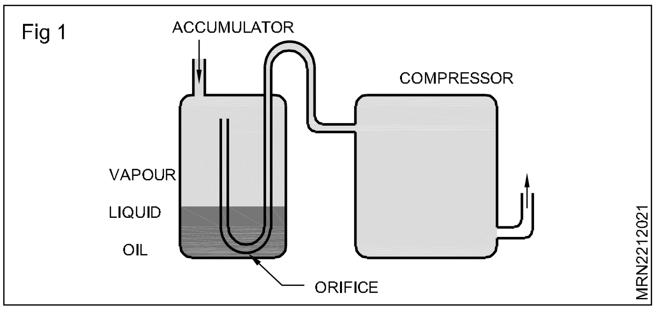
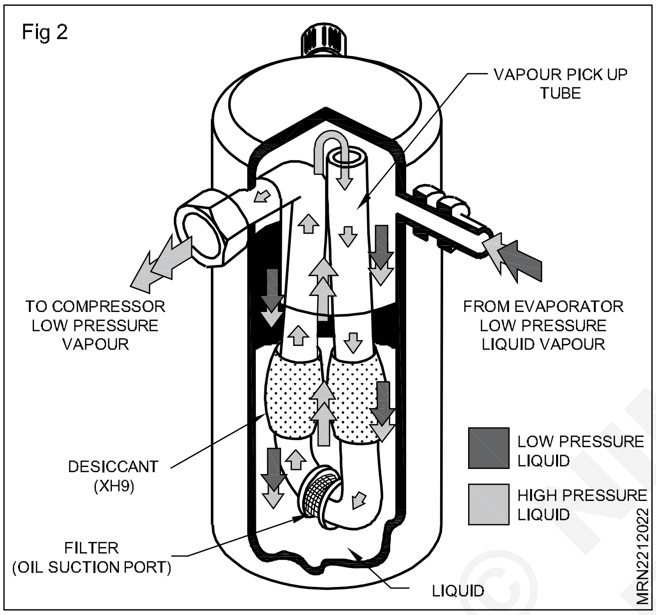


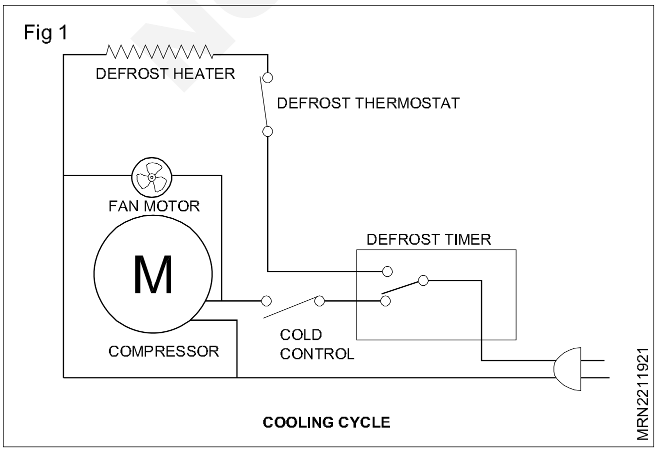
Fig 2



Defrost system: The heart of the defrost system is the control. The most common control is a mechanical defrost timer switch which is a motorized device that opens and closes several electrical contacts. Each contact can be thought of a simple light switch but instead but instead of a light, one connects the defrost heater, circuit, another connects the cooling system. When one of these is switched on, the other is switched off. A motor on the timer (NOT illustrated) turns a cam that opens and closes these contacts at set intervals (see below for other types).

Cooling cycle

Fig 1



During the cooling mode, the defrost timer closes a contact to the compressor circuit so it will run. The circuit to the defrost heater is open.

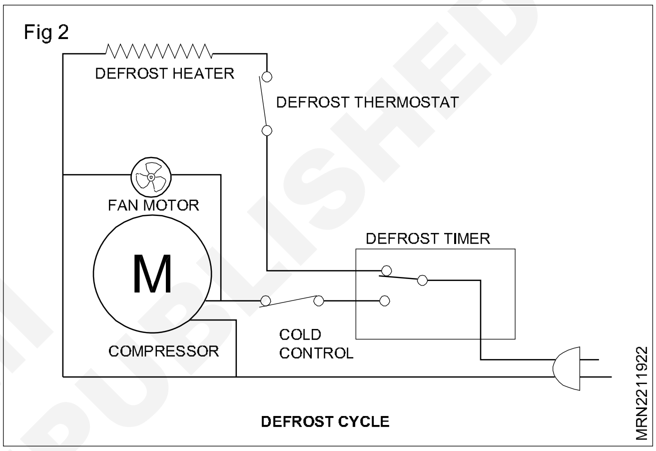
While in this mode, the thermostat (a.k.a cold control) cycles the compressor and fan motors on and off to maintain an appropriate temperature.

Defrost cycle

The defrost timer eventually switches into defrost mode and supplies power to the defrost heater(s) to melt any frost that has accumulated on the evaporator (cooling) coil.

The cold control contacts remain closed but since the defrost timer is no longer feeding power to that circuit, the compressor does not run.

Fig 2

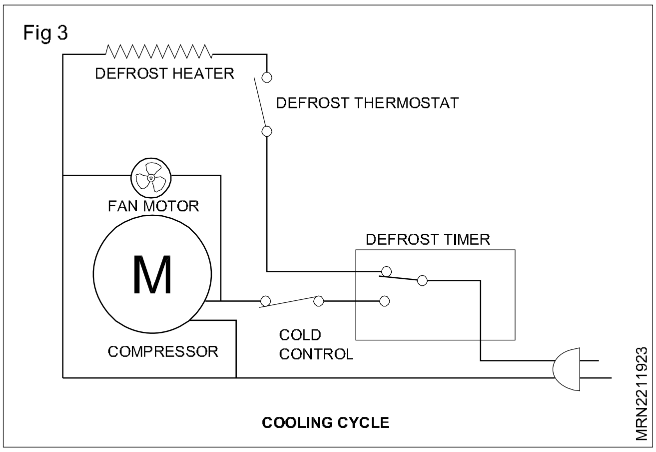


Once the defrost termination thermostat (a.k.a. defrost limit switch) senses a set temperature, it opens the circuit to the defrost heaters, shutting them off. The timer remains in the defrost cycle until the timer advances back to the cooling mode. Since the limit switch is open, the heaters are no longer on for the rest of the cycle.

Cooling cycle

When the timer again advances back into the cooling mode, the compressor will start to run along with any air circulating fans. The defrost limit switch will remain in the open condition until it is reset by cold temperatures.

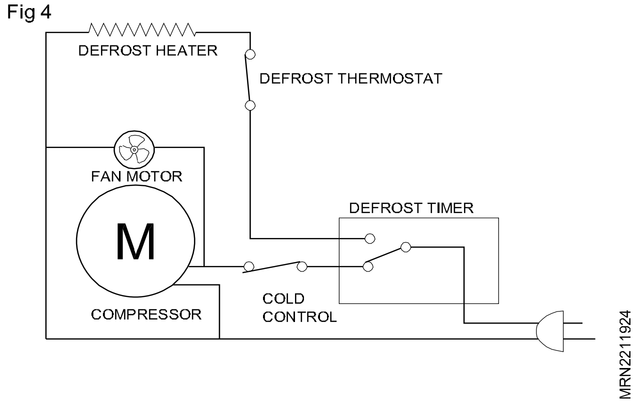
Fig 3



Once a set colder temperature is reached, the defrost termination thermostat closes again. This is OK since the defrost timer is no longer supplying power to the defrost circuit, the heater does not get energized.

When the defrost timer again advances into the defrost mode, the limit thermostat will already be closed and will allow power to be supplied to the defrost heater to melt any frost that has developed on the evaporator coil again.

Fig 4



Defrost problem symptoms

The most common symptom of a defrost system failure is a complete and uniformly frosted (noticed) evaporator coil. Frost may also be visible on the panel covering the evaporator, usually in the rear of the freezer compartment.

Excessive frosting can be cause by the defrost heater or limit thermostat being open (i.e. defective), a mechanical defrost timer sticking and never advancing into the defrost cycle or a problem in an electronic defrost control or one of its sensors failing to allow the defrost heaters to be energized.

Sometimes (but fairly rarely) both heater and cooling system can be energized by the timer at the same time. This can result in thawing then refreezing of food in the freezer compartment often leading to freezer burn on that food. In most cases the evaporator coil will remain mostly in an unfrosted state. The defrost heaters will cycle on and off as the defrost thermostat opens and closed due to the temperature it senses.

Refrigerator

Objectives: At the end of this lesson you shall be able to
- **explain refrigerant and desirable qualities**
- **properties of refrigerants**
- **refrigerants impact on environment in t-ways, ozone depletion and global warming (green house effect)**
- **describe montreal protocol phase-out schedule of ozone depleting refrigerants (HCFCS)**
- **Nomenclature of refrigerants**
- **refrigerant blends and glide**
- **refrigerant applications.**

Refrigerant

Refrigerant is a heat transfer media. It is a medium of heat transfer, which absorbs heat at a low temperature and pressure due to evaporation and liberates it at high temp and pressure due to condensation.

The heat-carrying medium employed in a refrigerating system is known as refrigerant. The refrigerant absorbs heat at low temperature level and rejects it at high temperature level. The rejection of heat is facilitated at the expense of mechanical or heat energy.

The fluid changes from liquid to vapour during the process of absorbing heat and condenses to liquid from vapour while liberating heat in most of the refrigeration system, such fluid is called refrigerant

History

The natural ice and a mixture of ice and salt were the first refrigerants. In 1834 either Ammonia, Sulphur Dioxide, Methyle Chloride and Carbon Dioxide came into use as refrigerant in the vapour compression refrigeration cycle.

Most of the early refrigerant materials have been discarded for safety reasons of for lack of chemical or thermal stability.

In the present days many new refrigerants including Halo-carbon compounds, Hydro-carbon compounds are used for air-conditioning and refrigeration applications.

But in recent times the scientist found that the Halo-carbon compounds eating up the ozone layer. Hence Ozone friendly refrigerant R-134 a is introduced in the refrigeration system.

Refrigerant Numbering

Refrigerants are produced by number of manufactures under their trade names. A universal numbering system has been adopted for identifying the refrigerants of the same chemical composition. Therefore refrigerants are identified by number. The number follows the letter R, which means refrigerant. The identifying system of numbering has been standardized by ASHRAE (American Society of Heating Refrigeration and Air-conditioning Engineers)

A refrigerant followed by two digit number represents Methane base. While three digit number represents Ethane base. The first digit on the right is the number of fluorine (F) atoms in the refrigerant. The second digit from the right is one carbon (C) atoms, but when this digit is zero, it is omitted.

The general chemical formula $\mathbf{C_m H_n CL_p F_q}$

Which is $\mathbf{n+p+q=2m+2}$

M = number of carbon atoms

N = number of Hydrogen atoms

P = Number of chlorine atoms

Q = number of fluorine atoms

The inorganic refrigerants are designated by adding 700 in this molecular mass of the compound. For example the molecular mass of the ammonia is 17, therefore it is designed by R-(700+17) or R-717

Desirable properties of an ideal Refrigerant

A refrigerant is said to be ideal if it has all of the following properties. The standard comparison of refrigerants is based on evaporating temperature of -15° C and a condensing temperature of +30°C.

- Low boiling point
- Low freezing point
- High Latent heat of vapourisation
- High Critical Pressure and Critical temperature
- Low specific heat of liquid and High specific heat or vapour
- Low Specific volume of vapour
- Evaporator and condenser pressures should be positive
- High thermal conductivity
- Non-corrosive to metal
- Non-flammable
- Non-explosive
- Non-toxic

Refrigerants

Refrigerants are the medium (Chemical compound) of heat transper 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 (C_2H_6) 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 CH_4, Formula $CHClF_2$ - Dichloro-difluoro metane)

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 CH_4, 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 CH_4, formula $CHClF_2$, 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 (C_2H_6) - formula CF_3 CH_2F - Tetra Fluro 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 CF_3CH_2 or $C_2H_2F_6$.

Other numbering codes

1 Refrigerants which are numbered starting with the digit 4 like R-404A, R-407C, R-410A are zeotropic mixtenes, 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 upto 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 21^0C.

Class 2: Denotes refrigerants having lower flammability (LFL) of 0.1 kg/m3 at 14.7 psia & 21^0C 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 & 21^0C 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 posses 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 Di-electric strength

10 Environmentally safe (No ozone depletion, No green house effect)

ENVIRONMENTAL IMPACT OF CFC & OTHER REFRIGERANTS:

Ozone Depleting Potential (ODP):

By the mid nineteen eightees 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 (O_3) into oxygen (O_2). 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 beckoned 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 (SF6), 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

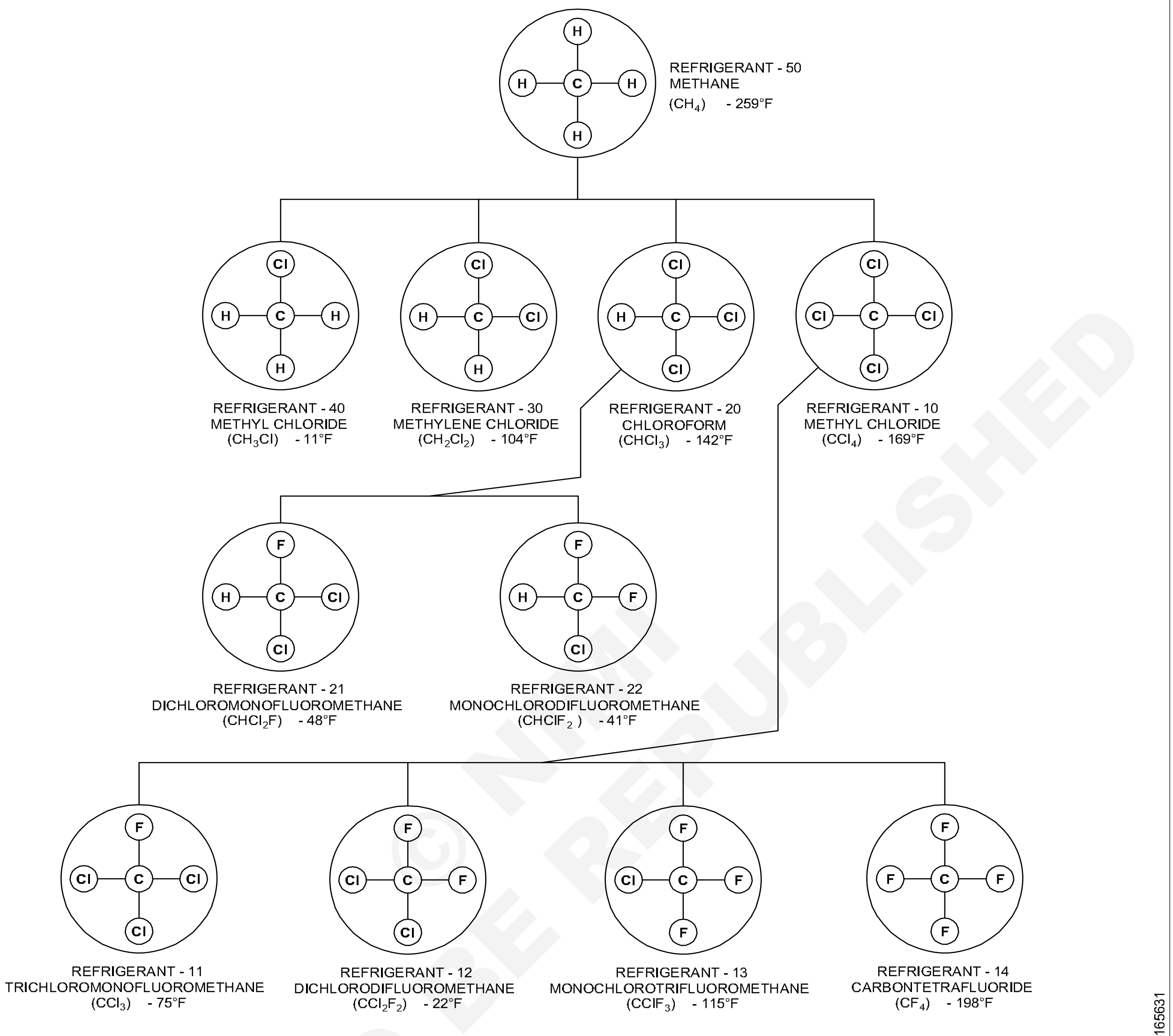
2 R-1-34a

3 HC blend

These Refrigerants are used in vapour compression system refrigerators HC blend of refrigerant is a equal blend (R290)propane and boa/ISO-butane) in 50/50 ratio.

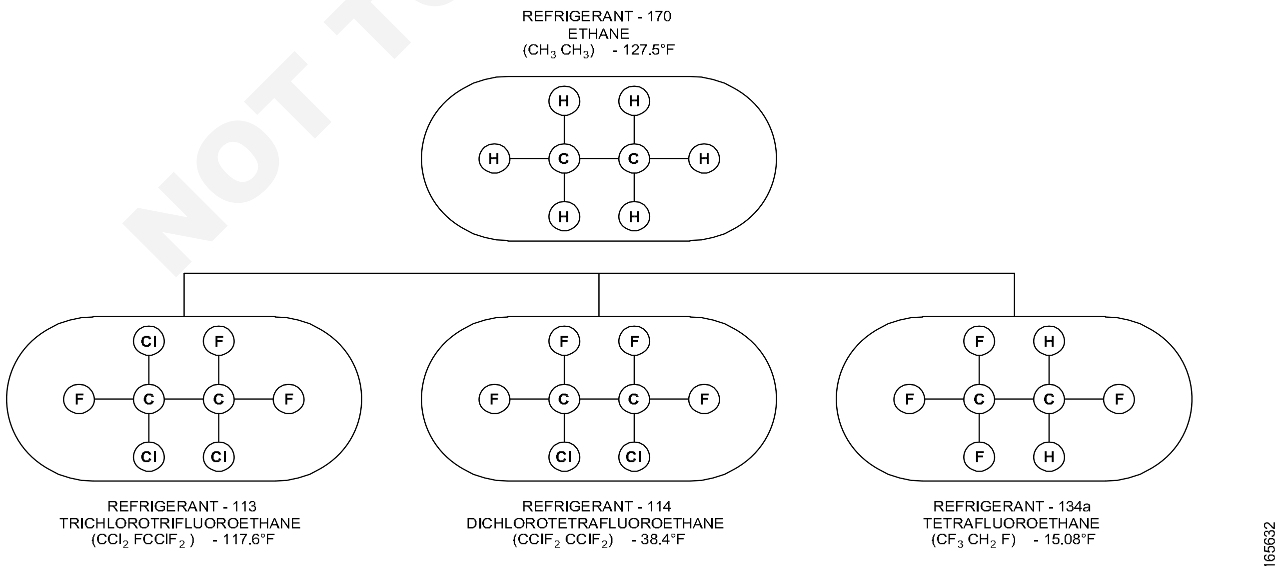
Density of HC's are as low, equallent to 40% of the CFC when charged by weighing.

Fig 1



METHANE SERIES REFRIGERANTS.

Fig 2



ETHANE SERIES REFRIGERANTS.

- Low cost
- Not effected on stored product
- Easily and regularly available
- Easy to liquefy at moderate pressure and temperature
- Easy to locating leaks by odour or suitable indicator.
- Mixes well with oil
- High co-efficient of performance and
- Ozone friendly

Properties of refrigerant

The properties of refrigerant are sub-divided into four main groups:

- Thermo Dynamic Properties of refrigerants
- Physical Properties of refrigerants
- Chemical properties of Refrigerants
- Other Properties of Refrigerants

Thermo Dynamic Properties of refrigerants

1 Boiling Temperature

2 Freezing Temperature

3 Evaporator and Condenser pressure

4 Critical temperature and pressure

5 Co-efficient of performance and power requirements.

6 Latent Heat of Vapourisation

7 Specific volume

Chemical properties of refrigerant

1 Flammability

2 Toxicity

3 Solubility of water

4 Miscibility

5 Effect on perishable materials

Physical Properties of Refrigerant

1 Stability and inertness

2 Corrosive property

3 Viscosity

4 Thermal conductivity

5 Dielectric Strength

6 Leakage tendency

7 Cost

Other properties of refrigerants

1 Odour

2 Leak-Tendency

3 Refrigerant and oil relationship

4 C.O. P. And H.P. requirement

5 Cost and availability

Classification of refrigerants

Refrigerants may be divided in two main classes according to their manner of absorption or extraction of heat from the substances to be refrigerated. The refrigeration are classified into two groups. Primary refrigerants and secondary refrigerants.

Properties of Refrigerants in common use

Table 1.0 gives the chemical names, chemical symbols, group, 'Ozone Depletion Potential' (ODP), 'Global Warming Potential' (GWP) and 'Acceptable Exposure Limit' (AEL) of (single sub-stance) refrigerants commonly in use.

Table 1.0

Properties of refrigerants in common use

Chemical name	Symbol	Group	ODP	GWP_{100}	AEL
R-11 - Trichloro fluoro methane	(CCl_3F)	CFC	1	4600	1000
R-22 - Monochloro difluro methane	$CHClF_2$	HCFC	0.05	1700	1000
R-123 - Dichloro trifluoro ethane	$CHCl_2CF_3$	HCFC	0.02	120	50
R-134a - Tetrafluoro ethane	CH_2FCF_3	HFC	0	1300	1000
R-600a - Isobutane (natural)	C_4H_{10}	Hydrocarbon	0	3	1000
R-717 - Ammonia (natural)	NH_3	Inorganic Compound	0	0	50

Chemical name	Symbol	Group	ODP	GWP_{100}	AEL
R-404A - Pentafluoro ethane/ 1,1,1 - Trifluoro ethane/ 1,1,1,2 - Terafluoro ethane	CHF_2CF_3/ CH_3CF_3/ CH_2FCF_3	HFC Blend	0	3800	1000 1000 1000
R-407C - Difluoro methane/ Pentafluoro ethane/ 1,1,1,2-Tetrafluoro ethane	CH_2F_2/ CHF_2CF_3/ CH_2FCF_3	HFC Blend	0	1700	1000 1000 1000
R-410A - Difluoro methane/ Pentafluoro ethane	CH_2F_2/ CHF_2CF_3/	HFC Blend	0	2000	1000 1000
R-290 - Propane	C_3H_8	Hydrocation	0	3	1000
R-32 - Difluoro methane	CH_2F_2	HFC	0	650	1000
R-744 - Caron dioxide	CO_2	Inorganic Compound	0	1	1000

Note: AEL: Acceptable Exposure Level in parts per million (PPM)

CFC (Chloro Fluoro Carbons): No hydrogen atom in the molecule; have great stability and so have long life in atmosphere for many years; ultimately enter the stratosphere, where they break down releasing chlorine, which depletes the ozone.

HCFC: Hydro Chloro Fluoro Carbons: Replacement of one or more of the halogen atoms in CFCs with hydrogen atoms in the molecule considerably reduces its lie in the atmosphere and so has been impact on the environment than the CFCs, yet have the chlorine content harmful to ozone.

HFC: Hydro Fluoro Carbons (no chlorine, contains hydrogen and fluorine atoms).

Table 2

Some important properties of the commonly used refrigerant

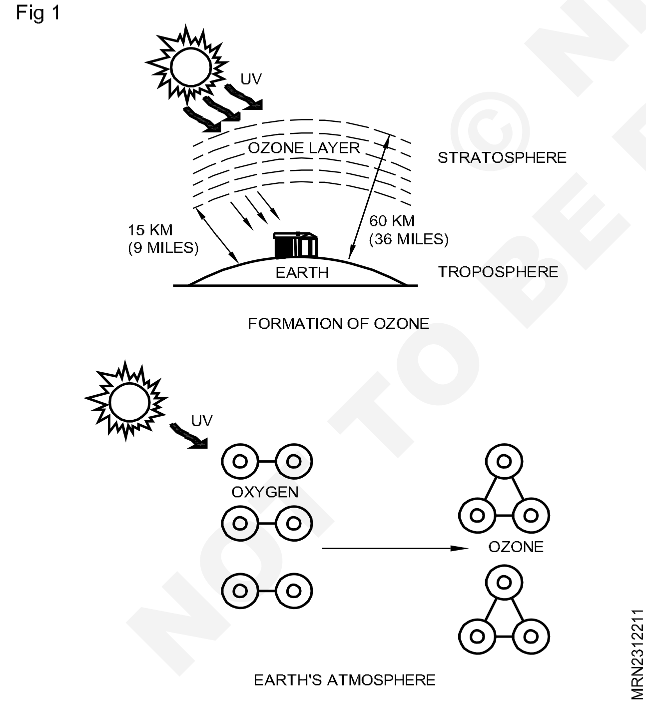
Refrigerant		R22	R123	R134a	R600a	R717	R404A	R407C	R410A	R290
Boiling point	°C	-40.8	27.87	-26.2	-11.73	-33.3	-46.6	-43.8	-51.6	-42.1
	°F	-41.4	82.2	15.2	10.9	-28	-51.88	-46.84	-60.88	-43.78
Critical Pressure	Kg/cm^2	49.7	36.44	40.44	36.2	115.5	37.3	46.3	47.7	42.48
	Psig	707	518	575	514	1642	531	659	678	604
Critical Temp.	°C	96	184	101	135	133	72	86	70	97
	°F	205	363	214	275	271	162	187	158	206
NRE**	Kcal/Kg	38.83	34.01	36.02	62.82	263.43	27.1	37.47	40.02	66.4
	Btu/lb	69.89	61.22	64.83	113.1	474.18	48.79	67.45	72.04	119.52
Comp. displacement	m^3/m	0.1	1.3	0.17	0.321	0.097	0.1	0.11	0.068	0.097
per TR**	:cm	3.55	46.02	6.021	11.36	3.44	3.61	3.97	2.45	3.44
Discharge gas temperature**	°C	53.3	34.44	43	45	98.9	30	35	30	30
	°F	128	94	109.4	113	210	86	95	86	86
Bhp/TR (theoretical)**		1.011	0.974	1.07	1.07	0.989	0.999	1.01	0.981	0.992
COP**		4.75	4.63	4.42	4.55	4.84	5	4.28	5.01	4.66

Refrigerant	R22	R123	R134a	R600a	R717	R404A	R407C	R410A	R290
Safety@	A1	B1	A1	A3	B2	A1	A1	A1	A3
Miscibility with mineral oil	fair	good	nil	nil	nil	nil	nil	nil	nil
Synthetic oil	good	-	good	good	good	good	good	good	good

Refrigerants impact on environment: Many of the refrigerants in use for the past several decades have had an impact on the environment, in two ways-ozone depletion and global warming (green house effect).

Ozone layer - its depletion: Ozone is a variant of oxygen, the ozone molecule having three atoms of oxygen (O3) while the oxygen molecule is made up of only two atoms (O2). An ozone layer surrounds the earth's stratosphere, which is about 11 kilometers above the surface of earth at the equator and 5 to 6 kilometers at the poles (Fig 1). The ozone layer absorbs the sun's ultraviolet (UV) rays substantially, thus acting as a protective umbrella for life on earth from the harmful effects of high concentration of UV radiation. If depletion of the ozone layer occurs in the stratosphere, UV radiation to the earth will increase. Consequence of this can be health hazards such as skin cancer, severe infections diseases, environmental problems like global warming, melting of polar ice caps, rising of sea level, droughts a matter of grave concern for life on earth.

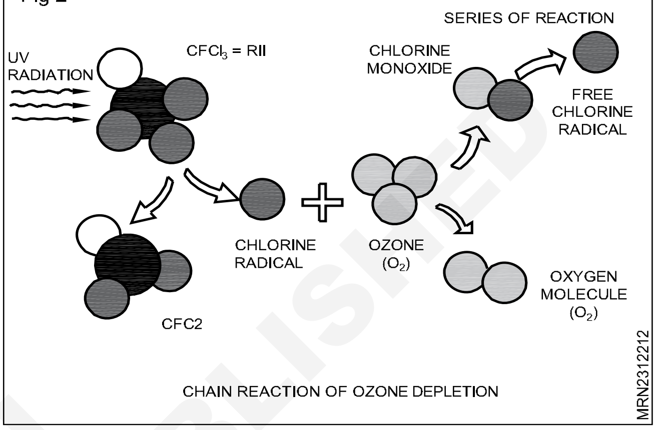
Fig 1



Halons (used to extinguish fire) are compounds containing, bromine, fluorine, and carbon. Like CFCs, halons break down in the stratosphere releasing bromine. Bromine is even more destructive on the ozone layer than chlorine. (Fig 2)

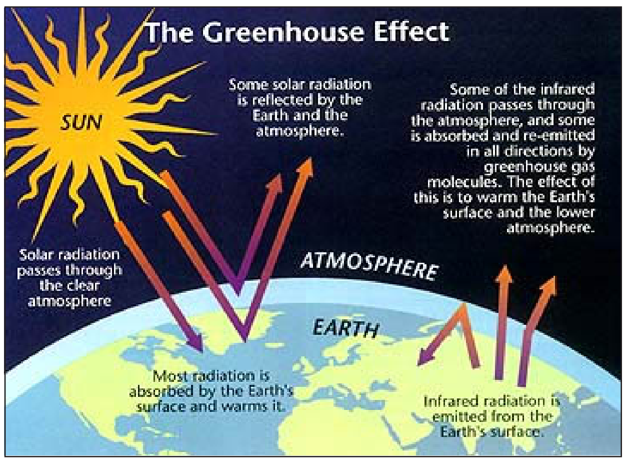
Ozone - Depletion Potential (ODP): The potentials of compounds for ozone depletion, obviously vary according to their chlorine/bromine content and the period of their stability in the atmosphere. This potential is known as ozone depletion potential (ODP). ODP is a factor based on the percentage weight of chlorine in a compound and ist lifetime (stability) in the atmosphere.

Fig 2



Greenhouse effect - global warming potential (GWP): Some of the heat absorbed by the earth from the sun is reflected back to the space thus not allowing the earth's temperature to rise above a certain level. A film of gases envelops the earth's atmosphere. Some of these gases trap part of the reflected heat preventing its reflection back to space. This increase the earth's average temperature leading to 'Global Warming'. (Fig 3) This is known as the 'greenhouse effect' and the gases that trap the heat are known as greenhouse gases (greenhouse: a room or a house of glass walls and roof for the cultivation of plants at controlled (high/tropical) temperature and (high) humidity condition). Obviously, higher concentration of the greenhouse gases in the atmosphere will lead to a warmer earth and consequently harmful ecological changes.

Fig 3



The main greenhouse gases in the atmosphere are carbon dioxide (CO2), methane and mitrous oxide. All halogenated refrigerants (CFCs, HCFCs and the chlorine-free HFCs too) are found to be greenhouse gases. HCFCs (e.g R-22) and HFCs (such as R-134a) have a shorter atmospheric life than CFCs. They are destroyed in the lower atmosphere itself by chemical reactions and so they have lower ODP and GWP values.

Table

CFC abd HCFC phase-out schedule

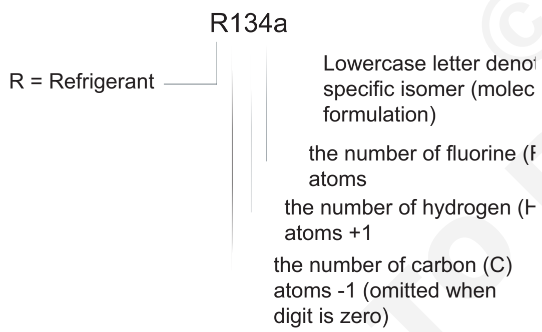
Phase-out Schedule	India and other	Developing A5 Countries	Developed	Countries
	CFC (R-11, R-12 etc)	**HCFC** (R-22, R-23, etc)	**CFC** (R-11, R-12 etc)	**HCFC** (R-22, R-23 etc)
New appliance manufacturing	1 Jan, 2003	Phase-down schedule only		Phase-down schedule only
Servicing purpose	1 Jan, 2010	1 Jsn, 2040		1 Jan, XXXX

The 1 Jan, 2010 schedule got preponed to 2008 and CFC was totally phased-out ahead of its original schedule.

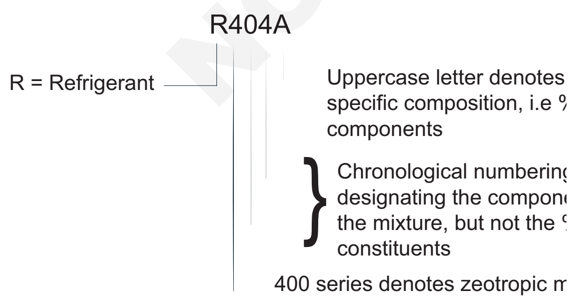
Production/use of HFCs (R-32, 125, 134a, 143a and their blends - R404A, 407C and 410A) is not regulated by the Montreal protocol, but may be regulated by individual countries.

Nomenclature

Refrigerants are classified by ASHRAE, and their familiar 'R' numbers are assigned according to certain rules. For example, the classification of halogen refrigerant derived from saturated hydrocarbons and consisting of only one substance is illustrated by the example below:



Mixture are designed by their respective refrigerant numbers and mass proportions. For example:



Zeotropic mixtures are assigned an identifying number in the 400 series. This number designates which components are in the mixture, and the following upper case letter denotes the proportions. The numbers are in chronological order of the refrigerant's approval by ASHRAE.

Example: R470A (R32/R125/R134a (20/40/40)), R407B (R32/R125/R1344a (10/70/20)), R407C (R32/R125/R134a(23/25/52)), etc.

A zeotropic mixtures are in the 500 series. Example: R507 (R125/R143a (50/50)).

Miscellaneous organic compounds are in the 600 series; numbers are given in numerical order, for example, R600a, isobutene; and inorganic compounds are in the 700 series. Identification numbers are formed by adding the relative molecular mass of components to 700.

Example: R717 corresponds to ammonia which has a molecular mass of 17.

Refrigerant blends and glide

Many of the HFC refrigerants are mixtures or blends of two or more individual chemicals. Mixture can be azeotropes, near azeotropes or zoetropes.

Azeotropes exhibit a single boiling point, strictly speaking at one particular pressure, but nevertheless they may be treated as a single substance. The first azeotropic refrigerant was a CFC, R502, so the use of refrigerant blends is not new. Where the boiling point varies throughout the constant pressure boiling process, varying evaporating and condensing temperatures exist in the phase change process.

The temperature glide can be used to advantage in improving plant performance by correct design of heat exchangers. A problem associated with blends is that refrigerant leakage can result in change in the proportion of components in the blend. However, the changes are small and have negligible effect on performance. The following recommendations apply to the use of blends:

Equipment must always be charged from the liquid phase, or the component concentrations will be incorrect.

Ingress of air must be avoided.

Blends which have a large temperature glide, greater than 5K, should not be used with flooded type evaporators.

Some mixtures exhibit a glide of less than 2K, and these are called 'near azeotropes'. For practical purposes they may be treated as single substances. Examples are R404A and R410A.

Refrigerant applications

The refrigerants most commonly used today and their applications are considered below. Further developments and environmental considerations could further restrict the use of HCFs in the future. The so-called natural refrigerants with virtually zero ODP and zero GWP when released into the atmosphere represent a long-term solution to the environmental issue of refrigerant leakage, where they can be efficiently and safely applied.

R134a and R470C

The refrigerants are primarily used for air conditioning and have replaced R22 in many applications. R134a has a relatively low pressure and therefore about 50% larger compressor displacement is required when compared to R22, and this can make compressor more costly. Also larger tubing and components result in higher system cost. R134a has been very successfully used in screw chillers where short pipe lengths minimize costs associated with larger tubing. R134a also finds a niche where extra high condensing temperatures are needed and in many transport applications.

R470C is zeotropic mixture consisting of 23% R32, 25% R125 and 52% R134a. it has properties close to those of R22, and is for this reason has been extensive use in Europe due to rapid R22 phase out. Its glide and heat transfer properties generally penalize the system performance, although counter flow heat exchange can deliver some benefit with plate heat exchangers.

R410A

This fluid looks discouraging at first because of is poor theoretical performance (as shown in Fig), low critical temperature and high pressure. However, the refrigerant side heat transfer is about 35% better than with R22, whereas for R407C and R134a it is poorer. The pressure drop effect in equivalent heat exchangers is 30% less. Research has shown that systems optimised for R410A can deliver up to 5% better system COP than R22 equivalent systems, whereas R407C systems tend to be about 5% poorer. Many air-conditioning suppliers are switching to R410A, especially for direct expansion type systems where an added advantage is that smaller pipe sizes can be used.

R404A

R404A is a HFC that has been designed for commercial refrigeration where it is now widely applied. It has superior performance to the other HFCs in low-temperature applications and also exhibits low compressor discharge temperatures which makes it suitable for single stage compression avoiding the need for inter-stage cooling.

R717 ammonia

Ammonia has long used as a refrigerant for industrial applications. The engineering and servicing requirements are well established to deal with its high toxicity and low flammability. Technical developments are extending the applications for ammonia, for example, low-charge packaged liquid chillers for use in air conditioning. Ammonia cannot be used with copper or copper alloys, so refrigerant piping and components have to be steel or aluminium. This may present difficulties for the air-conditioning market where copper has been the base material for piping and plant. One property that is unique to ammonia compared to all other refrigerants is that it is less dense than air, so a leakage of ammonia results in it rising upwards and into the atmosphere. If the plant is outside or on the roof of a building, the escaping ammonia can drift away without harming occupants. Ammonia can be detected by its characteristic odour at very low concentrations, and this acts as an early warning signal. The safety aspects of ammonia plants are well documented, and there is reason to expect a sustained increase in the use of ammonia as a refrigerant.

R290 propane and other hydrocarbons

Hydrocarbons such as propane and butane are being successfully used in new low-charge systems where CFCs and HCFCs have previously been employed. They have obvious flammable characteristics, which must be taken into account. There is a large market for their use in sealed refrigerant systems such as domestic refrigerant and unitary air conditioners.

Safety aspects of using a refrigerant

ASHRAE standard classifies refrigerants according to their toxicity and flammability. The classification uses capital letter to denote toxicity of the refrigerant and its flammability is designated by a numeral, as under:

Class A - No toxicity identified even at a low concentration of 400ppm by volume

Class B - Where evidence of toxicity is identified

Class 1 - Does not propagate flame in air at 21°C and atmospheric pressure

Class 2 - Lower flammability

Class 3 - highly flammable.

So there are six groups viz A1, A2, A3, B1, B2 & B3 in the safety classification. (Refer Table) Refrigerants with very low/ nil toxicity and non-flammable are the least hazardous (identified as group A1) and those coming under group B3 are the most hazardous. Table 9.3 shows some of the relevant physical properties of the commonly used refrigerants along with their safety classification.

Table Classification of refrigerant on safety
Safety Classification
Capital letters corresponds to toxicity, digit to flammability

	Class A	Class B
Class 3	**Toxicity has not been identifies below 400 ppm**	**Evidence of toxicity at concentrations below 400 ppm**
Highly flammable as defined by a lower flammability limit of less than or equal to 0.10 kg/m3 at 21°C and 101 kpa or heat of combustion greater than or equal 19 KJ/Kg	R170 R290 (Propane) R600a	
Class 2		
Having a lower flammability limit of more than 0.10 Kg/m3 at 21°C and 101 kpa and a heat of combustion of less than 19 KJ/ Kg	R141b R142b R32 R 1234yf	
Class 1		
Do not show flame propagation when tested in air at 21°C and 101 kpa	R718 (water) R744 (CO_2) R22 R125 R134a R407C R404A R410A	

Safe handling of flammable refrigerant

Simple precautions: The sources of ignition are flames due to brazing torches, match sparks from the electrical components like door switches, relays, OLPs or loose wires.

All repair and servicing must be carried out in a well-ventilated area, to prevent accumulation of refrigerant leaked out.

Smoking should be strictly prohibited in the work area.

Do not work near any ignition source.

Always wear protective goggles and gloves.

Keep only required quantity of HCs in the work area.

Use only dry powder fire extinguishers.

HC refrigerants should be handled and stored in dry and ventilated areas away from any fire. Building up of static electricity should be avoided. Keep the cylinders upright with valves closed and capped and away from direct sun light.

A flammable gas alarm should be fitted in a bulk storage area. Cylinders should be stored on the ground floor. Empty cylinders should be separately stored.

During transporting keep the cylinders in upright position. The vehicle should have adequate ventilation to avoid the build up of flammable mixture in case of leak. Do not allow smoking or any naked flames near the vehicle.

The regulations, applicable to local LPG (cooking gas) are applicable to hydrocarbons. To check whether a cylinder is empty weight it. Its pressure is not an indication of the amount of refrigerant remaining. In order to warm the cylinder, use only water or air at 40°C.

During the transport of hydrocarbon cylinders, carry two dry chemical powder (sodium bicarbonate) fire extinguishers of 1kg capacity each. Keep one at drivers, cabin and the other in the load compartment. While unloading the cylinders, they may be gently placed on a thick and heavy rubber mat.

If a cylinder is burning cool the other cylinders using water. Burning cylinder should be rolled on. Keeping it upright, to an open area and let the gas burn off.

Montreal protocol

The montrcal protocol is an international treaty designed to protect the ozone layer by phasing out the production of numerous substances that are responsible for ozone depletion.

It was agreed on 16th September 1987.

India became party – 17th September 1992

India has phased out production & consumption of cfcs & halons as of 1st january 2010

HCFC Phase-out for Article 5 countries

Base level: Average of 2009 and 2010

Freeze: January 1, 2015 – **achieved**

35% Reduction: January 1, 2020 – **achieved**

67.5% Reduction: January 1,2025

100% reduction: January 1, 2030 with a service of 2.5% annual average during the period 2030 – 2040

Physical Properties

- ASHRAE A1 safety classification
- Non flammable & safe to use
- Zero ODP
- GWP of 1725 (IPCC assessment report 2)
- Molecular weight is 72.6
- Boiling point at 1 ATM is -51.5°C
- Critical Temperature is 71.8°C
- Composition (wt%) R – 32/R – 125 = 50/50

Property	S.I.Units	Value
Molecular weight	Kg/kmol	72.59
Critical Temperature	°C	71.35
Critical Pressure	Bara	49.02
Critical Density	Kg/m^3	459.53
Atmospheric Bubble point	°C	-51.443
Atmospheric Dew point	°C	-51.364
Latent heat of vaporisation at Atmospheric pressure	kJ/kg	279.12
Saturated vapour density at atmospheric pressure	kg/m^3	4.1742
Liquid vapour pressure @25°C	bara	16.574

Physical Properties:

- ASHRAE A2L classification
- Mildly flammable
- Zero ODP
- Molecular weight is 52.02
- Boiling point at 1ATM is – 51.65°C
- Critical temperature is 78.4°C
- GWP of 650 (IPCC assessment report)

Usage instructions:

- R32 cannot be used as a 'drop-in' replacement for R410A in existing systems charging can be done in liquid or vapour phase

Applications:

Domestic and commercial air – conditioning

Some of its main **characteristics** are:

- It is a more energetically efficient refrigerant than R-410A and has a GWP of 675, which is 68% lower than R-410A.
- Its refrigeration capacity is similar to that of R – 22 and R – 502
- The equipment requires less refrigerant charge compared to R-410A.
- Same tubing and POE oils as – R -410A.
- Safety classification: A2L, low toxicity and low flammability

Applications:

Initially used in some new air –conditioning equipment, it is also staring to be considered as an alternative at low temperatures.

It has been used as a component in well – known industry HFC mixtures such as R -407 C, R -410A, R-442A (RS-70), etc.

R -32 classified as flammable and is therefore not a refrigerant designed for refits of R-410A.

Property	S.I units	value
Molecular weight	kg/kmol	52.02
Critical temperature	°C	78 11
Critical pressure	bara	57.82
Critical density	kg/m3	424 00
Normal boiling	°C	-51 651
Latent heat of vaporisation at atmosphere pressure	kJ/kg	381 86
Saturated vapour density at atmosphere pressure	Kg/m3	2 9879
Liquid vapour pressure @ 25 C	bara	16 896

Refrigerant		Atmospheric lifetime (years)	Ozone Depletion potential (ODP) (100 Year)	Global Warming Potential (GWP)
Ammonia	R – 717	-	0	<1
CFC (no more)	CFC – 11 (Baseline ODP)	50	14000	
	CFC – 12	102	1	10900
HCFCs	HCFC – 22	13.3	0.055	1820
	HCFC – 123	1.4	0.02	93
	HCFC – 141b	9.4	0.11	630
HFCs	HFC – 134a	14.6	0	1300
	HFC – 245fa	7.3	0	820
	R – 32	-	0	675
HCs	HC – 290 (Propane)	-	0	3
	R – 1270 (Propylene)	-	0	<2
HFC Blends	R -404A	-	0	3260
	R -407A	-	0	1770
	R-407C	-	0	1530
	R-410A	-	0	1730
CO2	R-744	-	0	1
HFOs	1234yf, 1234ze	-	0	4.7

Physical Properties:

- ASHRAE A1 safety classification
- Non Flammable & safe to use
- Zero ODP
- GWP of 3260 (IPCC assessment report 2)
- Molecular weight is 97.6
- Boiling point at 1 ATM is -46.5/ -45.8°C
- Critical Temperature is 72.1°C

Applications:

- Transport refrigeration
- Supermarket display cases, cold rooms
- Ice machines – process cooing

Usage Instructions:

- Compatible with POE lubricants
- Charging must be done in liquid phase

Composition (wt%) R – 143a/ R – 125/ R – 134a = 52/44/4.

Property	S.I. Units	Value
Molecular Weight	Kg/ kmol	97 60
Critical temperature	*C	72 05
Critical Pressure	Bara	37 29
Critical Density	Kg/ m3	486 54
Atmospheric Bubble point	*C	-46 2
Atmospheric Dew point	*C	45 5
Latent Heat of Vaporisation at Atmospheric pressure	Kg/K/g	199 61
Saturated Vapour Density at Atmospheric pressure	Kg/m3	5 48
Liquid vapour pressure @25°C	Bara	12 5

Physical properties:

- ASHRAE A 1 safety classification
- Non-flammable & safe to use
- Zero ODP
- GWP of 1526 (IPCC assessment report 2)
- Molecular weight is n86.2
- Boiling point at 1 ATM is – 43.6 C°
- Critical temperature is 86.0 C°

Application

- Residential and commercial conditioning systems
- Direct expansion fluid chillers and some commercial refrigeration systems

Usage instructions

- Compatible with POE lubricants
- Charging must be done in liquid phase

Composition (wt.%) R-32 /R-125/R-134a + 23/25/52

Property	S.I Units	Value
Molecular weight	Kg/kmol	86 20
Critical temperature	C°	86 03
Critical pressure	Bara	46 29
Critical density	Kg/m3	484 20
Atmospheric bubble point	C°	-43 627
Atmosphere dew point	C°	36 629
Latent heat of vaporisation at atmospheric pressure	KJ/kg	256 29
Saturated vapour density atmospheric pressure	Kg/m3	4 6306
Liquid vapour pressure @ 25 C°	Bara	11 903

R -600a advantage

- Zero ozone depletion potential
- Very low warming potential (< 4)
- High thermodynamic properties leading to high energy efficiency.
- Good compatibility with components.
- Low charges allowing smaller heat exchangers and dimensions

Applications:

- The most common application are using in domestic refrigeration (refrigerators and freezers).
- Other applications include small display cabinets and vending machines

Molar mass	g/mol	58.12
Boiling point	°C	-11.80
Melting point	°C	-159.6
Critical temperature	°C	134.98
Flash point	°C	-83
Vapour pressure	kPa	204.8
Critical pressure	MPa	3.66
Density .25°C	g/cm^3	0.551
Critical density	g/cm^3	0.221
Specific heat capacity	J/l*mol	96.65
Solubility in water	g/f	0.024-0.061
Explosive limits	%	1.4-8.3
GWP		4
ODP		0

Transfer of refrigerants

Objectives: At the end of this lesson you shall be able to
- **explain about refrigerant cylinders**
- **describe recovery.**

Refrigerant cylinders: Cylinders are made of steel. The cylinder valve is connected at the top. The cylinder valve is packing type. Packing is used to prevent leakage of gas through the threads of the stem. Further, caps are used to prevent refrigerant leakage at the top through packing nut and outlet of the cylinder.

The refrigerant cylinder contains the refrigerant liquid at the bottom and high pressure vapour above the liquid. This pressure depends upon the temperature of the cylinder or the atmospheric air. When the cylinder valve is opened keeping the cylinder upside down refrigerant in liquid state comes out.

Transferring refrigerant from one cylinder to the other. Small cylinder is cooled to decrease the pressure inside. The pressure of the gas inside the large cylinder, which is at atmospheric temperature is high. After purging open the valves to transfer the liquid refrigerant from large cylinder to small cylinder.

Fig 1

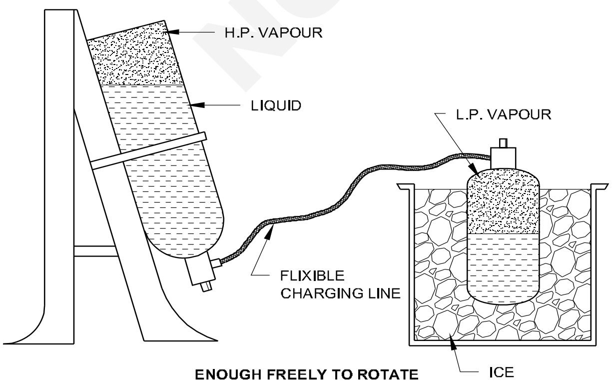
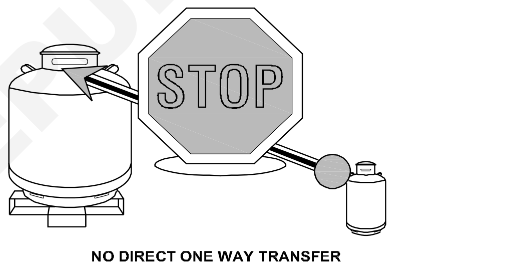


Fig 2



Proper push/ full liquid and vapor refrigerant transfer process

For illustrative purposes

A = Vapor line number one

B = Vapor Line number two

C = Liquid line

D = Refrigerant Recovery Equipment

Refrigerant recovery equipment

Fig 3

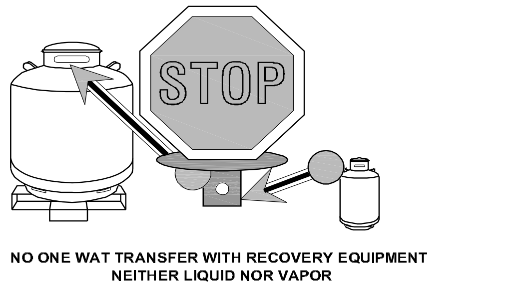
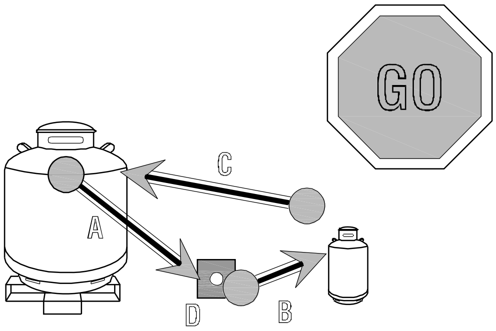


Fig 4



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PROPER PUSH/PULL LIQUID AND VAPOR REFRIGERANT TRANSFER PROCESS

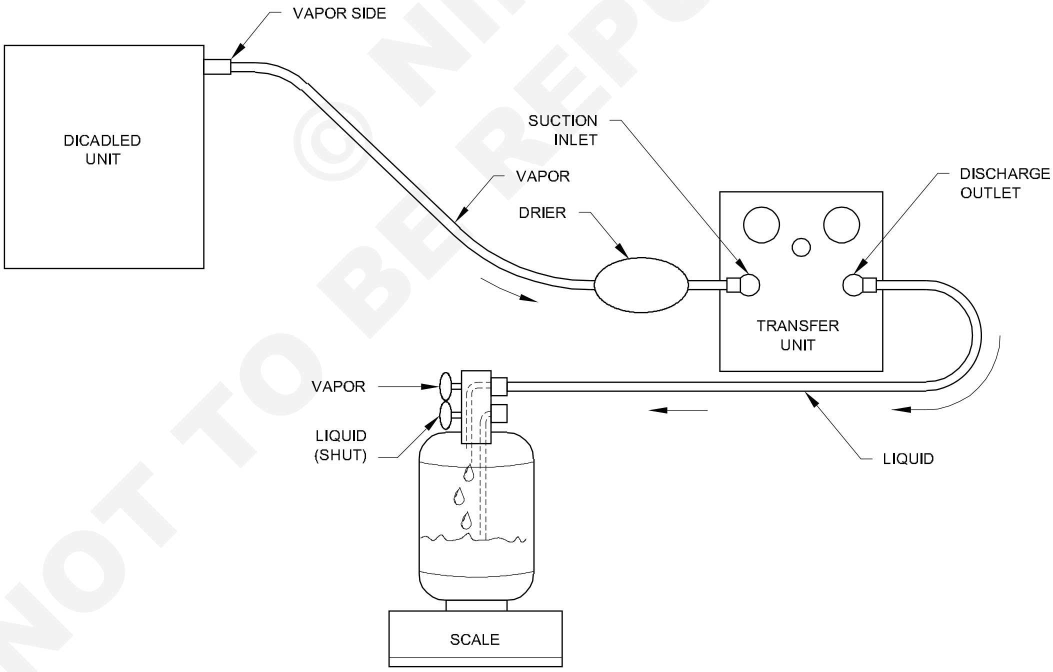
Recovery

Removing refrigerant from a system in any condition and storing it in an external container is called "recovery." Removal of refrigerant from the system is necessary, in some instances, when repair of a system is needed. To accomplish this, you can use special recovery equipment, which is now a requirement when removing refrigerant from a system. This equipment ensures complete removal of the refrigerant in the system.

Recovery is similar to evacuating a system with the vacuum pump and is accomplished by either the vapour recovery or liquid recovery method. In the vapour recovery method (Fig 5) a hose is connected to the low-side access point (compressor suction valve) through a filter-drier to the transfer unit, compressor suction value. A hose is then connected from the transfer unit, compressor discharge valve to an external storage cylinder. When the transfer unit is turned on, it withdraws vapour refrigerant from the system into the transfer unit compressor, which, in turn, condenses the refrigerant vapour to a liquid and discharges it into the external storage cylinder.

In the liquid recovery method (Fig 6), a hose is connected to the low-side access point to the transfer unit compressor discharge valve. A hose is then connected from the transfer unit compressor suction value through a filter-drier to a two-valve external storage cylinder. A third hose is connected from the high-side access point (liquid value at the receiver) to the two-valve external storage cylinder. When the transfer unit is turned on, the transfer unit compressor pumps refrigerant vapour from the external storage cylinder into the refrigeration system, which pressurizes it. The difference in pressure between the system and the external storage cylinder forces the liquid refrigerant from the system into the external cylinder. Once the liquid refrigerant is removed from the system, the remaining vapour refrigerant is removed using the vapour recovery method as previously described.

Fig 5



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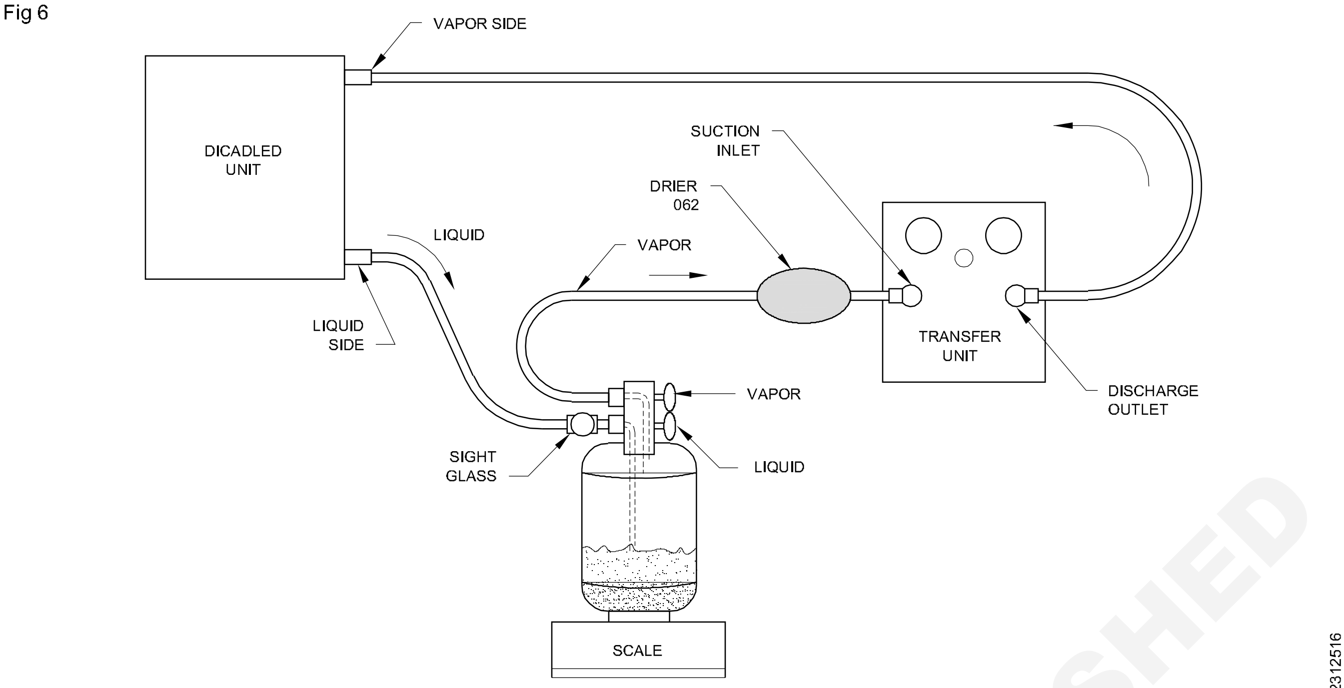
THE VAPOR RECAVERY METHOD

Fig 6



THE VAPOR RECAVERY METHOD

Cylinder & valves - Safety

Objectives: At the end of this lesson you shall be able to
- **explain about refrigerant handling safety**
- **explain about refrigerant leak.**

Refrigerant Handling Safety

Refrigerants used in refrigeration and air conditioning systems must be used properly to avoid potential hazards. Most refrigerants have low boiling points and present dangers of frostbite and eye damage. Refrigerant liquids with higher boiling points can cause respiratory and skin irritation. Refrigerants can also damage the environment if handled improperly. In the mid-1970s it was suggested that Freon and other CFCs were, by chemical reaction, destroying the ozone present in the stratosphere. Depletion of the ozone could create a threat to animal life on the Earth because the ozone absorbs ultraviolet radiation that can induce skin cancer. The use of Freon in aerosol-spray containers was banned in the United States in the late 1970s. By the early 1990s, accumulating evidence of ozone depletion in the Polar Regions had heightened worldwide public alarm over the problem, and in 1992 most of the developed nations agreed to end their production of Freon and other CFCs by 1996.

Here are guidelines for the safe handling of refrigerants.

- Instructions must ensure that personal who handle refrigerants are properly trained in their safe use and handling, and have reviewed the MSDS for the refrigerant used.
- Wear safety goggles and gloves at all times when handling refrigerants or servicing a refrigeration system.
- Wear the proper respiratory protection while working with refrigerants. Check the MSDS for the proper level of protection required.
- Proper ventilation or respiratory protection is required for any work on equipment in an enclosed area where a leak is suspected.
- Always ventilate or test the atmosphere of an enclosed area before beginning work. Many refrigerants which may be undetectable by human senses are heavier than air and will replace the oxygen in an enclosed area causing loss of consciousness.
- Inhaling refrigerants can cause sudden death. Intentional inhalation of refrigerants to produce intoxication can cause the cause sudden death. Internal inhalation of refrigerants to produce intoxication can cause the heart to cease functioning properly and may be fatal.
- Refrigerant cylinders should never be filled over 80% of their capacity (liquid expansion may cause the cylinder to burst).
- Check the I.C.C. cylinder stamp to ensure the cylinder is safe. Always check the refrigerant number before charging to avoid mixing refrigerants.
- Always check for the correct operating pressure of the refrigerant used. Use gauges to monitor the system pressure.
- Always charge refrigerant into the low side of the system to avoid damaging the compressor, or causing the system to rupture.
- R-717 and R-764 are very irritating to the eyes and lungs. Avoid exposure to these refrigerants.
- R-717 is slightly flammable and mixed with the proper proportions of air may form an explosive mixture.
- Fluorocarbon refrigerants should be treated as toxic gases. In high concentrations, these vapors have an anesthetic effect, causing stumbling, shortness of breath, irregular or missing pulse, tremors, convulsions, and even death.
- Ammonia is a respiratory irritant in small concentrations and is a life threatening hazard at 5,000 parts per million (ppm).
- Ammonia is also flammable at a concentration of 150,000 -270,000 ppm
- Always stand to one side when operating an ammonia valve. Ammonia can burn and damage the eyes, or cause loss of consciousness. Ammonia leaks may be detected by their smell, or with a sulpur candle or sulpur spray vapour.
- Refrigerant oil in a hermetic compressor is often very acidic causing severe burns. Avoid skin contact with this oil.
- Liquid refrigerant on the skin may freeze the skin surface causing frostbite. If contact with the skin occurs, wash immediately with water, treat any damaged skin area for frostbite, and seek medical treatment.
- Never cut or drill into an absorption refrigeration mechanism. The high pressure ammonia solutions are dangerous and may cause blindness if the solution contacts your eyes.
- Ensure that all liquid refrigerants is removed and the pressure is at 0 psi before disassembling a system.

- Do not smoke, braze, or weld when refrigerant vapors are present. Vapors decompose to phosgene acid vapors and other products when exposed to an open flame or hot surface.
- When soldering, brazing, or welding on refrigeration lines, the lines should be continuously purged with low pressure carbon dioxide or nitrogen.
- Following work, the lines should be pressure tested with carbon dioxide or nitrogen.
- If refrigerant makes contact with the eyes, immediately wash with mineral oil as this absorbs the refrigerant. Then wash your eyes with a prepared boric acid solution.
- If the refrigerant is ammonia, wash with water for at least 15 minutes. Seek medical attention as soon as possible.
- Purged refrigerants must not be released into the atmosphere. Federal law governs their disposal, and they must be collected and disposed of properly.
- Do not allow temperatures where refrigerant cylinders are stored to reach 125 degrees F. Temperatures can easily exceed 125 degrees F in your vehicle during not weather.
- Inspect refrigerant cylinders regularly. Do not use the cylinders if they show signs of rust, distortion, denting, or corrosion. Store cylinders secured and upright in an area where they will not be knocked over or damaged.

Refrigerant leak

Causes for refrigerant leakage

- Compressor vibration (which causes refrigerant line connection to become loose)
- Escape through the walls of rubber hoses.
- Shaft sealing (Due to non use of A/C for a longer period)

A leakage rate between 50g to 100g of refrigerant per year is normal

Difference between R-12 and R-134a leakage

R-12	R-134a
Only residue will appear at leakage point	Synthetic refrigerant oil does not appear as only residue at leakage point

Method adapted to check leakage

- Oxygen free nitrogen method/pure nitrogen method
- Electronic tester method
- Dye method

Area to check for leakage

- All connections and pipes
- Compressor drive shaft
- Compressor service valves and sealing gasket
- Condenser and evaporator matrix tube ends
- Receiver/drier or accumulator connection
- Pressure switches
- Hoses

The refrigerant circuit must be under pressure when performing a leak test.

If the A/C system is still operation there should be sufficient pressure in the circuit (at least 3.5 bar) to carry out an effective leak test).

If the system charge is too low, the refrigerant will need to be recovered

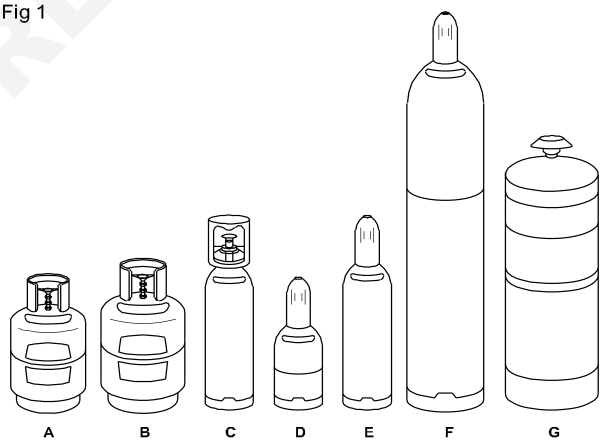
If the system is empty do not charge it with refrigerant carry out leak testing with oxygen free nitrogen.

Refrigerant Cylinders and Valves

Most refrigerants are supplied by refrigerant manufacturer and stored in by cylinder holding say 60 kg. (132 ibs.) apporx. Of liquid and vapour when full. Those must be stored upright, with caps in place, in cool and well ventilated stores located well away from boiler rooms, or areas in which operations presenting fire hazards - welding, for example -are carried out.

Types: There are three types of refrigerant cylinder. (Fig 1)

Fig 1



COMMON REFRIGERANT CYLINDERS.

- Storage cylinder as described, under 'introduction' above
- Returnable service cylinder of small capacity.
- Disposable (Use and throw away) cylinders.

Cylinders are made of steel or aluminium. The larger ones usually have a fusible plug safety device threaded into the concave bottom as a protection against over heating or excessive pressures. A value at the top provide a connection for charging service cylinders.

Storage cylinders

It is most economical to purchase refrigerants in big cylinders. These become storage cylinders which are frequently positioned upside down with the value at the bottom. This makes charging service cylinders much easier. Storage cylinders are fitted with a valve and usually a protective cap, which may be screwed over the value for shipment.

Returnable service cylinders

Service cylinders should be weighted before and after filling. In this way the amount of refrigerant in the cylinder may be readily determined. Only the specified weight of refrigerant should be charged into it. A cylinder should not be filled beyond 80% of its volumetric capacity.

Disposable cylinders

These containers are easy to handle and they eliminate the problem of refilling.

Most disposable cylinders are filled with relief valves. Usually these are located in the valve body. Some 'throw away' refrigerant containers are sealed cans. The top is made in such a way that a special value can be tightly clamped on the top of the can. This valve, when clamped on the can, can be made to puncture it or depress a valve pin and provide a means of drawing refrigerant from the can.

Colour code for refrigerant cylinders

The cylinder used for transporting refrigerants are colour coded to permit easy identification of the refrigerant in the cylinders. This practice helps to prevent accidental mixing of refrigerants within a system.

However, one must always read the label and identify the refrigerant before using the cylinder. The colour code shown is not a requirement of all manufacturers. Popular refrigerants, with their R-number and cylinder colour code, which follows.

Cylinder volume (Fig 2)

Cylinder volume can be calculated by the following formula:

V= D2 I

Where D = Diameter (inner) of cylinder meters

I = Length of cylinder in meters

V= Volume of cylinder in m^3 (cube meter)

Mass of refrigerant

The weight of refrigerant for a cylinder can be calculated by the following formula

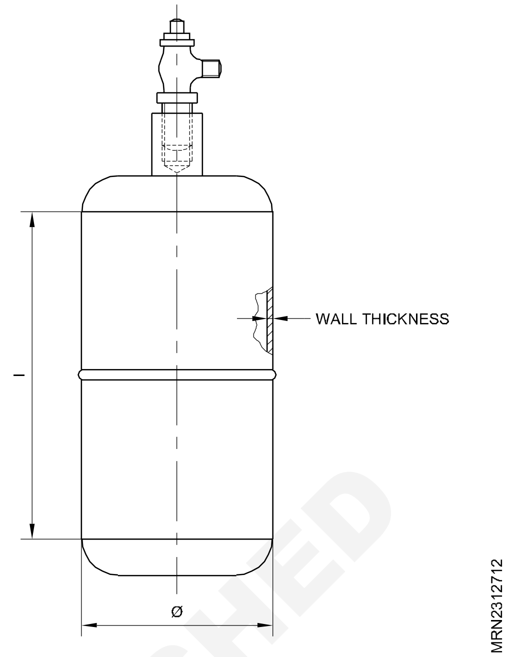
M=V x d

Where M = Weight of refrigerant in kg.

V= Volume of cylinder in m^3

d=Density of refrigerant in kg/cm^3 (at particular condition)

Fig 2



Refrigerant Number	Cylinder colour code
R-11	Orange
R-12	White
R-22	Green
R-502	Orchid
R-717	Silver
R-134A	White

Refrigerant Cylinder valves

Cylinders are fitted with back seating type valves screwed directly into the cylinder necks, and protected by heavy caps. These valves are either open, or closed:

1 When the valve is front seated it is closed and the refrigerant is sealed within the cylinder.

2 When the value is back seated, the charging part will be open, and refrigerant will flow through it.

Standard valve outlet are ¼" SAE (6 mm) fittings which should be kept sealed and cupped when the cylinder is not in use with the valve cap in place to avoid accidental damage.

Identifying cylinders

While the cylinder label is the primary means of identifying the properties of the gas in a cylinder, the colour coding of the cylinder itself provides a further guide.

Most important colours

Poisonous and/or corrosive gases	Yellow
Combustible gases	Red
Oxidizing gases	Light blue
Inert gases	Light green

Pure gases

Acetylene	Maroon
Oxygen	White
Argon	Dark green
Nitrogen	Black
Carbon dioxide	Grey
Helium	Brown
Hydrogen	Red
Nitrous oxide	Blue

AGA cylinder colours

Industrial gases	Black
Acetylene	Maroon
Food gases	Green
Specialty gases	Silver grey
Medical gases	White

HFCs Refrigerant Colour codes

Number	Cylinder Colour	Refrig. Name	Application
R-23	Light Gray	Trifluoromethane	Low temperature refrigerant
R-134a	Light sky Blue	Trifluoromethane	Automotive industry and refrigeration systems
R-404A	Orange		R-125+R-143a+R-134a Medium and low temperature
R-407C	Chocolate Brown	R-32+R-125+R-134a	R-22 Replacement
R-410A	Rose	R-32+R-125	Replacement for residential air conditioning
R-507		Light Brown	Refrig. 125/143a Replacement for low-temp commercial refrig.
R-11	Orange	Trichloromonofluoromethane	Centrifugal chillers
R-12	White	Dichlorodifluoromethane	Reciprocating and rotary equipments
R-13	Light Blue	Monochlorotrifluoromethane	Used in low stage of cascade systems
R-13B1	Coral	Bromotrifluoromethane	Low to Medium temperature applications
R-113	Purple	Trichlorotrifluoroethane	Low capacity centrifugal chillers
R-114	Dark Blue	Dichlorotetrafluoroethane	High capacity chillers
R-500	Yellow	Refrig.152A/12	Industrial and commercial reciprocating compressors.
R-22	Light Green	Monochlorotrifluoromethane	Residential, commercial and industrial
R-123	Light Gray	Dichlorotrifluoroethane	R-11 replacement for centrifugal chillers
R-124	Deep Green	chlorotetrafluoroethane	Medium pressure chillers
R-401A	Coral Red	R-22+R-152a+R-124	Medium temperature systems
R-401B	Mustard yellow	R-22+R-152a+R-124	Transport refrigeration, domestic refrigerators
R-402A	Light Brown	R-22+R-125+R-290	Ice machine, vending, supermarket and food service
R-402B	Green Brown	R-22+R-125+R-290	Supermarket, food service and transport

Refrigeration System

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

- **the need and importance of deep vacuum**
- **the type of vacuum pumps needed for deep evacuation**
- **the levels of vacuum that need to be reached**
- **the various types of vacuum gauges**
- **the units in which deep vacuum is expressed**
- **the quantity of refrigerant in weight that has to be charged into a system**
- **how refrigerant can be charged**
- **how refrigerant charge can be accurate**
- **how refrigerant can be charged using charging stills**
- **how refrigerant can be charged using weigh scales**
- **other methods of charging.**

Evacuation

Evacuation is the removal of moisture and non-condensable gases like oxygen, nitrogen, carbon di oxide etc., (which are present in the air) from a refrigeration system. Removal of moisture is also known as dehydration and removal of the non-condensable gases as degassing.

Evacuation = dehydration + degassing

Why Evacuate

a) Oxygen, nitrogen and other such gases, when present in a refrigeration system, do not condense in the condenser of the system (hence known as non-condensable) but take up space in the condenser that was designed for refrigerant vapour and rob the condenser of capacity and efficiency by raising discharge pressures and temperatures. This causes higher compressor discharge gas temperatures and heat which aggravates contamination and chemical breakdown of the lubricating oil, finally leading to compressor failure. Hence, degassing is a ‘must’.

b) Moisture (particularly free water) is a major contaminant as it is responsible for the following:

   i Formation of ice crystals or hydrates in the capillary or expansion valve, leading to poor performance of the system and ultimately compressor failure.

   ii Corrosion of metal parts in the refrigeration system, including the compressor.

   iii Chemically reacts with the refrigerant & lubricating oils (particularly synthetic oils for HFC refrigerants) to form acids and compounds that cause harmful reactions with the compressor oil and materials in the system leading to oil breakdown and sludge formation on compressor components like discharge valves, valve plates and copper plating on the bearings.

   iv It also causes Hermetic Motor winding insulation to breakdown.

How do we evacuate the system

Nitrogen, oxygen and water vapour and other gases are first removed by the vacuum pump. Water that exists as a liquid must be changed into a vapour by boiling it. Then it can be drawn out of the system by a vacuum pump.

Boiling point of water at various pressures

The pressure at which water will boil and become vapour is shown in the table for various temperatures. Now, to make water inside a refrigeration system boil off and become vapour, we have

(a) Either heat the refrigeration system to the boiling point - for e.g., at atmospheric pressure water boils at 100°C and the system has to be heated to this temperature. Obviously this is neither feasible nor desirable.

(b) Reduce the pressure inside the system, so that water starts boiling at the ambient temperature. If the water temperature is 25°C, from the table it can be seen that the vacuum under the system will have to be reduced to about -29.10"Hg or 23 mm of Hg or 30 mill bar or 23,000 microns of Hg to make the water boil. As the water starts boiling it draws latent heat of vapourization from the surroundings including the water itself and the temperature of the water reduces still further. This also means that the vacuum inside has to further reduce to enable the water which has now reached lower temperatures to boil. Thus at 10°C it reduces to 10,000 microns or 13 milli bar or -29.65" of Hg. Quite apart from the free water boiling out at such low vacuums, water that has been dissolved in the lubricating oil and held tightly by it will not boil off unless the vacuum goes even deeper. For CFC-12 systems a vacuum of at least 750 microns should be reached and for non CFC refrigerants like HFCs, the vacuum should go as deep as 100 microns.

Water Boiling Temperature Vs Pressure

Temperature °C	Microns (Hg)	mm (Hg)	Inches (Hg)	Millibar	Psia	Pascals
100	760,000	760	0.00	1013	14.7	101300
70	233,680	234	-20.80	303	4.52	30,300
50	92,456	92	-26.36	120	1.79	12,000
40	55,118	55	-27.83	72	1.07	7,200
30	31,750	32	-28.75	45	0.61	4,500
25	23,000	23	-29.10	30	0.44	3,000
20	17,500	17.5	-29.30	23	0.34	2,300
10	10,000	10	-29.65	13	0.196	1,300
0	4,572	4.5	-29.82	6	0.147	600

Need for a vacuum pump

From the foregoing it is clear that a vacuum pump that can develop a deep vacuum of at least 50 to 100 microns is necessary to achieve system vacuums of about 200 microns.

What type of vacuum pump?

Reciprocating compressors (Hermetic & open type) are commonly used in the field for pulling vacuum. It is important to know that such vacuum pump cannot develop vacuum below 75,000 microns (water at about 45°C will boil at this pressure) and so they should not be used for evacuation for refrigeration systems.

To pull deeper vacuum rotary vacuum pumps have to be used. These come in single and two stages. Single stage vacuum pumps are used for operating vacuums of about 10,000 microns and hence not recommended for refrigeration. Two stage rotary vacuum pumps are capable of generating deep vacuum upto 20 to 50 microns and these are the pumps that should be used.

Construction of two stage Rotary Vacuum Pumps

Effect of Altitude

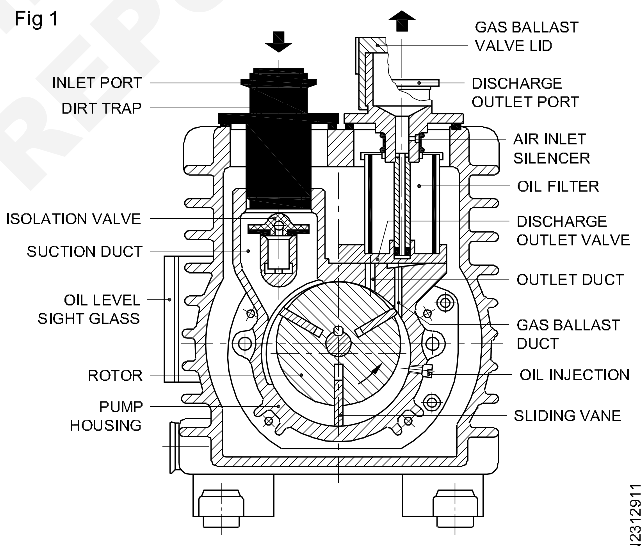
1. Atmospheric pressure at sea level is 1013.25 millibas or 14.7 psia.
2. For every 100 metres of elevation change, pressure changes by about 10 millibars.
3. Therefore, in a place like Pune, where the elevation is 569 m, the atmospheric pressure will be about 56 millibars lower i.e., 1013.56, 957 millibars.
4. On account of this, a millibar vacuum gauge, which shows '0' vacuums at 1000 millibars will show a reading of 56 millibars at Pune and never go below this.
5. Similar altitude connection is applicable for other locations like Bangalore, Mysore, Hyderabad, Indore, etc.

Ready Reckoner for Vacuum

Vacuum gauge resolution	Equivalent microns
10 millibar (in Millibar vacuum gauge)	7500
10 mm Hg (in vacuum gauge 760.0 mm)	10,000
1" Hg (In vacuum gauge 0-30" Hg)	25,000

Rotary Pumps (Fig 1)

Fig 1



CROSS SECTION OF A SINGLE STAGE SLIDING VANE ROTARY PUMP

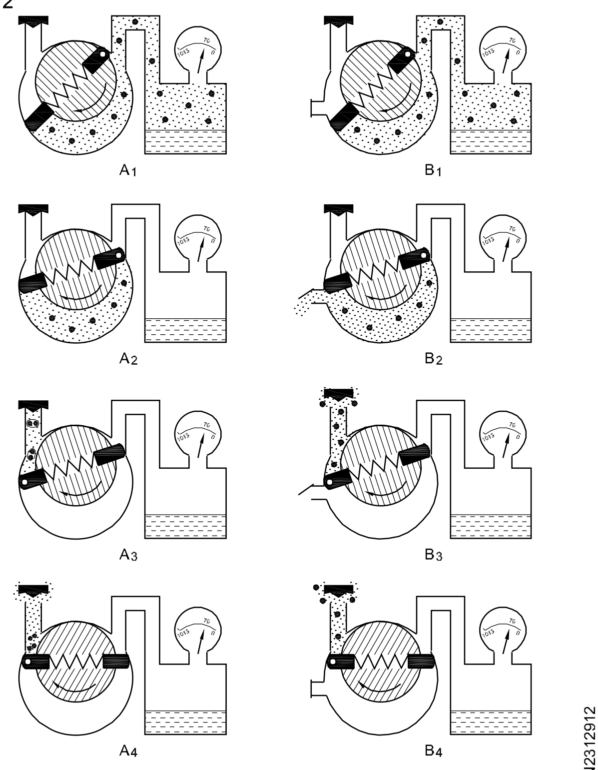
(Positive displacement pumps)

Rotary vacuum pumps belong to the group of positive displacement pumps.

A positive displacement pump is understood to be a mechanical vacuum pump which transports the gas with the aid of pistons, rotors, vanes, valves and other devices, compresses it and expels it. There are so-called oil-sealed and so-called "dry" rotary pumps. Oil sealing of the moving parts allows compression ratios upto 10^5 in one stage. Without oil sealing as in the case of a "dry" pump the internal leakage is much higher, consequently the compression ratio obtainable much lower, about 10.

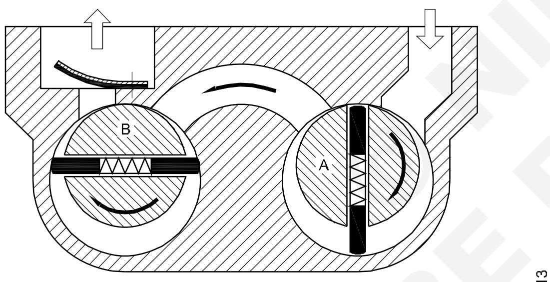
Rotary vane pumps (Figs 2 & 3)

Fig 2



PUMPING PROCESS IN A ROTARY VANE PUMP

Fig 3



A = HIGH VACCUM STAGE
B = ROUGH VACCUM STAGE

TWO STAGE SLIDING VANE ROTARY PUMP

Rotary vane pumps consist of a cylindrical housing (stator) (1) in which rotates in the direction of the arrow an eccentrically mounted, slotted rotor (2). The rotor contains vanes (16) which are forced apart usually by centrifugal force, and in some models by springs. These vanes slide along the stator walls and thereby push forward the air drawn in at the inlet (4) to eject it finally through the oil above the outlet discharge valve (12).

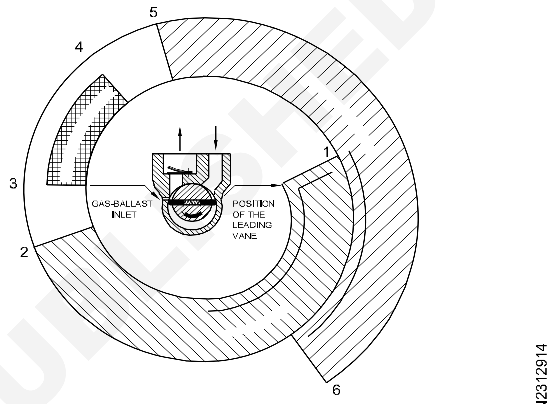
The oil charge of the rotary vane pump, but also of other types of oil-sealed positive displacement pumps, serves as lubrication and sealing medium, fills the dead space and any gaps and adds to the cooling of the pump by conducting the compression heat.

Lower working and ultimate pressures are produced by two-stage rotary vane pumps than with single-stage oil-sealed pump the oil is bound to come in contact with the outer atmosphere, where it adsorbs gas which in the course of the oil circulation partly escapes into the vacuum side of the pump and thus limits the obtainable ultimate pressure. In the two-stage oil-sealed displacement pumps produced by LEYBOLD-HERAEUS already predegassed oil arrives at the “vacuum” stage of the pump, i.e., stage 1. Consequently the ultimate pressure is already in the high vacuum pressure range, whilst the lowest working pressure is about at the lower limit of the medium vacuum pressure range.

Supply of very little oil or no oil at all to the “vacuum” stage (stage 1) in order to achieve an even lower ultimate pressure can lead in actual practice to great difficulties and affects the reliability of operation of such pumps considerably.

Gas ballast (Fig 4)

Fig 4



WORKING PROCESS OF A ROTARY VANE PUMP WITH GAS-BALLAST DEVICE

The use of a gas-ballast device with rotary vane, rotary piston and trochoid pumps enables not only permanent gases but also large quantities of condensable vapours to be pumped. The gas-ballast device inhibits condensation of vapours in the working chamber of the pump.

If vapours are pumped, they can only be compressed to their saturation vapour pressure at the temperature of the pump; if for example, only water vapour is pumped at a pump temperature of 70^{o}C, it can only be compressed to 312 millibar (saturation vapour pressure of water at 70^{o}C. On further compression, the water vapour condenses without increase of its pressure. An over-pressure is not obtained in the pump so the outlet discharge valve is not opened, rather the water vapour remains as water in the pump and emulsifies with the pump oil. As a result, the lubricating properties of the pump oil deteriorate very quickly - indeed, the pump can, it too much water has been taken up, even seize up.

The gas ballets device developed in 1935by Geode prevents possible condensation of the water vapour in the pump by the following significant measures.

Before the actual compression action begins in the working space in exactly regulated quantity of air (“the gas ballets”) is let in, namely, just so much, that the compression ratio in the pump is decreased to a maximum of 10:1. Now the pumped vapours can be compressed with the gas ballast before their condensation point is attained and ejected out of the pump. The partial pressure of the pumped vapours, however, should not exceed a certain value; it must be so low bat with a compression by the factor 10. The vapours cannot condense at the working temperature of the pump. In the case of the pumping of water vapour only, this critical value is known as the (maximum) water vapour tolerance.

This is schematically illustrated the pumping process in a rotary vans pump with and without gas ballast device during pumping of condensable vapours.

Without gas ballast

1) The pump is connected to the vessel which is already almost empty of air (approx. 70 mbar). It must therefore transport mostly vapour particles. It works without gas ballast.
2) The pump chamber is separated from the vessel. Compression begins.
3) The content of the pump chamber is already so far compressed that the vapour condenses to form droplets. Over pressure is not yet reached.
4) The residual air only now produces the required over pressure and opens the discharge outlet valve. But the vapour has already condensed and the droplets are precipitated in the pump.

With gas ballast

1) The pump is connected to the vessel which is already almost empty of air (about 70 m bar). It must therefore transport mostly vapour particles.
2) The pump chamber is separated from the vessel. Now the gas-ballast valve opens, through which the pump chamber is filled with additional air from outside. This additional air is called “gas ballast”.
3) The discharged outlet valve is pressed open; particles of vapour and gas are pushed out. The over pressure required for this to occur is reached very early because of the supplementary gas-ballast air, as at the beginning of the whole pumping process. Condensation cannot occur.
4) The pump discharges further air and vapour.

Pressure, Compound and Vacuum Gauges

Pressure Gauges

Read pressures above atmospheric pressure and calibrated in lbs/sq.inch or kg/cm^2, are of Bounden or Bellows type. Gauges used in refrigeration also indicate the saturation temperatures for the particular refrigerant used in ^{O}F or ^{O}C.

Compound Gauges: Read pressures above atmospheric pressure and also read pressures below atmosphere. Calibrated in lbs/sq inch for pressures above atmospheric and 0 to -30" Hg for pressures below atmospheric.

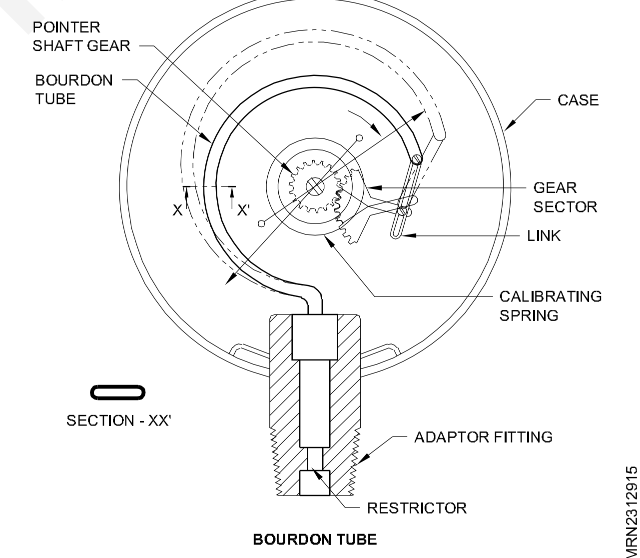
Vacuum Gauges

1. Read only the pressures below atmospheric i.e., vacuum dual type gauges, Bourdon type or Bellow type are calibrated in 0 to -30" Hg, or 0 to -760 mm Hg, or 760 mm - 0 mm Hg (Torr gauges) or 1000 to 0 millibars (millibar gauges).
2. More accurate vacuum gauges that specifically read deep vacuum are :
   a Thermocouple and Pirani gauges that read vacuum from 1000 microns to 0 microns.
   b McLeod gauges that are like Manometers.

Attached are information sheets on the various types of gauges ranging from Dual type Bourdon pressure and compound gauges, vacuum gauges to thermocouple and Pirani type vacuum gauges. Also included is a sketch showing how a thermocouple type vacuum gauge has to be connected to a refrigeration system to read the vacuum.

Attached below is a view of the Bourdon tube operating element in a gauge (Fig 5). The Bourdon tube is a flattened metal tube (usually a copper alloy) sealed at one end and curved and soldered to the gauge fitting at the other end. A pressure rise in a Bourdon tube tends to make it straighten. This movement will pull on the link, which will turn the gear sector counterclockwise. The pointer shaft will now move clockwise to move the needle. On a decrease in pressure, the Bourdon tube moves towards its original (clockwise) position and the points moves counterclockwise to indicate a decrease in pressure.

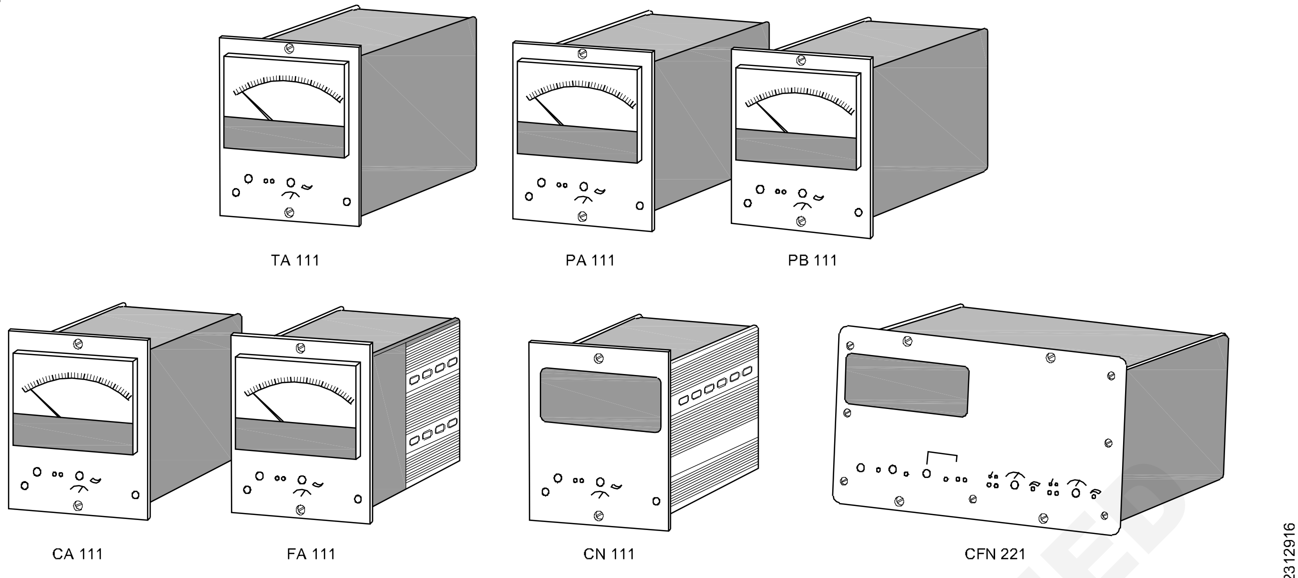
Fig 5



Electronic Pressure Gauges (Fig 6)

Thermal pressure gauges (Thermocouple, Penning, convection): Electronic pressure gauges known as “thermal” gauges work on the following principle: a filament placed in a given atmosphere is heated using the Joule effect. Its equilibrium temperature depends on the heat it exchanges with its environment. The quantity of heat exchanged by convection varies with the pressure.

Fig 6



ELECTRONIC PRESSURE GAUGES

This technique is the commonly used for measuring pressures above 10^{-4} mbar/Torr.

Electronic pressure gauges

Thermocouple : TA 111

Thermocouple pressure gauges are part of the thermal pressure gauge family. They measure the thermal conductivity of the gas, which is a function of its pressure. A thermocouple is soldered to a spiral filament which is heated by a constant current. When the pressure decreases, the heat exchange decreases which causes the thermocouple's temperature to rise and the transmitted voltage to rise. This voltage represents the pressure measured.

Charging refrigerant in a system

Refrigerant charge quantity

Every mechanical refrigeration system that is opened for repair/service has to be charged before returning to operation. The unit's name plate normally shows the weight of refrigerant that should be charged.

Charging by liquid or vapour

1 Either liquid or vapour can be charged into the high side of the system.

2 Only vapour should be charged into the low side of the system with compressor OFF or ON.

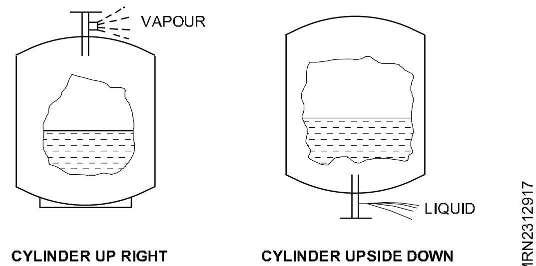
3 When charging zeotropic blends like HC290/HC600a or R407C, they should be drawn out of the cylinder as a liquid and then charged into a vapour by use of a calibrated restrictor device of the appropriate capacity.

4 To get liquid or vapour out of a cylinder depends on how the cylinder is stood. If the cylinder is kept upside down and the system is charged, then saturated liquid refrigerant will be introduced in the system.

5 Vapour charging

Normally the refrigeration unit system has to be completely evacuated and dehydrated before charging. The refrigerant cylinder if kept upright will provide only vapour. However if kept upside down it will provide liquid which will have to be converted to a vapour by throttling. The required weight of refrigerant is released into the low side of the system. If the required weight or full charge does not enter the system, the system's compressor can be started to complete the charging procedure.

Fig 7



6 Liquid charging

This is much faster than vapour charging as the density of liquid is much higher. It is normally resorted to, in big systems where the charge is quite high and vapour charging would be too slow a process.

Liquid charging is always done on the high side of the system with the compressor 'OFF' and the refrigerant cylinder upside down. It is safest on systems that have a liquid charging valve or 'King valve' between condensing and metering device.

When the conditions are right the entire charge may be introduced this way. If the entire charge does not go in, close the high pressure and cylinder valves and stop the flow of refrigerant. Then set the refrigerant cylinder upright and introduce the remaining vapour into the low side with the system compressor running.

(a) Charging Accurately

Most problems that occur in RAC are the result of over or under charging. Both are serious errors and should be avoided using accurate charging methods. Effects of under and over charging are

Under charge	Over charge
Low, low side pressure	High, High side pressure
High superheat	High discharge gas temperature
over heated compressor motor	Flood back of liquid
Low system capacity	Low system capacity
Poor efficiency	Poor efficiency
Sludge / carbonization	Sludge / carbonization

Refrigerant Charging

Charging with a charging cylinder

An accurate method of charging small amounts of refrigerant is to use a charging cylinder, sometimes called a dial-a-charge. It works well for fully charging systems that hold up to a few pounds of refrigerant.

The charging cylinder allows the level of refrigerant to be viewed in the charging cylinder. Graduations on the cylinder permit the correct amount to be introduced. Avoid venting the cylinder to the atmosphere.

Charging by weight

Installing the full charge in a system that is too large for the charging cylinder is best done by weight. An accurate refrigerant charging scale is recommended. A battery-operated electronic model is preferred.

Charge accuracy should be within 1% of the design total system charge. For that reason, the scale must be matched to the system size. A scale for small systems - those that have 5 pounds of refrigerant or less - must be accurate to a fraction of an ounce. Larger systems can be charged accurately with a scale that is accurate to the nearest ounce. Systems of 50 tons or larger capacity can be accurately charged with a scale that reads to the nearest pound. Never use bathroom or produce scales for refrigerant charring. They are too inaccurate.

Before charging a system, record the beginning refrigerant cylinder weight (9190 lbs), then calculate and record the desired, final weight (150 lbs). Charging is complete when the desired weight is achieved.

Some electronic refrigerant scales do the calculating for you, so that you can read directly the amount of charge that has entered the system. Some can be set to automatically dispense a preset amount of refrigerant and turn off when that amount has entered the system.

Be careful to prevent the gauge manifold and its hoses from changing position and effecting the charge. If they do, a false weight indication may result.

(f) Other methods of charging

(i) Use of manufacturer's charging charts

The manufacturer of equipment which has a factory filled charge provides a chart which correlates outdoor dry bulb temperature, indoor air wet bulb temperature and the temperature of a refrigerant line as well as refrigerant pressures. With this information, the chart or calculator is read to determine the need for charge adjustment. A typical chart is shown below. Sometimes manufacturers also provide the suction superheat for different load conditions. For TXV fitted equipment, the sub-cooling for different loads will be prescribed by the manufacturers.

(ii) Charging by sight glass

If a sight glass is used in the liquid line it can be used to determine when charging is completed. When the system is only partly charged, bubbles of refrigerant gas can be observed in the sight glass. Charging is continued until the bubbles disappear and saturated liquid refrigerant is seen in the sight glass. This is a rough method of charging and is not recommended if better methods described above are available.

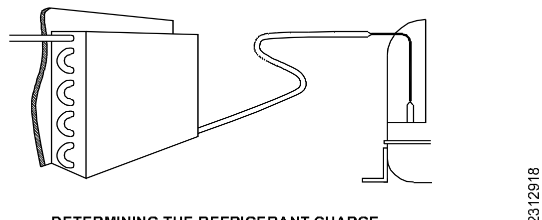
(b) Charging refrigerant using front line method

This again, is a rough way of charging refrigerant in small hermetic system using capillary tubes. When a system of this type is operated without evaporator load, the back pressures will normally drop below freezing point and frost will form on the coil. In the diagram below, evaporator load has been removed by placing a piece of cardboard over the coil face thus shutting off air flow. Refrigerant will not evaporate rapidly and some will pass through evaporator and evaporate in the suction line. Tests have shown that under these conditions a properly charged. Unit will normally frost to within a few inches of the compressor. By factory testing , the manufacturer can provide this final frost point to the installer/ serviceman. By recreating the frost line on the suction line, the installer can determine the proper charge.

If the frost line does not reach the point designated by the factory, refrigerant should be added and vice versa. Refrigerant should be removed if the frost goes beyond the designated point.

If the frost line does not reach the point designated by the factory, refrigerant should be added and vice versa. Refrigerant should be removed if the frost goes beyond the designated point.

Fig 8

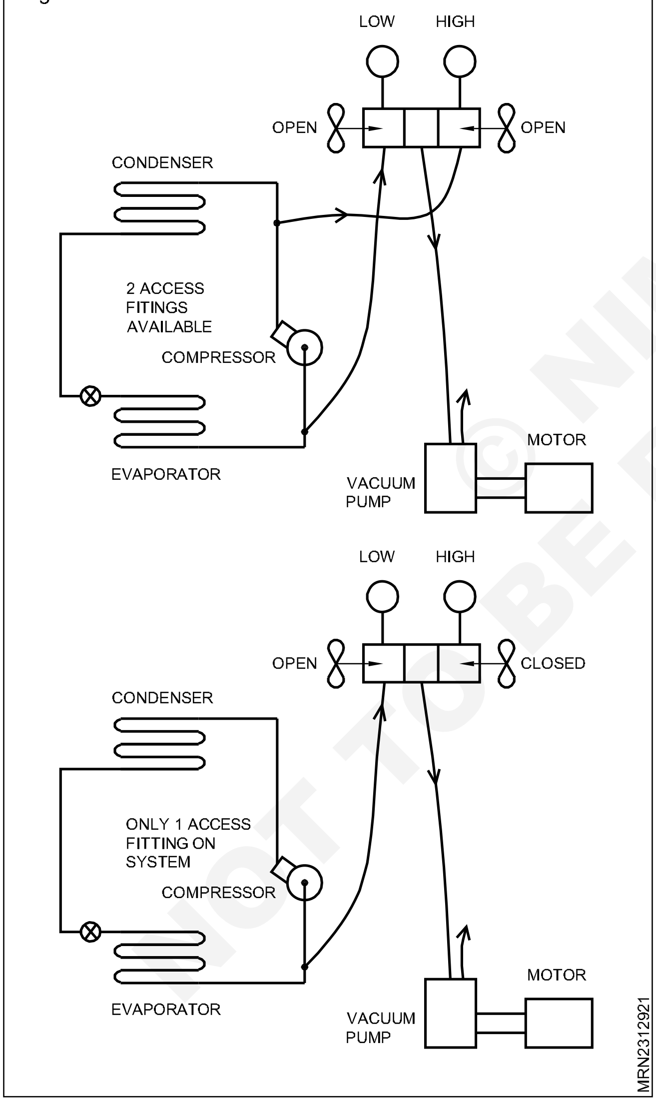


DETERMINING THE REFRIGERANT CHARGE FROM THE POSITION OF THE FROST LINE

Refrigerant leak detection methods

Objectives: At the end of this lesson you shall be able to
- **explain about evacuating the system**
- **checking for leaks after reassembly**
- **checking for leaks - pressure method**
- **checking for leaks - vacuum method**
- **state how to find leaks in operating systems.**

Fig 1



Checking for leaks after reassembly

Whenever a system has been opened and reassembled, the work that you did in reassembling the unit must be leak tested. Before you evacuate and recharge the system, pressurize the system with the compressor not running. Ten to fifteen psi of pressure should be sufficient. Use the refrigerant that you will use when charging the system. If the system is large, you may want to use nitrogen or compressed air in order to save the expense of the refrigerant that will bled off to atmosphere.

Using a soap and water solution, carefully check each connection. An effective way to test the joint is to hold the dauber on the pipe to form a little puddle, then move the puddle slowly around the joint. Work slowly, carefully, and thoroughly. A couple of minute saved in haste can cost a call back and a complete new refrigerant charge. If there are places that you can not see, use a mirror places behind the connection.

Leaking mechanical connections (flare or compression fittings) may be tightened with the pressure in the system. Leaking brazed connections require that the pressure be bled from the system and the joint repaired. Following the repair, repeat the leak test until you have found that each of the joints you have made is leak tight. If there had been no indication of refrigerant leakage prior to your servicing the unit, the rest of the connections in the system are presumed to be all right.

Checking for leaks: Pressure method

The leak-check method described previously will always work, assuming that the leaking joint is accessible and that every suspicious point in the system is checked. Unfortunately, this is not always possible. In order to prove that the entire system is leak tight without checking every inch of it, we can use either a pressure test or a vacuum test.

In order to run the pressure test, the entire system is pressurized to 20 to 30 psi with refrigerant, air, or nitrogen. The system is allowed to sit undisturbed for 30 min to 1 hour, depending on the physical size of the system, with the manifold gauges attached. There should be zero loss in pressure noted on the manifold gauges. Even the slightest drop in pressure indicates a leak that will, over a period of time, render the system inoperative.

There is one trap to avoid in running the pressure test. If there is only a low-side pressure fitting, then only the low-side may be pressurized from the refrigerant can. Even if there are no leaks in the system, it may appear that you have a leak. You must therefore allow the pressures to equalize before you can be sure of leaks. The pressure in the low-side will leak into the high-side will leak into the high through the compressor valves and the metering device. If it is a cap tube system, this may not take very long. If it is a TXV system, it may take an hour or more until the high and low-side pressures have equalized.

If there are both high and low-side access fittings, turn off the valve on the refrigerant can after the system is pressurized, and open both valves on the manifold gauges for a few seconds. This will allow any difference between the high and low-side pressures to equalize through the manifold before starting the test. Then any drop in pressure will indicate a leak to atmosphere and not an internal leakage from one section of the system to the other.

The pressure test is useful to prove that your system is leak tight, but it is of no value in helping you pinpoint the location of any leaks.

Checking for leaks: Vacuum method

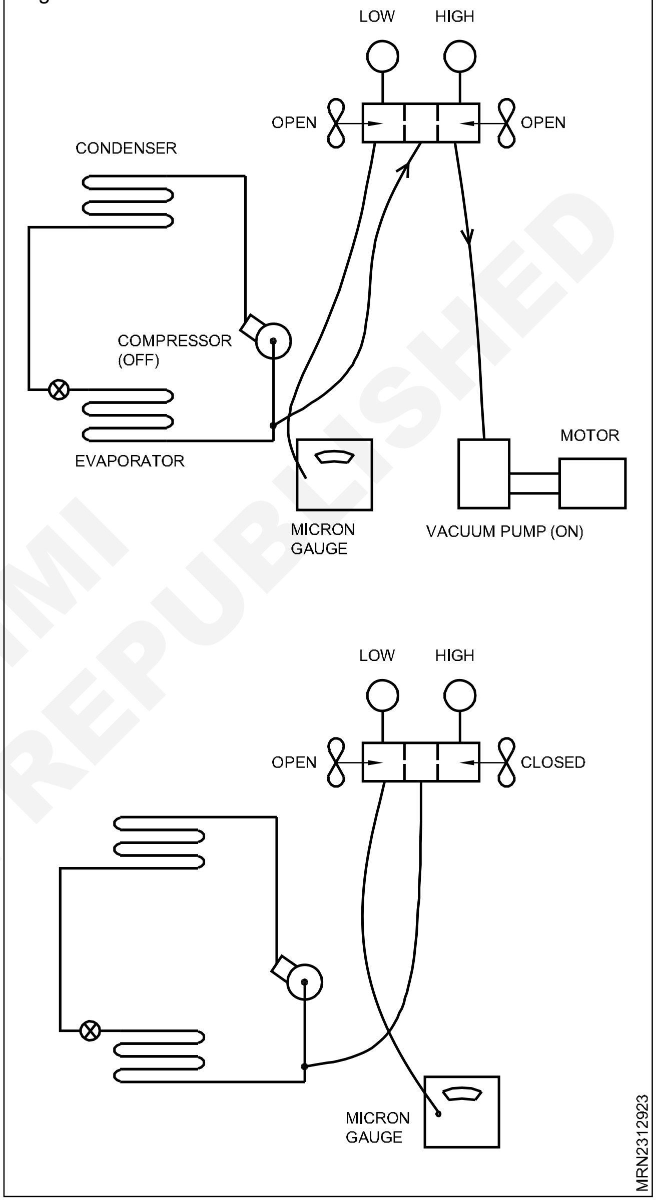
The vacuum method of checking for leaks is similar to the pressure method. Instead of pressurizing the system to higher than atmosphere pressure, we pull a vacuum of 30 in Hg. Any leakage of air into the system will cause a loss in vacuum. The maximum pressure difference we can create with this method is 14.7 psi between atmosphere and the system, with the vacuum test, however we have a tool available to us that is far more sensitive than the manifold gauges in sensing a change it pressure (vacuum) (Fig 2) shows the hook up for a micro gauge. A micron is a unit of length equal to a millionth of a meter. The micron gauge spreads the vacuum scale between 29 in Hg and 30 in. Hg into 25.400 microns, so it can easily detect even the smallest change in vacuum because of leakage.

With the micron test, you can be fooled into thinking there is a leak if there is moisture in the system. under the deep vacuum of the test, moisture that may be being held in a filter dryer or dissolved in the oil will vaporize, causing the same loss of vacuum as would be caused by a leak. Therefore, allow the micron gauge test to continue for 10 or 15 min to determine if the pressure increase stops (moisture) or if it continues its rise (indicating a leak).

As with the pressure method, this test can only tell you if the system is tight. If there is a (Fig 3) method evacuating the system and testing for leaks with a micron gauge. Note that the high-side valve must be closed before turning off the vacuum pump.

Leak, other tests must be used to locate the source of the leak.

Fig 2



Recovery of refrigerants

Objectives: At the end of this lesson you shall be able to
- **explain the purpose of using a piercing valve**
- **describe different types of piercing valves**
- **state the reasons for recovery of refrigerants**
- **state the meaning and differences between recovery, recycling and reclamation**
- **explain the construction and working of recovery machines.**

Purpose of using piercing valve

Piercing valves are used to tap a line for recovery, testing or charging hermetically sealed system. Typically it is installed on a refrigeration line for the sake of recovering charge to service a system. It can also be used to connect the gauges for reading pressures.

How does it operate

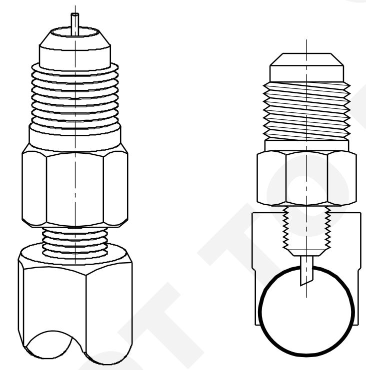
Piercing valves are clamped to refrigeration tubing, sealed by a bushing gasket and pierce the tube with a tapered needle. The sharp needle, part of the valve assembly pierces the tubing when the nut on the valve is tightened to allow access to the system. Some piercing valves provide access to the system by a Schrader Valve Service Port. Others provide access to the system by back seating a movable valve stem.

Line piercing access

Copper Saddle

Braze/Tapper (Fig 1)

Fig 1



Quick clean access to systems under pressure.

Eight body sizes contoured to match specific tube size. Hardened steel piercing needle. Furnished with cap. Core pre-torqued at 2.9-2.96 in lb.

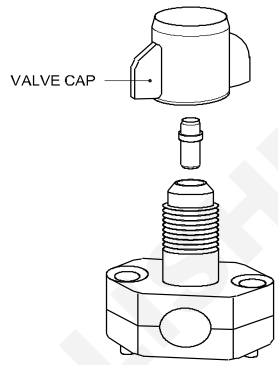
Sizes Available - 1/4", 5/16", 3/8", 1/2", 5/8", 3/4", 7/8", 1-1/8" (6, 8, 10, 12, 16, 20, 22, 28 mm)

O-Ring Seal

Line Piercing (Fig 2)

Spring loaded needle automatically back-seats forming a leak proof seat. 100% restriction free. Simple installation.

Fig 2



Two models fit ¼”, 5/16", 3/8", ½” and 5/8" OD tubing.

Available sizes

Description

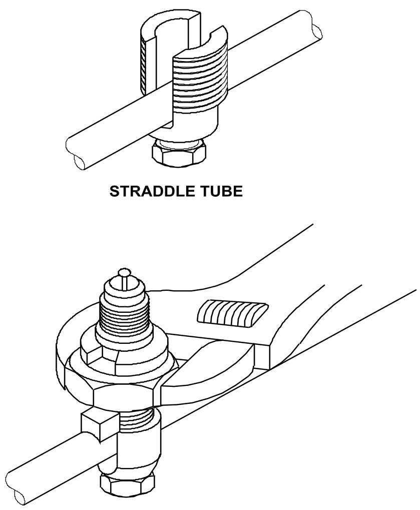
1/4" - 3/8" - Line Piercing Valve

1/2" & 5/8" - Line Piercing Valve

Service or Control

E-Z Tapper (Fig 3)

Fig 3



Use on Water and Refrigerant Lines

Eliminate line restriction by back seating stem when servicing through access port or use valve for flow control. To add branch connection, close valve and remove valve core. Stainless steel piercing needle.

Valve fits 3/16" thru 3/8" and their metric equivalent OD tube sizes. Self-aligns on tube. Valve core for built-in flow check. Furnished with cap.

Reasons for Recovering Refrigerants

Refrigerants like CFCs & HCFGs cannot be vented into the atmosphere as they cause ozone depletion in the Stratosphere and also contribute to Global warming. HFC refrigerants also should not be vented because of their Global warming potential.

The ozone depletion potential of a refrigerant or compound “x” is the ratio of ozone destroyed by a fixed amount of compound “x” to the amount of ozone destroyed by the same mass of CFC-11.

$$ODP_x = \frac{\text{Global loss of ozone due to x}}{\text{Global loss of ozone due to CFC} - 11}$$

Thus ODP of CFC-11 is 1.00 by definition.

The Global Warming Potential of a compound (Green House Gas) and known as GWP, is the ratio of Global warming from one unit mass of Green House Gas to that of one unit of unit mass of CO_2 over a period of time (100 years). CFCs, HCFCs & HFCs are all considered Green House Gases.

Given below are the ODP and GWP of commonly used refrigerants.

Refrigerant	ODP	GWP
R-11 (CFC)	1.00	3800
R-12 (CFC)	1.00	8100
R-22 (HCFC)	0.05	1700
R-134a (HFC)	0.00	1300
R-290 (H.C.)	0.00	3
R-600a (HC)	0.00	3

Definitions

Recover: To remove refrigerant in any condition from an appliance and store in an external container without necessarily testing/processing many in any way.

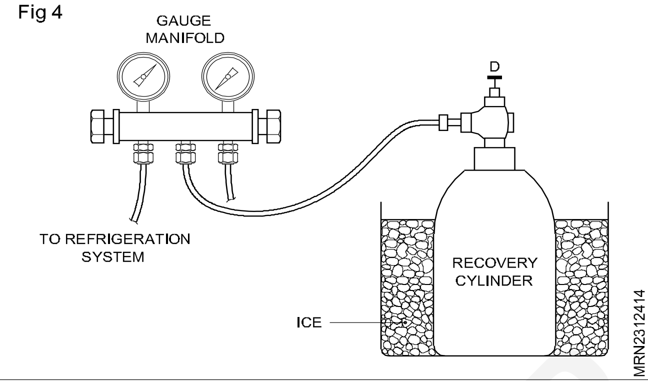
Recycle: To extract refrigerant from an appliance and clean the refrigerant for reuse without melting meeting the purity of the original refrigerant supplied by the refrigerant gas manufacturers. Recycling normally means to reduce contaminants in used refrigerants by cleaning, using an oil separation process and by single or multiple passes through devices which reduce moisture, acidity and particulate matter, like replaceable core filter drier.

Reclaim: To reprocess used refrigerant to a purity equivalent to new product (gas) specifications which may be achieved through distillation etc.

Methods of Recovery

I. Passive methods (No external recovery machines used) (Fig 4)

Fig 4



(a) Charge migration

(i) Movement of refrigerant takes place due to natural difference in pressure between system and recovery cylinder.

(ii) The process can be speeded up by

(a) Evacuating the recovery cylinder.

(b) Place recovery cylinder in ice bath.

(c) Supply heat to the system.

(b) Use of System’s Compression Compressor

The hook-up will be the same as in the previous diagram for charge migration but the high side of the manifold will be connected to the system’s high side. The system’s compressor is used to pump out the refrigerant either as a vapour if service valves are used on compressors or as a liquid from the condenser exit. When the refrigerant is pumped out as a vapour the refrigerant will condense in the recovery cylinder which is kept at a low temperature in a bucket of ice.

The system’s compressor should not run below O psig (i.e. Atmosphere pressure) to prevent damage to it. Even though most of the refrigerant is recovered in this way, the system still contains significant charge. An additional method will be needed to recover the remaining refrigerant. For effective recovery of refrigerants like R-12, R-22 the system compressor has to work below atmospheric pressure and this may damage hermetic compressors that rely on refrigerant vapour to cool the motor windings. Hence special ‘recovery units’ are needed to extract a high percentage of refrigerant.

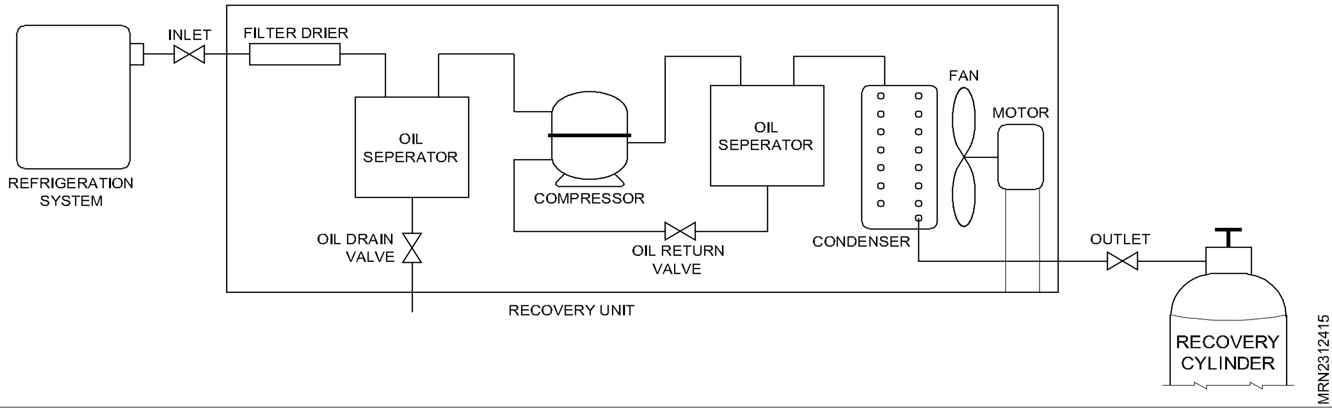
II. Active Methods of Recovery

Recovery Machines (Fig 5)

(a) Vapour Recovery

Refrigerant is usually recovered as a vapour from the system by the recovery machine which usually has a compressor (can handle only vapour). The discharge vapour from the compressor flows to a condenser where the refrigerant condenses and moves to the recovery cylinder for storage.

Fig 5



A simple layout of a recovery machine is described in the sketch below.

The above diagram of a recovery unit shows :

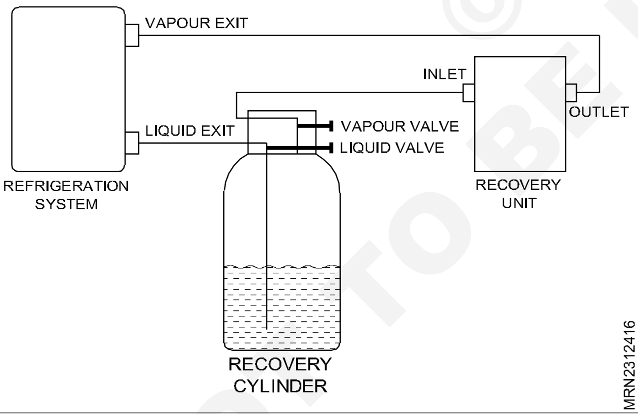
(a) The vapour from the refrigeration system is sucked by the recovery unit's compressor through a drier and an oil separator. Separated oil is withdrawn from the bottom.

(b) The compressed vapour then passes through a second oil separator, where the compressor's oil is separated and returned to the compressor through a solenoid valve.

(c) The compressed vapour then passes through a fan cooled condenser and the condensed liquid into the recovery cylinder.

(b) Vapour & Liquid Recovery (Push-Pull) (Fig 6)

Fig 6



Liquid Recovery

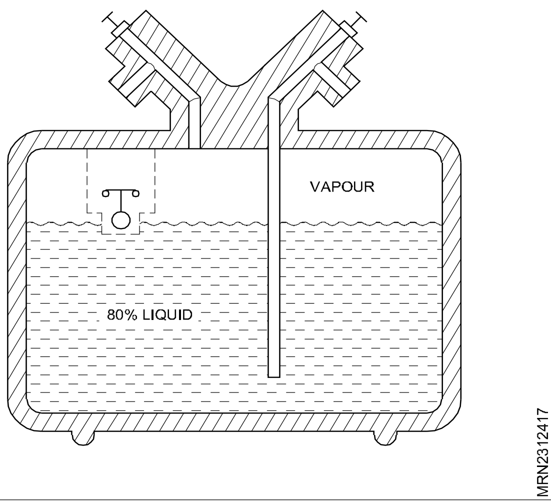
Liquid recovery increases the speed of recovery and puts less strain on the recovery unit. In little bigger systems, a common method called 'Push-Pull' liquid recovery method is used.

1. The intake of the recovery machine is connected to the vapour fitting on the recovery cylinder.
2. The outlet of the recovery machine is connected to the vapour connection of refrigeration system.
3. Thus the recovery unit's compressor discharge, by passes the condenser and pumps high pressure vapours into the refrigeration system's vapour port.
4. The pressure in the refrigeration system thus builds up and forces the liquid (from liquid outlet valve of refrigeration system) into the recovery cylinder.
5. For this, special recovery cylinder having liquid and vapour valves are required.
6. After the liquid has been recovered the recovery machine is then used as a conventional vapour recovery machine described under 'vapour recovery' i.e. (a).

This method can be used only for refrigeration systems that have separate outlets for liquid (King valve on Receiver) and vapour.

Special Recovery Cylinders (Fig 7)

Fig 7



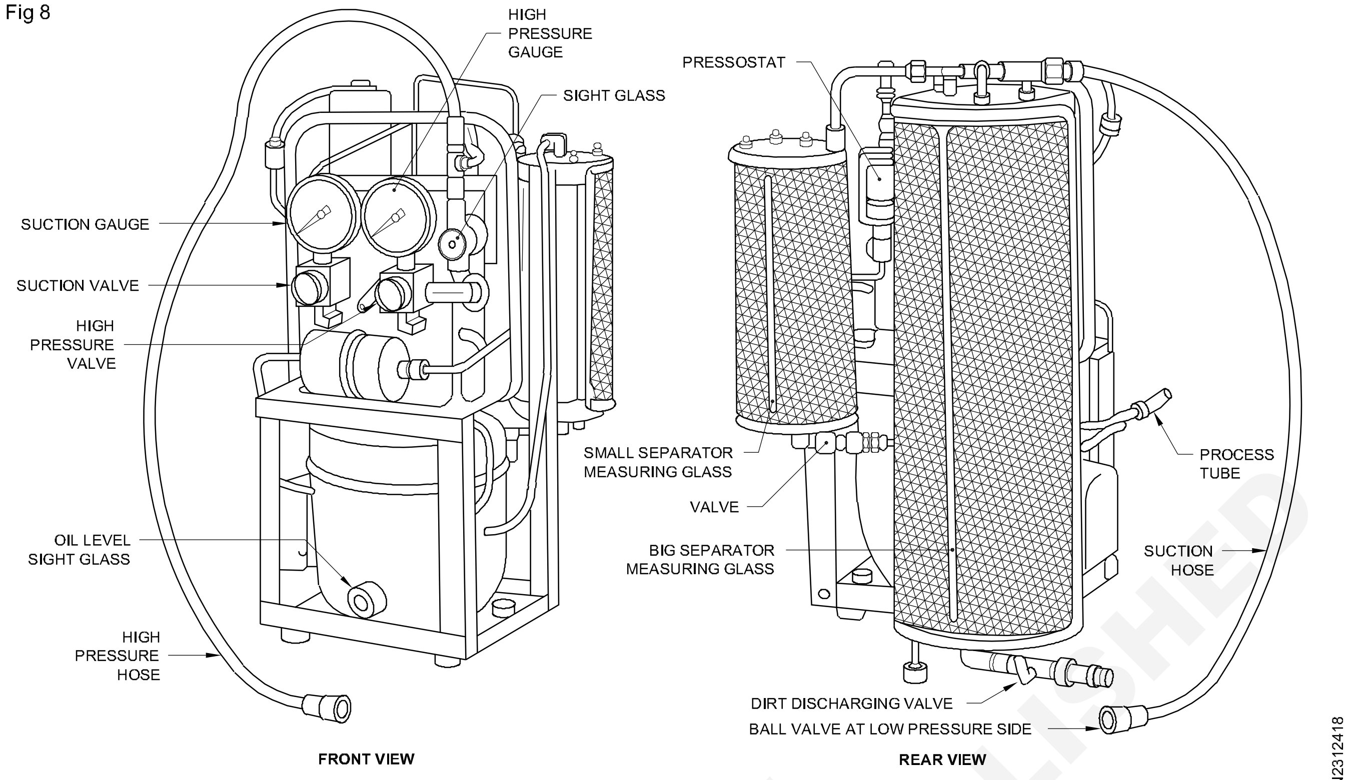
Special recovery cylinder with float switch which will stop the recovery unit when liquid level exceeds 80% of the volume.

Recovery & Recycling Machines (Figs 8 & 9)

See overleaf, the following :

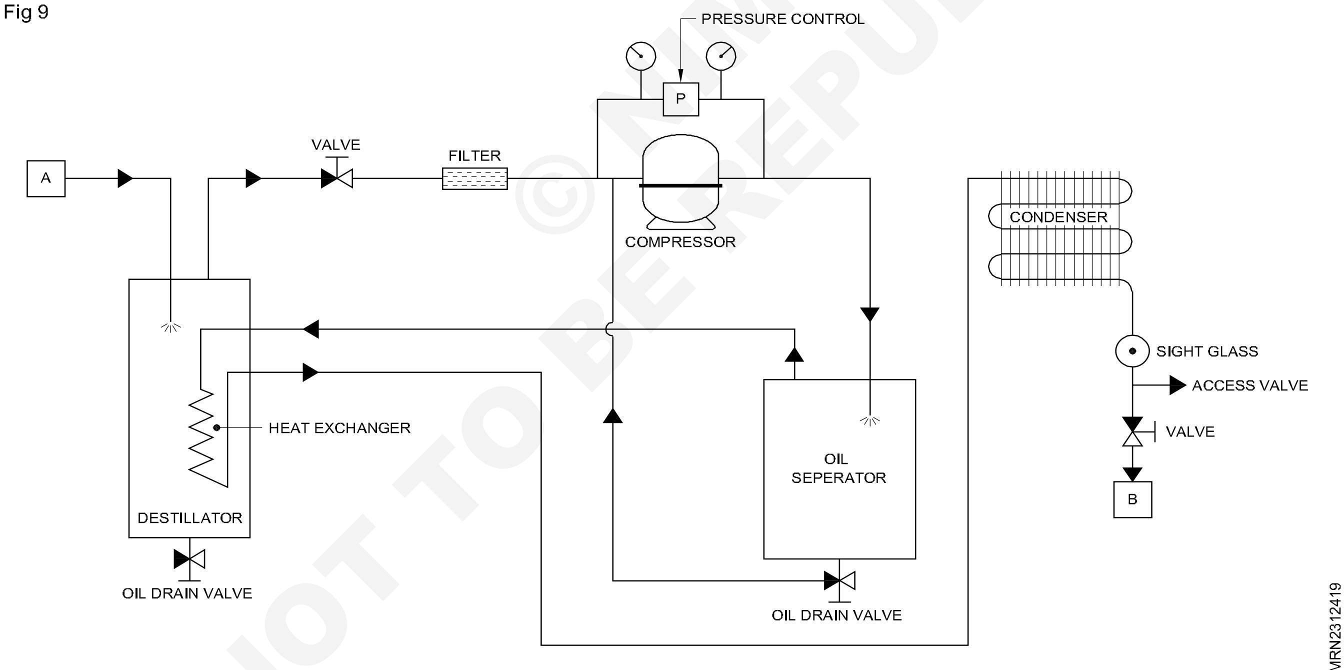
1) Schematic diagram of a single pass recovery and recycling machine.
2) Schematic of a multipass recovery and recycling machine.

Fig 8



RECOVERY AND RECYCLING UNIT

Fig 9



Recycling sequence (Fig 10): This process removes moisture, air, and the remaining acid from the refrigerant. The liquid pump, magnetically coupled to prevent leakage and reduce heat generation, circulates the refrigerant through a filter-drier unit. This recycling process is repeated until the refrigerant is clean, dry and for reuse. The air purge indicator detects pressure differences created by the presence of air in the tank. The air is purged manually.

Oil less Refrigerant Recovery Unit (Fig 11)

Features

- Pumps liquid direct
- Patented pump out feature
- 1/2 H.P. oil-less compressor
- Electrical cord wrap
- EPA and ARI certified (pending)
- R410A compatible
- Easy to use
- Attractive compact design
- Portable/light weight
- Quiet operation

Fig 10

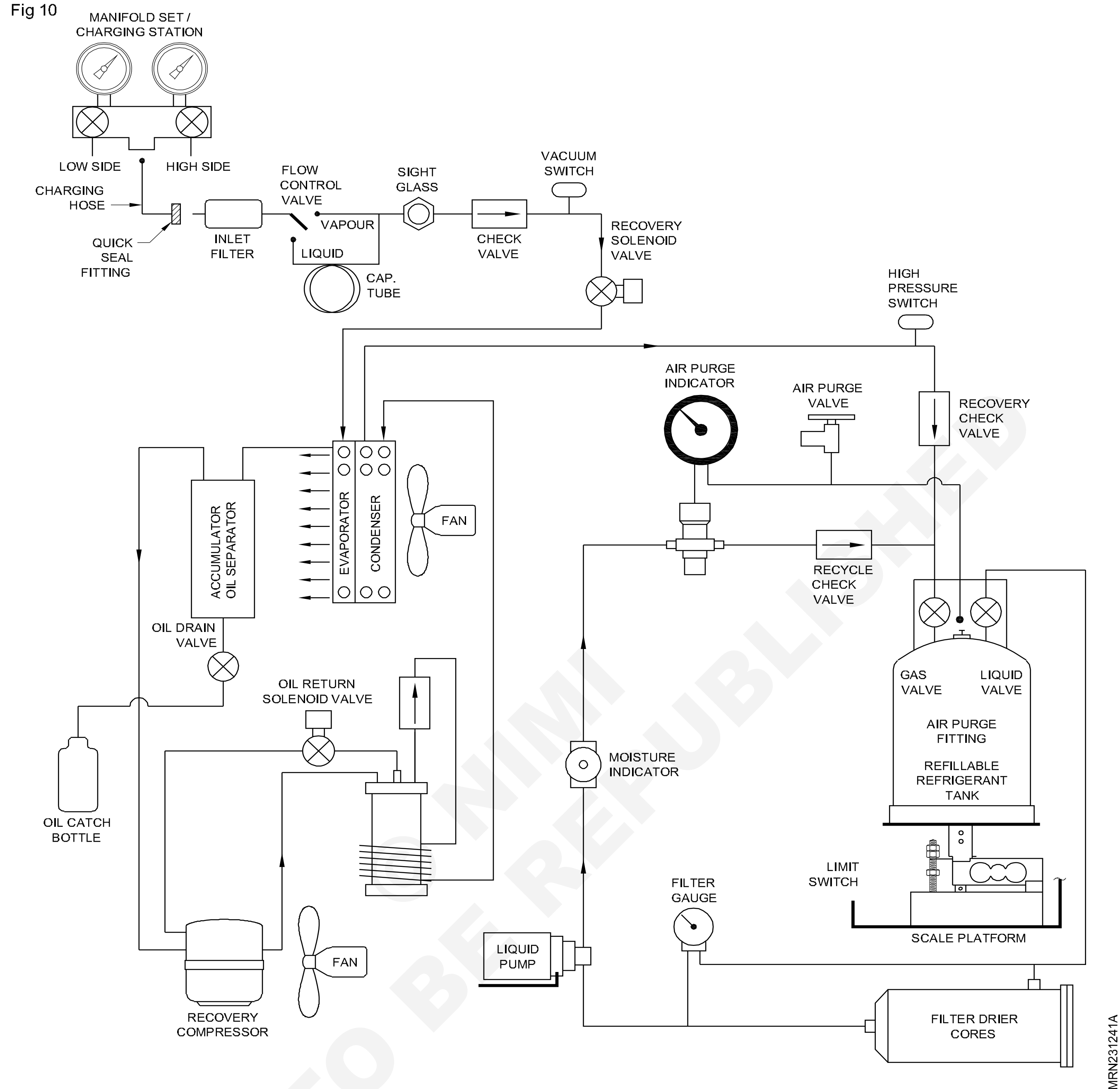
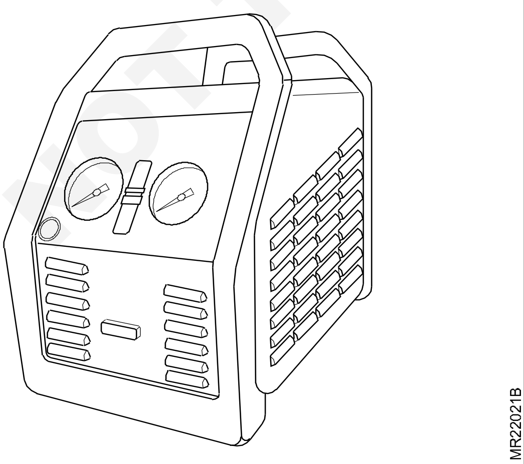


Fig 11



Applications

- Commercial A/C
- Commercial Refrigeration
- Roof top units
- Ice machines
- Residential A/C
- Appliances

Power : 8A, 115V, 60Hz, 1PH

Weight : 35 lbs

Dimensions : 15" H x 10 1/2" W x 18" D

Available : 4A, 220V, 50Hz, 1PH

	Direct liquid refrigerant	**Push/Pull liquid refrigerant rates (lbs/min.)**	**Vapour refrigerant recovery rates (lbs/min.)**	**Shut off vacuum**
GS 2000	upto 3.75 lbs/min.	upto 10 lbs/min.	upto 0.33 lbs/min.	20°

Retrofit CFC filled domestic Refrigerator with HFC's

Objective: At the end of this lesson you shall be able to
• explain retrofit CFC filled bottle cooler with HFC -134a refrigerant.

Retrofitting of CFC filled bottle with the HFC 134a refrigerant

Retrofit is a process where a defective CFC system can be changed to HFC 134a charged system by converting mechanical fitting and taking precautionary steps.

Retrofit CFC appliances to HFC not advised, due to high cost involving most of the component replacement. First access the refrigerator to be retrofitted with HFCs. If the present CFC filled system is in good condition. No need to retrofit from CFC to HFC refrigerant.

And if the bottle cooler has problem where the sealed unit has to be opened (in case of shortage of gas, gas leaks, filter drivers blocked). The following procedures and precaution has to be taken.

The equipment used such as vacuum pump, recovery machine has to be independent (separate equipment such as vacuum pump and recovery machine has to be allotted for HFCs unit). The hoses and tools used for charging and oil charging should be separate for HFCs unit. Since these tools get cross contaminated if used with other unit using CFC's or HCs. Also oil used in HFCs are hygroscopic (High moisture absorbent). Hence a strict vigil and concentration to be taken while using the tools and equipment.

Now attach pierce valve to charge line and connect recovery machine to charge line and pump out the CFC-12 in the system.

Remove compressor (removing leg bolts, motor leads) by cut open copper tubes using tubing cutter. Also strip out condenser, capillary tube and the filter strainer. Immediately plug all the ends of copper tubing of the components and the system to avoid moisture entering the system.

And change with new compressor which has polyester oil lubricant and displacement of the compressor slightly large and inside the compressor. Some plastic materials which work well with HFC and POE oil.

Now flush evaporator, using dry nitrogen with sufficient pressure and plug the ends. Change with new condenser 20% extra larger and flush with dry nitrogen before connecting to system.

By using newly developed capillary cutter, cut new capillary tube, 20% larger than the existing size. Flush capillary with dry nitrogen and immediately connect to the system by brazing.

Here new filter driver is used (molecular sieve type) which has greater moisture absorbing potential and molecular sieve filter drivers does not get pondered as in the case of silica gel driers used in CFC-12.

Connect new filter to the system and braze all the joints and pressurize the system using dry nitrogen by giving sufficient pressure and check leak in the system using soap-solution. And make 100% sure that there is no leak in the system.

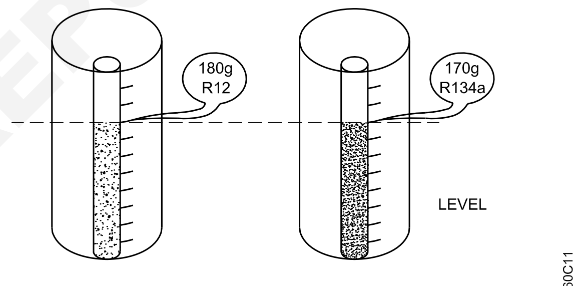
Evacuate the system using 2 stage rotary vacuum pump to an vacuum of 5 microns, break the vacuum to confirm the system holds the vacuum for 10 minutes.

Connect HFC 134a gas cylinder to the system with manifold valve purge air from all the hoses connected by opening HFC 134a gas partially. Now charge the system with HFC 134a and weigh the amount of gas charged by using electronic weighing machine.

The amount of HFC 134a charged is as follows. Charge approximately 95% of HFC 134a that is usually charged using CFC-12 refrigerant.

If CFC-12 charged 180 gms x 95% of CFC 134a = 170 grams charged HFC 134a (Refer Fig.1 showing charging cylinder calibration).

Fig 1



CHARGING CYLINDER CALIBRATION

The suction pressure should be around 14 psig and discharge at 200 psig. Disconnect hoses connected the charge line and by using pinch off pliers, crimp charge line at two places and seal the end of charge line by brazing.

Leak test the system using soap-solution and take care to clean all the joints checked for leaks, before commissioning refrigerator. Start the refrigerator, load it and run for some prescribed time until the desired cooling is attained. Label the bottle showing HFC 134a.

Thermal insulation material

Objectives: At the end of this lesson you shall be able to
- **describe insulating material**
- **state the property of insulation materials**
- **list the types of insulating materials**
- **explain the method of laying insulation**
- **describe the purpose of false ceiling.**

Insulating material

The material having extremely low thermal conductivities are called insulating material. The heat flow rates from the air-conditioned buildings (from building to outside for winter air-conditioning and from outside to building for summer air-conditioning) can be economic running of refrigerant plants as well as heating plants.

Insulating materials used for domestic refrigerants, cabinets, brine pipe lines, refrigerant pipe lines and cold storage rooms as well as insulating material used for steam carrying pipes, ducts carrying the hot air and for boilers are primarily selected for their ability to the flow of heat.

There are numerous kinds of insulating materials. Other factors that must be considered in their selection eliminate many insulators for specific applications. The selection of an insulating material for a particular purpose depends upon number of required properties of insulating materials. The selection is also done on the basis of economic and structural consideration.

Desired properties of an ideal insulating material

The required properties of an ideal insulating material are described as follows:

Low heat conductivity: The thermal conductivity must be as possible which will reduce required thickness of the insulating material. The conductivities of different insulating material are given in the appendix.

The resistance to components, resiliency, vibration and voting resistance of the insulating materials are also required properties for some applications.

Permanence: Material may disintegrate as a result of internal chemical activity or as a result of exposure to surrounding conditions. The insulating materials must have high resistance to the above mentioned activities.

Strength: The insulating materials used must withstand the pressures coming on some materials adopt themselves readily to various types of constructions. Structural strength is generally obtained by the use of wood or framework.

Light weight: This is necessary to avoid the use of heavy structural members. This becomes more important for refrigeration and air-conditioning systems used for moving vehicles as automobiles, railways, marine and aeroplane.

Water-Repellent: Moisture absorbed by the insulating material increases conductivity and reduces strength. Material that resists absorption either as free water or water vapour should be selected. Moisture absorbing insulation deteriorates rapidly due to growth of mould.

Sanitary: Materials that provide a medium for vermin infestation should be excluded as insulation. Insulators of vegetable origin are regarded as food for certain forms of vermin.

Odorless: it should not repel any type of objectionable odour when either wet or dry insulation materials derived from vegetable sources are always subject to decomposition over a period of time. Such materials may develop odours unless special consideration is given to the method of construction.

Fire-proof: This is an important factor when it is used for fire-proof warehouses.

Types of insulators made from natural materials

Cork-board: The bark from the trees is dried and pressed and baked at moderate temperature. During this process, the natural gum melts and spreads, binding together the entire mass. Thickness varies from 0.5 cm, to 1.5 cm. It is able to resist the flow of heat because it consists of homogeneous mass of small air-cells separated from one another by their one cell walls. Palco-bark is loose insulation made from bark of redwood and is similar to cork board in thermal properties.

Celotex: Celotex, a proprietary material, is an excellent example of a fireproof fibre wall board in which bagasse (sugarcane after juice is removed) is a principal ingredient. In the manufacture of celotex, the fibres are cooked to dissolve all soluble matter and then water proofing chemicals are added. The final product is an odourless light material.

Kapok: This is silky fibre found within seedpod of the ceiba tree. The slabs for household refrigerator requirements are made in various sizes depending on the type of cabinet. It is also used in loose form for different purposes. It is so light and fluffy that it settles only due to its weight.

Hair felts: This is high grade insulating material made from cattle hair which has been washed, cleaned and compressed into mat like sheets. Hair felt may be applied in the form of pads.

Insulating papers: although paper itself is an insulator, it is generally used to protect other insulating materials from moisture. The best insulating papers are those that have been coated with asphalt to give them greater durability and high resistance to moisture absorption.

85% magnesia: It is made from light carbonate of magnesia with approximately 15% asbestos fibre added to give strength. This material after being moulded and baked can be used at temperature up to 300°C. It is very commonly used in heating systems.

Wool type insulators: The wools, such as rock wool, mineral wool, glass wool and slag wool are all names given to insulating materials made by melting the principal element from which they are formed, such as rock, glass, slag and certain types of minerals and blown by air into fibrous form, after which they re usually ground. They are used either as fill in their loose form or mixed with binder to form wall boards.

Foils: Aluminium foil as an insulation has been used in refrigerated rail cars, refrigerated compartments on board ships, household cabinets and other applications where light weight is desired.

Special insulating materials: Many high quality insulating materials are developed during the last decade with extensive research work. Some of them are discussed here.

Silica Aerogal: When a silica aquagel is dried by heating at normal pressures, it shrinks to about one-fifth of the original volume and product is similar to well known silicagel. If the water in the aquagel is replaced with alcohol and resultant product is heated to the critical temperature of alcohol with a pressure in excess of critical pressure, shrinkage is eliminated and the product is left with a bulk density a about 90 kg/m3. The material consists of extremely fine pores of submicroscopic size and it has been calculated that the pore volume is approximately 94% of the total. This material has some interesting properties. It has lower K value than air lowest reported K value of any known material. The insulating value can be further reduced by the addition of powdered silica which retards the transmission of infra-red radiation through the silica aerogel. Presently, this material is available only in powdered form.

Foam glass: It is a trade name for a porous glass block insulation with sealed pores. It is suitable for the exterior wall and the floor or low temperature rooms on account of its structural strength.

Vermiculate: It is form of mica (aluminium, magnesium, silicate) that expands to many times its original volume when heated. After crushing and grading for size, the material is bagged and ready for pouring into place.

Fibre glass: It is found that the fibrous insulation materials are the most suitable and efficient ones among the wide range of insulation materials available all over the world.

Plastic forms: Foamed plastics are finding rapidly growing applications as thermal insulation for modern air-conditioned buildings. These materials are making inrods into conventional insulating methods, often despite higher cost for their light weight and outstanding insulating properties. Principle demand is for foamed polystyrenes and polyurethane's. However, foamed phenolices, vinyls and expoxides have recently entered into the field for a variety of special applications.

Polystyrene: Polystyrene foams can be supplied in nearly any desired shape for large production runs. Principally, the materials is available in the form of foamed sheet or pipe covering and is used thermal insulation is cold storage rooms, tanks and vessels.

Urethane: Rigid urethane foam is available as an industrial product since the middle 1950's. Present-day world consumption (as per 1978 report) is at the rate of 5,00,000 tons a year. The overwhelming bulk of this material is used for insulation. About 35% is used in refrigeration and 45% in building industry. It is known as super insulation in air-conditioning industry. Rigid urethane foam is increasingly specified for insulating pipes, ducts, walls, roofs, slab perimeters, basements and curtain walls in wide variety of new and existing structures. These materials are somewhat more expensive than polystyrene but because of economy of labour in their application, they are the predominant plastic foam used as thermal insulant.

Thermocole: It is one of the insulting materials in normal use. It is available in low and high density. This is available in various thicknesses ranging 0.25" to 5".

Thermocole is available in various shapes (moulded) of necessity.

Thermocole allows (Characteristically) low transmission of vapour, thereby heat entry through is cut short. This may vary with its low/high density.

It can be cut very easily even with knife to a required shape. Thermocole withstands cool/heat for a longer time.

The 'K' factor of an insulation material follows (thermocole).

Thermocole -0.20 btu/hr Ft2 deg.f°/inch

Fibre glass: Also one of the insulating materials used for its manufactured from inorganic materials (sand, dolomite, limestone). Glass fibre insulation does not shrink due to temperature variation.

This insulation materials used for higher temperatures also upto 450°C (842°C)

Fibre glass products does not absorb moisture from the ambient air.

Glass wool: Normally glass wool material is heavily thin weighted object in layers, soft (touching). It comes off in various sizes (thickness from 0.5" to 2.5". it comes in white, yellow colours mixed up with broken glass pieces.

Handling glass wool is hazardous and harmful (if it is breathed). Always it is advisable to handle glass wool with gloves and goggles (eye) while working on it. It also comes off in various densities.

Glass wools are of two types of uses. One type of glass wool used for low temperature refrigeration/air conditioning purpose. The other type is used for boiler materials (heat prevention) purposes.

The ‘K’ factor of insulation material:

Glasswool: 0.230-.27 Btu/Hr Ft2 deg. F°/inch.

Puff: The other mode of insulating materials used in water cooler at the evaporator tank’s external body.

For this kind of insulation two chemicals used namely ISO Cyanide-R11., Both available in liquid form in bottles (for lesser capacities) and cans (for higher capacities).

Both the liquids (chemicals) should always kept cool. When both of them added in a container and stirred in few minutes it becomes foamy (initially with thin and becomes thicker and becomes hard (sticks with the unit).

We should be careful that there is no air gap in the tank covered. It foams out with high density and uneven finish at the outer level.

Puff (materials) insulations are widely used by our manufacturer’s for their products as it keeps the temperature for a longer period.

The main disadvantage of the insulation is as soon as the chemicals are mixed and stirred it should be poured over the evaporator coil (or) outside the evaporator tank within the shortest period. If the time exceeds the solution starts framing at the container itself and becomes useless.

The evaporator tank should be covered well with wooden/steel boards with required gaps for insulation tightened all the corners well giving small gaps to pour the solution.

Method of laying duct insulation: when there is no chance of moisture condensation on the duct, glass wool can be used. Since it is economical and fire resistant. However if moisture condensation can occur greater care should be exercised in case of glass wool. First a uniform coat of bitumen is applied to the duct surface and the wool is stuck to the bitumen. The insulation is then covered with a polythene sheet which acts as a vapour barrier. The surface can be plastered after spreading chicken wire mesh as reinforcement.

Expanded polystyrene can be laid easily as it is rigid. Bitumen is applied on the duct and the insulation is stuck joints are also sealed with bitumen. No separate vapour barrier is needed other than a coat of bitumen. The insulation can be finished with cement and plaster or metal cladding.

Purpose of false ceiling: The conditioned air arrives through the ducts at the supply air diffusers and enters the conditioned space. Most diffusers are attached to the false ceiling and a variety of diffusers are available for different air spreading needs. The return air grills will be fixed to the false ceiling. The false ceiling prevents mixing of conditioned air and return air.

Return air usually flow into the plenum or return air box through grill placed in the false ceiling. Since substantial amount of energy goes into the air in the first place. It is a practice to recycle to air. The air is therefore brought back to the air conditioning. Plant room it is common to route the return air through the gap between the false ceiling and the main ceiling. A space referred to as a plenum, the false ceiling is also known as a return air duct.

Nitrile rubber or acrylonitrile butadiene rubber

Key learning points

Material composition of nitrile rubber.

Identification of nitrile rubber materials.

Applications of nitrile rubber: resistance to mineral oils, vegetable

oils and many acids.

Cost limitations.

Chemical name /designation: Acrylonitrile butadiene rubber.

Thickness and density range.

Service temperature range.

Reaction to fire of nitrile rubber.

Composition and Characteristics

Nitrile rubber (Armaflex) is a versatile and flexible closed cell elastomeric insulation suitable for applications up to an approximate maximum continuous operating temperature of 105ºC.

Fig 1

Elastomeric products are commonly based on a blend of poly vinyl chloride

(pvc) and nitrile butadiene rubber (nbr) using a chemical blowing agent. The

basic processing steps in manufacturing the product are mixing, extrusion, or

shaping or heating. During the heating step, the elastomeric portion is crosslinked, or vulcanized, and the chemical blowing agent decomposes to

Elastomeric products offer excellent flexibility.

Resistant to water vapour.

Resistant to thermal transmittance properties.

Oil and acid resistant (refer to manufacturer¡¦s data sheets before installation).

Excellent adhesive and coating receptiveness.

Good cutting characteristics and easy to fabricate.

Proper installation is critical to the insulation system¡¦s performance.

Uses

Elastomeric insulation or nitrile rubber products are used to prevent condensation on refrigeration copper piping, heating and ventilation pipe work and air-conditioning pipe work. Within its stated temperature range, there are few restrictions which would prohibit the use of this product with proper installation techniques. It can be used on hot and cold plumbing pipes and also as an insulation blanket on ductwork.

Applications

Refrigeration pipe work, heating and ventilation pipe work, airconditioning pipe work.

Heating and ventilation ductwork systems.

Vessels and curved or irregular surfaces.

Thickness and Density Range

Pipe insulation: 10, 13, 19, 25 and 38mm

Sheet insulation: 3, 6, 10, 13, 19, 25, 38 and 50mm.

Roll insulation: 10, 13, 19, 25, 38 and 50mm.

The typical density range is 50kg/m3 to 100kg/m3 depending on the choice of product.

Fig 2

Key Learning Points

Cutting and application of nitrile rubber.

Compatible adhesives.

Available forms of nitrile rubber.

Typical uses and applications.

Cost limitations.

Rules for Working with Nitrile Rubber (Armaflex)

Use good quality tools, in particular a sharp knife, fresh armaflex adhesive and a good brush.

Oval tubes should always be split on the flat side.

Use clean Armaflex material ¡V with no dust, dirt, oil or water on the surface, if the material is dirty clean before use.

Use the right dimensions.

Never pull glued joints when sealing them, always push the joints together.

Never insulate plants and systems that are in operation. Plant and equipment that has been insulted can be restarted 36 hours later as this is the length of time it takes for the adhesive to fully sure.

Cutting Nitrile Rubber

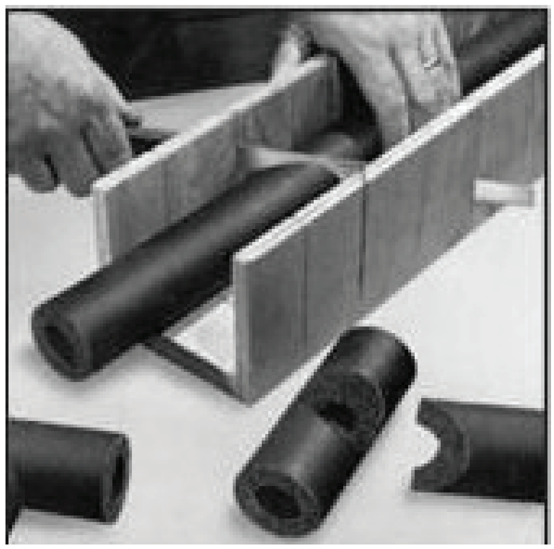
Refer to module 1-unit 10-section 4-application of insulation material to pipe work.

Use a sharp, non-serrated edge knife. Note the long knife length in the photo.

On smaller pieces of Armaflex pipe insulation, brace the piece to be cut with your hand as illustrated. This will insure a clean and accurate cut.

The illustrations below show sleeve-type fitting covers. The same fabrication steps may be used for copper tube fittings.

Fig 3



Health risks associated with nitrile rubber insulation

Inhalation: Inhalation of dust may cause irritation to the upper airways.

Ingestion: Exposure to dust can irritate mucous membranes and respiratory tract.

Skin: Exposure to dust may irritate the skin and cause reddening.

Eyes: Exposure to dust may cause eye irritation.

Handling and Storage

When using nitrile rubber insulation products, provide general or local ventilation systems as needed, to maintain airborne dust concentrations below the regulatory limits. Local vacuum collection systems are preferred since it prevents the release of contaminants into the work area by controlling it at source.

Handling: Avoid generation of dust. Wash hands before eating, drinking, smoking or using the toilet.

Storage: If storing for long periods, protect the product from the weather.

Hands: Wear gloves ¡V rubber or plastic gloves are recommended.

Eye protection: Wear safety glasses with side shields or dust goggles.

Ventilation: Use local exhaust ventilation when handling materials.

Work area: Keep the work area clean at all times to avoid trip hazards due to materials left on the floor. Develop a positive attitude towards working with insulation products and know the risks involved.

Information: Always refer to the manufacturer's data sheets for information on health and safety and precautions required when using the product.

Handling Adhesives

Hazards

Excessive skin contact may cause drying and cracking of the skin and result in dermatitis.

Contact with the eyes will cause irritation.

Inhalation may cause irritation of the respiratory track, coughing, headache, dizziness and nausea may occur.

Flexile foam insulation

Polyolefin is general term used for compound of olefin as a monomer. Polyolefin foams are composed of several materials that have been mix together to form a compound structure. Basically these are organic blowing agent and crosslink agent mixed together to form polyolefin resin.

XLPE sheets & tubings

XLPE is chemically cross link polyethylene, which is monomer of ethylene olefin. XLPE is closed cell fire retardant polyethylene foam used for much insulation application. It is available in both sheet and tube form. It is also available with facing of Aluminum foil, Fiber glass cloth or UV barrier

Densities (Kg/M3	30+/-3
Cell structure	Closed Cell
Pipe Diameter	1/4" to 4" (6mm to 100mm)
Thicknesses in (mm)	6,9,13,19,25,32 (Tubes and sheet)
Dimensions	1.25 Mt W (varies from 10 Mts to 30 Mts)
Temperature range	-40 Deg C to 115 Deg C
Thermal Conductivity	0.032/0.034/0.038W/mk
Uses:	Duck Insulation
	Chilled water & hot water application

Floor & wall Insulation

Underdeck / over deck & Roof insulation

Floor insulation

Wall insulation

Acoustic Insulation

Oxide Acetate foam is chemically cross link oxide acetate foam. Accolsolate is an open cell structure acoustic insulation utilize for large acoustic application.

Densities (Kg/M3)	30 to 60
Cell structure	Open cell, cross linked, Stress crack resistant
Physical appearance	One side open cell, Soft, Fexible and Glossy
Thicknesses in (mm)	10, 15, 25, 35
Temperature range	-70 Deg C to 100 Deg C
Thermal Conductivity	0.029 W/mk at 0 Deg C
Uses:	AC Ducting
	D.G. Looms
	Building and wall paritions

Oxide acetate sheets & tubings

It is cross linked closed cell oxide acetate foam used for thermal insulation in AC ducting, chilled water pipe, under deck/ over deck in RCC roofing and metallic roofing. This is UV resistive product also has Class "O" fire properties as per BS 476 part 6 material is also offered with factory laminated glass cloth and pure aluminum foil to give higher mechanical strength to the product.

Densities (Kg/M3)	30+/-3
Cell structure	Closed Cell, Cross linked, Stress Crack resistant
Physical appearance	Soft, Flexible and glossy

Thickness in (mm)	6,9,13,19,25,32 (Tube and sheet)
Temperature range	-70 Deg C to 100 Deg C
Thermal conductivity	0.029W/mk at 0 Deg C
Uses	Duct insulation
	Chilled water & hot water application
	Floor & Wall insulation
	Underdeck / Roof insulation
Thickness in (mm)	9,12,15,19,25
Fire safety	Class "O"
Advantages:	Acoustic duct lining
	Air handling unit
	Acoustic panel
	Speaker box acoustic lining
	Enclosures and canopy of factories.
	Machinery, fans, generator, engines and compressors.
	Audiometric room, Air conditioning of ventilations.
	Auditoriums, wall acoustic, Multiplexes recording rooms, studios, cinema hall partition, home theater.

Mechanical & electrical components of window AC

Objectives: At the end of this lesson you shall be able to
- **list past air conditioning equipment**
- **list present air conditioning equipment**
- **list future air conditioning equipment**
- **explain the main components of window A/C**
- **describe mechanical parts (auxiliary)**
- **explain the function of all the electrical components of a window air conditioner.**

Past air - conditioning equipment: One's comport as well as the success of certain industrial operations dealing with hygroscopic materials and processes depending on temperature and humidity.

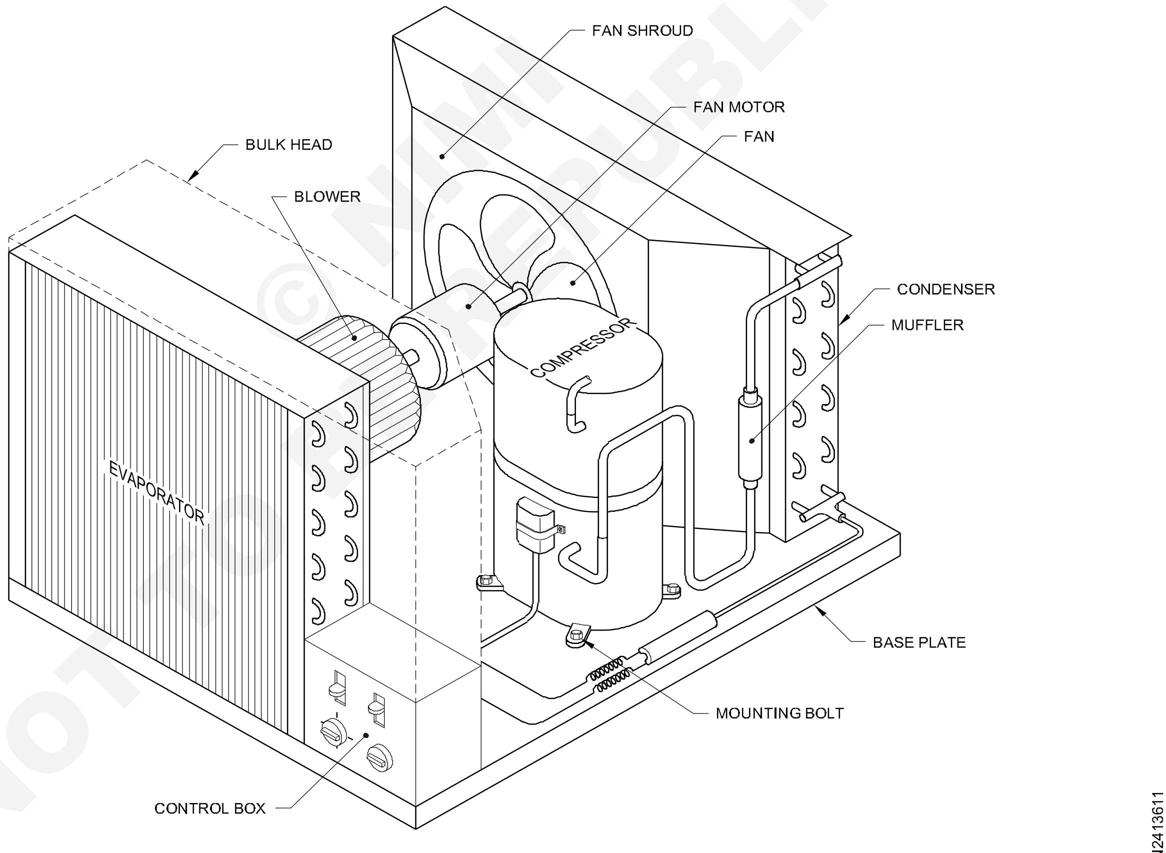
The First Mechanical atmosphere cooling and humidity control used cooled water; both to reduce temperature of the air and dehumidify it. Air was passed over water, cooled coils or through cooled water sprays.

It should be kept in mind that Air-conditioning is a use of refrigeration.

Present Air-conditioning equipment

Room Air conditioner: Room air conditioner is designed and assembled by a manufacturing company as a unit for mounting in a window through wall. It delivers conditioned air to an enclosed space without any ducts. The window AC is shown in Fig 1.

Fig 1



ROOM AIR-CONDITIONERS

Air- conditioning fundamentals

Air conditioner

Air conditioning is defined as the process of treating air so as to control simultaneously its temperature, humidity, cleanliness and distribution to meet the requirements of the conditioned space.

As defined the important actions involved in the operation of an air-conditioning system are:

- Temperature control temperature control for winter heating conditions requires automatic control of the heating source as a means of maintaining desired room temperature.
- Temperature control for summer cooling conditions requires automatic control for summer cooling

conditions requires automatic control of the refrigeration system to maintain the desired room temperature.

Humidity control for winter conditions usually requires automatic control addition of moisture to the heating system by humidifier.

Humidity control for summer conditions requires the automatic control of dehumidifiers usually this is above at the time the air to be cooled is passed over the cold evaporator surfaces.

Air filtering is the same for both summer and winter air conditions.

Air filtering equipment usually consists of very fine porous substances air is down through to remove contaminating particles, filters using oxide carbon and electrostatic precipitation may be added to the usual filtering mechanism to improve air cleaning. The air pollutants and methods used to remove them from the air are of different types.

Air Movement in an air conditioned area

Air movement is an important aspect in human comfort and as well as humidity aspect. If there is no air flow in an air conditioner on either side condenser/evaporator refrigeration cycle will not come into effect.

Air Movement will be constant, which make the unit viable, constant flow will be set according to the capacity of unit and the room by the related people who manufacture the unit.

According to capacity of the unit, the manufacturer will design and make according to their design which satisfy's the comfort part of human body/persons in the cooled area.

The chilling effect of air in a mixture of wind velocity and the relative humidity. Normally air movement is an important condition affecting the comfort cycle. If the air moves too fast, persons feel uncomfortable, if the air movement is too low the air becomes state and lacks oxygen (contamination).

Air movement in an air conditioned area

As you all know the air inside the room (which is air conditioned) will flow within the area. The same air is sucked through (evaporator inlet area) and is flown back to the same room only. Since the filter is provided in the evaporator inlet, the air inside the room is filtered for dust, moisture if any.

Normally it is designed that the cold air flow upto 15 feet length in a disbursed manner to the entire area at upwards as the air cooled normally lowers due to lower density and is sucked back to the filtered area (evaporator).

As per design, the normal capacity of area covering the room will be around 15' x 15', for better cooling effect false ceiling of the room is quite obvious. According to the capacity of the unit manufacturers providing air velocity is given below.

(As per design data) Table 1

Air flow	1 ton	1.5ton	2 ton
Rate (CFM)	400	480	620

This will vary from time to time and varies with the manufacturers.

Main components of window A/C

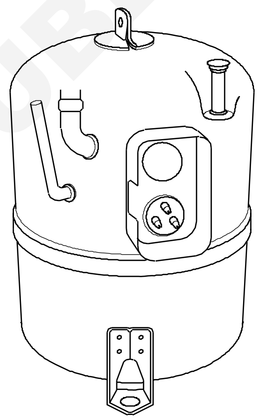
Room Air conditioner: Room air conditioner is designed and assembled by a manufacturing company as a unit for mounting in a window through wall. It delivers conditioned air to an enclosed space without any ducts.

The main components of window A/c are as follows.

- Compressor
- Condenser
- Filter drier
- Capillary tube
- Evaporator

Compressor: The compressor is the heart of the refrigeration system. It circulates the refrigerant around the system. It sucks the low pressure and low temperature refrigerant vapour, compress it. The vapour turns to high pressure and high temperature vapour and to condenser by discharge line. (Fig 2)

Fig 2

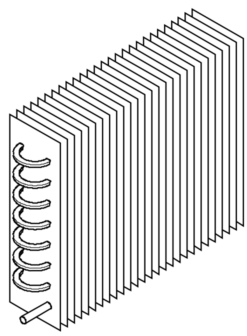


COMPRESSOR

MRN2413612

Condenser: Condenser is a heat transferring device to change the gas or vapour discharged by compressor to liquid to ready for the use in the evaporator. (Fig 3)

Fig 3

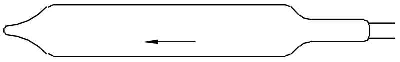


CONDENSER

MRN2413613

Filter drier: It is fitted in liquid line before capillary. It strain the dust and dirt. Absorb moisture in the system. It is filled with silica gel to absorb moisture. (Fig 4)

Fig 4

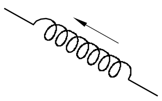


FILTER DRIER

MRN2413614

Capillary tube: It is a metering device in domestic refrigerators and air conditioners. The capillary tube consists of small diameter copper tube. The length of which depends upon the size of condensing unit and the kind of refrigerant used. (Fig 5)

Fig 5

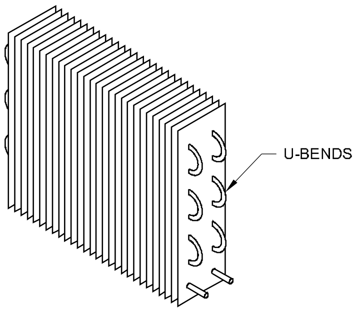


CAPILLARY TUBE

MRN2413615

Evaporator: Any heat transfer surface area in which a refrigerant vapourizing for the purpose of removing heat from the medium being cooled. (Fig 6)

Fig 6



EVAPORATOR

MRN2413616

Mechanical part (Auxiliaries)

Front grill

The front grill will be made of superior quality plastic. The internal construction is divided into two sections, one is the inlet air to be looked from room to evaporators through filter and the outer is evaporator cooled air to room.

Outer cover

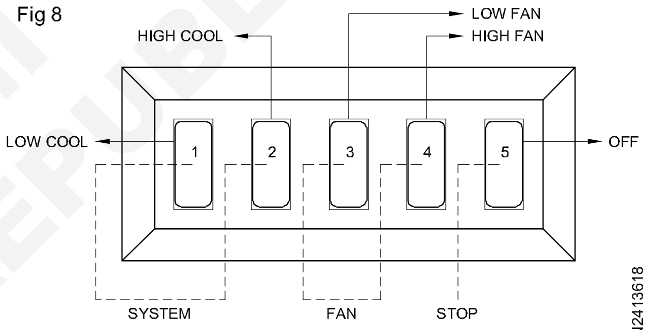
The outer cover is made of mild steel sheet and pointed with water proof point some manufactures make it of aluminium, the cover covers the entire components of the air conditioner and protects it from rain water dust and all natural damages, it is secured tightly to the window wooden frame with screws. It protects the A/c unit from falling behind.

The outer cover has louvers on both sides through the louvers opening the condenser fan sucks atmospheric air and throws it on the condenser heated surface this air Pick's up heat from the condenser and goes out of the condenser fans to the atmosphere, enabling the gas to be liquefied.

Electrical components of window air-conditioner

Selector switch: The air conditioning controlled by the selector switch ON and OFF, low fan, high fan, low cool and high cool can be selected as requirement. (Fig 8)

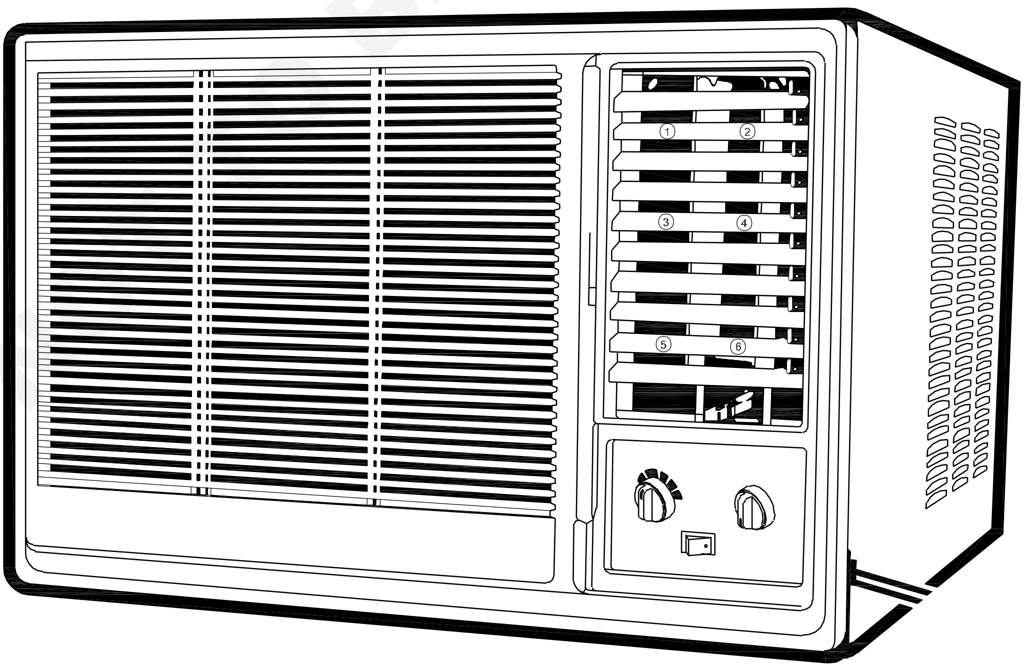
Fig 8



SELECTOR SWITCH

MRN2413618

Fig 7



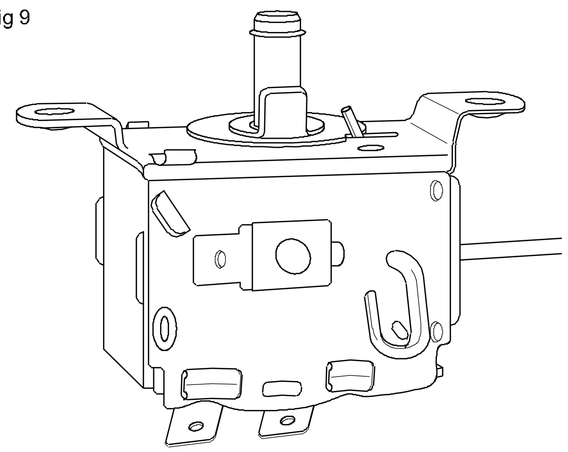
AIR FLOW CHECK POINTS

MRN2413617

Thermostat: It controls the room temperature by ON and OFF the compressor. The thermostat starts the compressor when the room becomes warm and reaches a predetermined setting. This setting is called ‘cut-in’ temperature.

As the compressor runs, the A/C unit cools the room. When the room temperature reaches the desired temperature low or ‘cut-out’ the thermostat disconnects the compressor from the circuit. The compressor stops. (Fig 9)

Fig 9

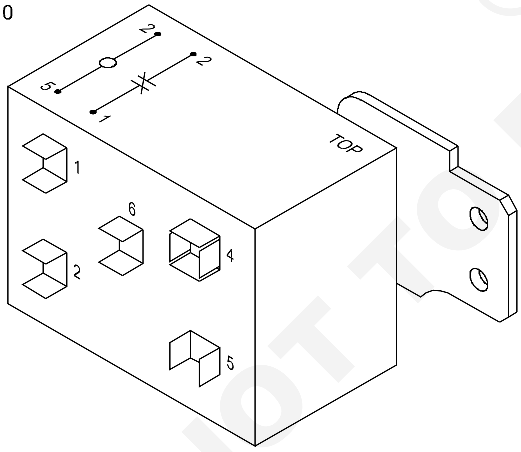


THERMOSTAT

MRN2413619

Relay: The relay coil is in series with the motor (compressor) running winding. The high current draw on starting causes the relay contacts to close. Connecting to starting capacitor to the compressor start winding circuit, speed increases, relay contact open. (Fig 10)

Fig 10

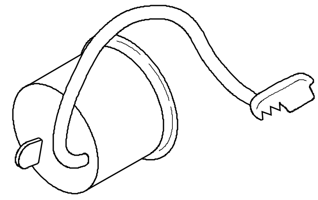


RELAY

MRN241361A

O.L.P: The OLP contains a resistor wired in series with the running current. If the current draw too high (overload), the resistor will heat up and cause a bimetal contact to break the circuit. (Fig 11)

Fig 11

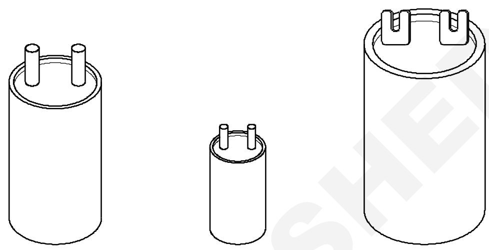


OVERLOAD PROTECTOR

MRN241361B

Capacitors: The capacitors have two ratings. The microfarad (μfd) rating and a voltage rating. Starting capacitors are the electrolytic type and are used in the motor start winding circuit to affect on increase in starting torque. (Fig 12)

Fig 12



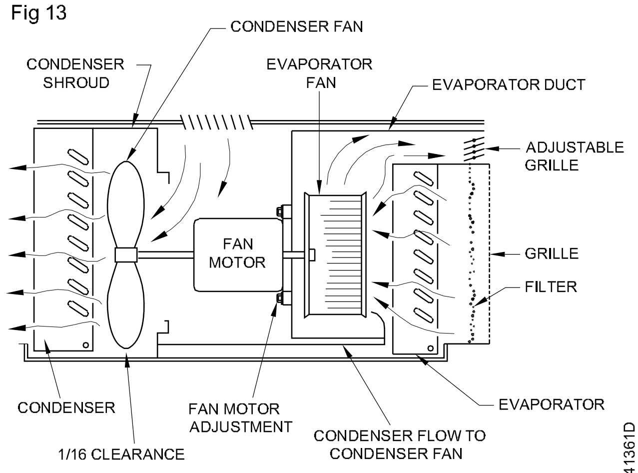
CAPACITORS

MRN241361C

Running capacitors are much lower in microfarad(μfd) rating than starting capacitors of comparable size. The running capacitor remains in the motor start winding circuit at all times during compressor operation.

The fan motor used in window model air-conditioner’s are designed with a single shaft that extends both side (one through shaft) as shown in Fig 13 one side the condenser fan blade will be fixed on the other side the evaporator fan will be fixed.

Fig 13



BASIC ARRANGEMENTS OF COMPONENTS IN WINDOW AIR-CONDITIONS.

MRN241361D

Electric circuits of window A/C

Objectives: At the end of this lesson you shall be able to
- **describe the electric wiring of window A/C by CSR method**
- **explain PSC circuit in window A/C**
- **explain the rotary compressor in window A/C.**

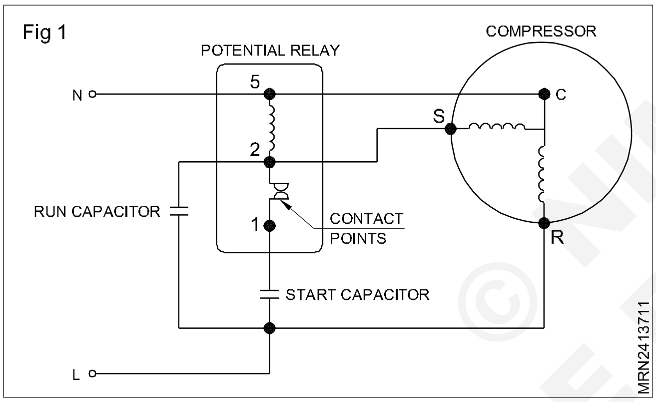
Electric wiring of window A/C by CSR method

Relay is an electrical operated switch used to disconnect the starting capacitor from the circuit when the motor reaches at its rated speed.

The potential type relays are used with capacitor start run (CSR) hermetic compressor motors for disconnecting the starting capacitor.

Construction: It has a potential coil and a set of contact points which remains close, when the motor is at stop condition.

The relay coil is connected in parallel with the starting winding and it is connected in the series of starting winding through the contact points (Fig 1). The running capacitor is directly connected in the series circuit of the starting winding.



Function: as the motor is energized the voltage in the starting winding and relay coil increases above the line voltage due to the capacitor in the series circuit of the winding. This increased voltage produces a strong magnetic field around the relay coil which attracts the plunger opens the contact points and disconnect the starting capacitor.

As the starting capacitor is disconnected somewhat voltage decreases in the starting winding and relay coil but remains enough to hold the plunger and keep the contact points open during the running time of the motor.

PSC Circuits in Room A/Cs

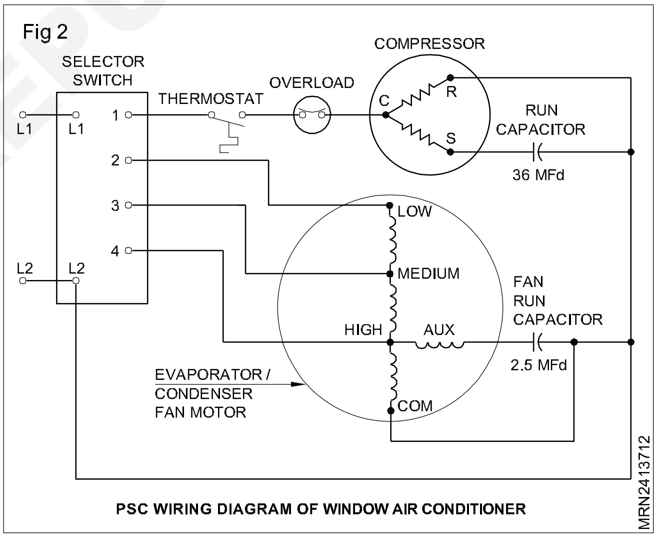
Window and split air conditioning units are used with CSR and PSC compressor motors.

CSR = Capacitor Start & Run

PSC = Permanent Split Capacitor

In PSC motor the starting torque is low. In CSR motor starting torque is high. In PSC motors the start winding remains in the circuit. These are no relay and no starting capacitor. In this circuit between the start and run windings there may be a run capacitor.

PSC circuit in window A/C: In (Fig 2) window air conditioner can energize the double shafted fan motor to run both the condenser and the evaporator fan. On any of three speeds high fan, medium fan and low fan. It can also energize the compressor with any of these fan speeds (high cool, medium cool and low cool). The compressor runs the same, regardless of the high, medium or low setting. The compressor will cycle ‘on’ or ‘off’ in response to the line voltage thermostat.

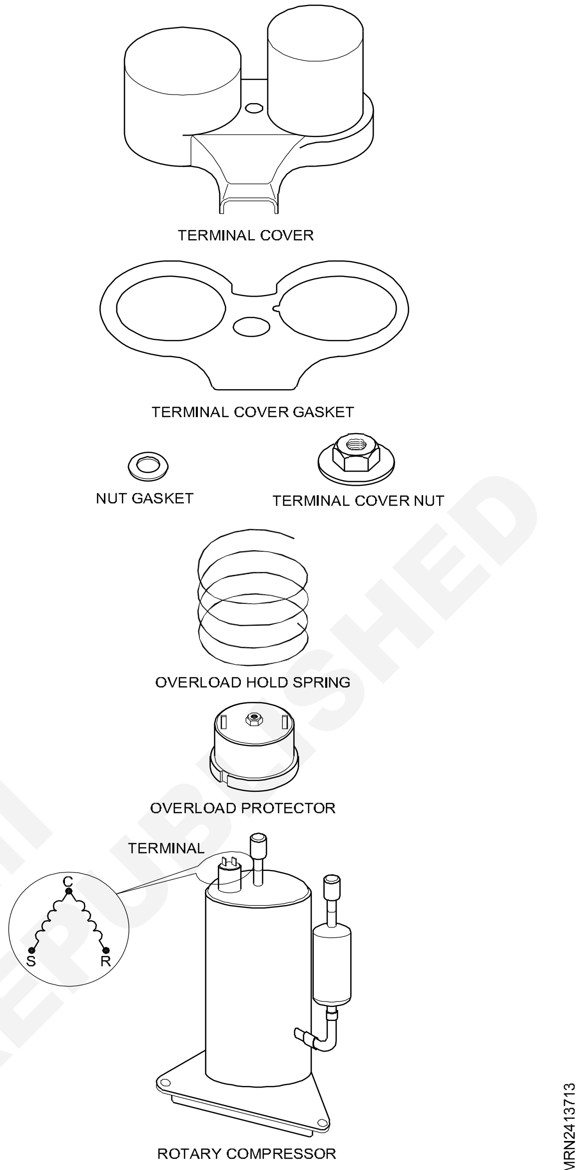


PSC WIRING DIAGRAM OF WINDOW AIR CONDITIONER

Rotary type compressor in window A/C: Rotary compressor winding not like reciprocating compressor winding.

Reciprocating compressor winding will have starting and running coil. But rotary compressor winding will be lengthwise and rotates longitudinally. This design is for high speed. (Fig 3)

Fig 4



Electrical components of window A/C

Objectives: At the end of this lesson you shall be able to
- **state the function of capacitor**
- **list the types of capacitors**
- **describe the different types of capacitors**
- **state the function of relay**
- **list the types of relay**
- **explain the potential relay (magnetic).**

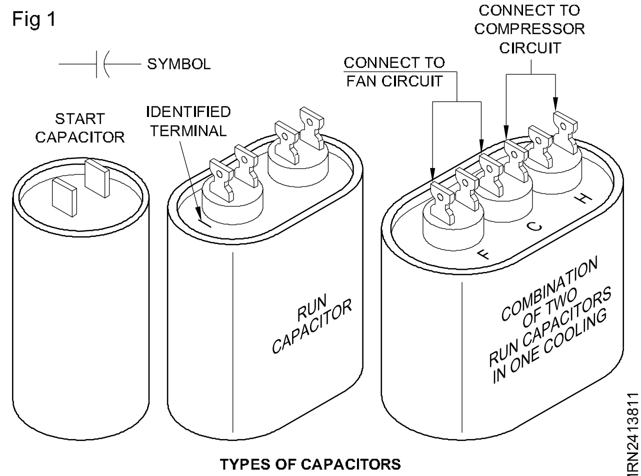
Capacitors: A capacitor (Fig 1) consists of two conducting plates separated by a dielectric(insulating) materials. When a voltage is applied to a capacitor electrons build up on one plate charging the capacitor. When the charge builds up on one plate, electrons are moved from the other plate. When a capacitor is used in an alternating current circuit, the build up of charge can be used to amplify the voltage as it build in the opposite direction. Capacitors are of two types and used for two different purposes.

Start capacitors are commonly round in cross section and designed to amplify a voltage to increase the starting torque of a motor. Start capacitors are designed to be used for only a few seconds at a time (during the startup of a motor). After this time, a switch wired in series must open or disconnect starting capacitor from the circuit.

Run capacitors are commonly oval or rectangular in cross section shape and designed to align the voltage and amperage cycles that have been separated by the back e.m.f generated by a motor winding. This improves the power factor reduces the running current of the motor.

The unit of capacitance is the Farad. A farad however is a very large unit of capacitance. In order to avoid using very small numbers, capacitors are rated in Microfarad (mfd). Run capacitors are usually lower Microfarad rating (2-40 mfd) than start capacitors.

Fig 1



TYPES OF CAPACITORS

Relays : In sealed compressor systems are different from the open type system.

Starting relays are found outside of the compressor

Types

- Current (magnetic)
- Potential (magnetic)
- Thermal
- Solid state (electronic)

Current relays: Current relays are usually found on low torque, fraction horse power motors (like refrigerator compressors)

Potential relay (Magnetic): Potential relays called as voltage relays are usually used with high torque, capacitor start motors.

As the motor speed pickups, higher voltage creates more magnetism in the relay coil pulling the contact points apart, opening the starting circuit. The relay coil is connected across the starting winding. It is made of small wire so very little current passes through it.

This minimizes the heating of the coil and core.

Resistance of the contact points to voltage must be high enough to prevent the points from opening before the motor reaches 90% of its full speed. Resistance must be low enough to positively open the prints and remove the starting winding from the circuit at right time. If not, the motor will overheat.

OLP (Over Load Protector): OLP is usually used in domestic units and commercial units. OLP is connected with electrical circuit in series. In air-conditioning units bimetal OLP is normally used. Bimetal control in series with the power supply to compressor. If the compressor over loaded bimetal will expand and bend. The end of the bimetal strip will open and the compressor stops(motor). It will not restart until the safety device cools down. It protect the compressor. (Windings)

Compressor winding (motor): Motor convert the electrical energy to mechanical energy by means of electro motive force.

In sealed unit compressors the rotor shaft is acting as crankshaft of compressor

There are two types of motor commonly using in refrigeration and air conditioning units. One is single phase and another one is three phase motor.

Single phase motor: All single phase motor will not start automatically. In room air conditioner compressors capacitor is provided

Start capacitor: Starting winding gets starting torque with the help of capacitor

Starting winding: It has more resistance. It helps to run the motor first by helps to run the motor by help of the capacitor

Running winding: It helps to run the motor continuously with running capacitor, when the starting winding cut off.

Thermostat and its function: Thermostat is an electrically operated switch/control instrument which controls the temperature of a refrigerated space or product by cycling (starting/stopping) the compressor.

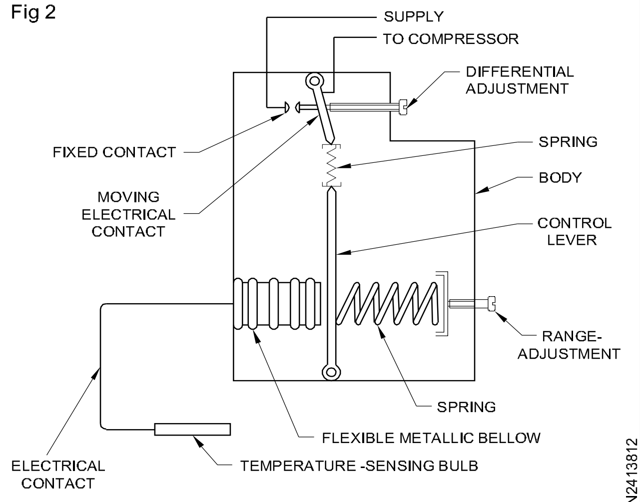
Thermostat has a temperature sensing bulb/element, it acts (connect/disconnect power supply to compressor) according to the temperature change/variation based on the setting.

There are two types of elements are commonly used in thermostats to sense and relay temperature changes to the electrical contacts or other actuating mechanisms. One is fluid filled tube or bulb that is connected to a bellows or diaphragm and filled with a gas, a liquid, or a saturated mixture of bath.

Temperature control: When a system is controlled by means of temperature it is called as temperature control. It maintains the evaporators temperature.

Cut-in: When the electrical connection is in contact (closed) the circuit will complete. So the machine will start. (Fig 2)

Fig 2



THERMOSTAT

Differential adjustment: The differential adjustment is built into the temperature control mechanism. The differential adjustment controls the temperature difference between the cut out and the cut in settings.

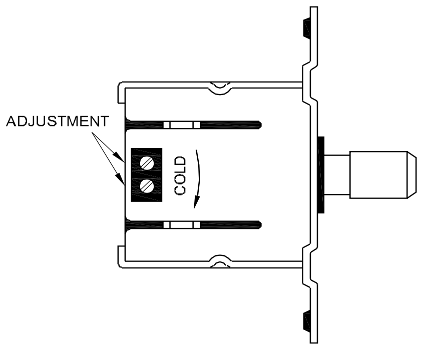
The parts of the temperature controls are;

- Thermal bulb
- Capillary tube
- Power element bellows
- Bellows spring
- Push rod (yoke)
- Electrical terminal
- Electrical contact points

Thermal bulb is clamped in the last coil of the evaporator or in the space. In room air conditioners thermal bulb is located at evaporator suction filter.

When the temperature increases in the evaporator the thermal bulb also get that temperature. The thermal bulb fluid Expand and the vapour pressure through the capillary tube push the power element bellows. Bellows gets into action. By this action push rod pushes the electric contact face. So the electrical contact is closed. Now the machine starts to work. (Figs 2 & 3)

Fig 3



THERMOSTAT EQUIPPED WITH ALTITUDE ADJUSTMENT

MRN2413814

When the temperature decreases in the evaporator the thermal bulb temperature also decreases. The vapour condenses in thermal bulb. So the power element reacts. By this action the electrical contact is opened and the machine will stop.

Relays: 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.

Potential relay: The potential or voltage type relays are used with capacitor start, capacitor run hermatic compressor motors for disconnecting the starting capacitor. It is mostly used in air conditioners.

The contact points are normally closed on this relay, when it is not energized. The relay winding is made parallel with the start winding and connected to non energized lines relay no.1 and 2. (In the series of starting winding through the contact points). The running capacitor is directly connected in the series circuit of the starting winding.

As motor is energized, the voltage in the starting winding and relay coil increases above the line voltage due to the capacitors in the series circuit of this winding.

This increased voltage produces a strong magnetic field around the relay coil which attracts the plunger opens the contact points and disconnect the starting capacitor. As the starting capacitor is disconnected some what voltage decreases in the starting winding and relay coil but remains enough to hold the plunger and keep the contact points open during the running time of the compressor motor. If not the motor will overheat. Fig 4, (5a, b, c)

Use

20 MFD run capacitor for 1.0 TR A/C

36 MFD run capacitor for 1.5 TR A/C

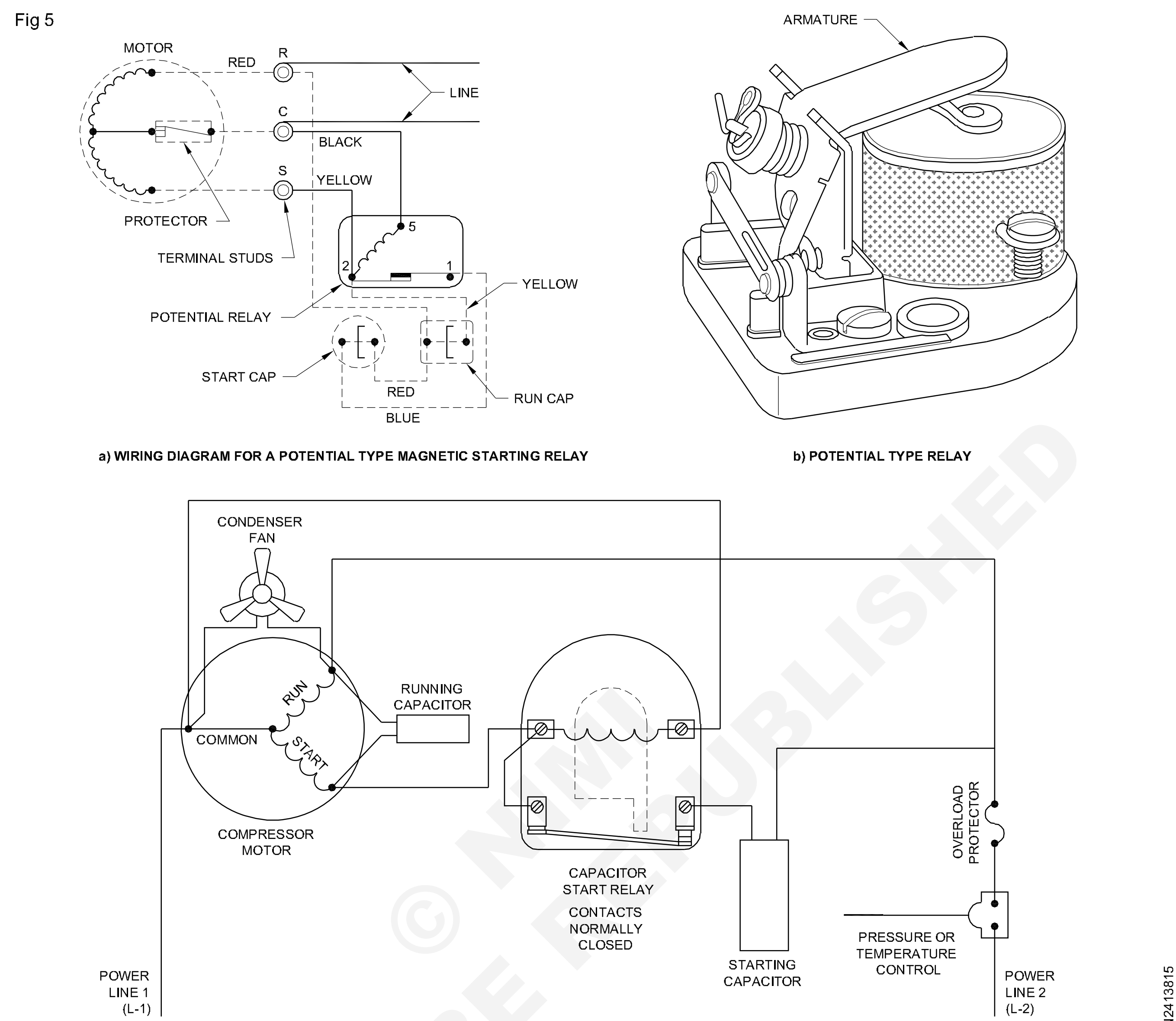
80 MFD starting capacitor for 1.0 TR A/C

100 to 120 MFD starting capacitor for 1.5 TR A/CT

Cut-out: When the electrical contact is open the circuit will not close. So the machine will not run. There are two adjustments in this control.

Range adjustment: Range adjustment provides for the correct minimum and maximum temperature in an automatically operated system. The range adjustment is an adjustable force pressing directly upon the bellows or diaphragm which
operates the switch. This force is always being exerted on the bellows whether the switch is in either the cutout or the cut-in position.

Fig 5



a) WIRING DIAGRAM FOR A POTENTIAL TYPE MAGNETIC STARTING RELAY

b) POTENTIAL TYPE RELAY

c) WIRING DIAGRAM FOR POTENTIAL RELAY

Mechanical & electrical components of split AC

Objectives: At the end of this lesson you shall be able to
- **explain the types of split air conditioner**
- **describe the details about the compounds**
- **study ventilation of room conditioner drain**
- **explain about remote control**
- **study the wiring diagram.**

Split air-conditioners have become very popular because of -

1 They are an alternative for air-conditioning of partition rooms, where window model air-conditioners cannot be used.

2 They are very silent in operation.

3 The room side units can be selected to match the interior decorations of the rooms.

Types of split air-conditioners

1 Direct room mounted split unit

The evaporator unit can be installed in different models, like floor mounting, wall mounting and ceiling mounting. The condensing unit is kept outside in a suitable location.

2 Duct able split unit

In this type the evaporator is normally mounted above false ceiling space and the cold air is supplied through ducting and delivered through the terminals (outlets) located at selected places.

3 Multi split unit

This system offers the feature of having individual room temperature control. Multi split units have been developed to cool two or three rooms simultaneously by having as many individual compressors and separate refrigerant circuits.

Split air-conditioner outdoor unit (wall mounted)

Objectives: At the end of this lesson you shall be able to
- **explain the features of split A/C's outdoor unit**
- **list the steps of outdoor units (condensing unit)**
- **list the specification of 1.5 ton and 2 ton split A/Cs.**

Split A/Cs consists of both indoor and outdoor unit connected together through refrigerant pipe line duly insulated and clamped.

Outdoor units will be supplied as per the requirements of the customer. Unit is placed at the top of the building/ top floor or even fixed at the M.S. Angles, frames grouted in the wall at about 150mm inner to the wall duly concreted.

Outdoor units consists of condenser, fan motor, compressor, electrical components and service valves duly assembled.

Tables Given shows the corresponding capacities of condenser, fan motors and fan blade dimensions.

Table 1

Capacity	0.5 ton	0.75 ton	1 ton	1.5 tons	2 tons
Refrigerant	R22	R22	R22	R22	R22
Condenser	17"x13" (2 row)	18"x15" (2 row)	22"x16" (2 row)	22"x16" (3 row)	22"x16" (4 row)
Condenser fan motor HP	1/33	1/2	1/10	1/5	1/4
RPM	1350	930	930	930	1350
Condenser fan blade diameter	10" (6 blade)	12-1/2" (6 blade)	13-1/2" 6 blade	16" 6 blade	16" 6 blade

All the screws mounted in the condenser guard will be tighten up gently to avoid noise/vibration. Fan blade/ propellers will be checked so that it should not touch the body.

Some of the outdoor units might come with 2 fan motors to cover the entire condensing area, both the fan motors will be connected in series. Even one fan motor fails condensation will be improper.

Fan motor will be mounted on the frame with bolt and nuts or some at condenser housing. That has to be checked up and tighten it well. Fan motor will be lubricated periodically.

For proper and better condensation, unit will be positioned where there is no obstruction of air/ wall nearby.

Service valves will be checked up for flare fittings and tighten the flare fittings if necessary.

All the electrical parts placed in the outdoor unit will be checked for proper connections and insulations.

The distance should be maintained between the indoor unit, as per supplier's manual. In case of change the distance of the outdoor unit, proper alterations will be made as per suppliers manual. Here some of the units (outdoor) sizes are given below.

CONDENSING UNIT

	1.5 TR	3 TR MRU	3 TR SRU
L (mm)	750	950	900
D (mm)	445	560	560
H (mm)	385	500	500
W (Kg.)	65	130	98

The normal running currents for various units are given below.

1 ton	-	7 amps
1.5 ton	-	8.5 amps
2 ton	-	12 amps

Some of the technical details of 1.5 ton and 2 ton capacity units are given below.

Capacity		1.5 Ton	2 Ton
Air Flow Rate M/Hr(CFm)		858 (514)	876.5 (525)
Cooling capacity		4550 KCAL/HR	6050 KCAL/HR
Power supply		230 volts±10%, 50HZ, single phase	230 volts±10%, 50HZ, single phase
Normal power		1850 watts	2350 watts
Rated current		8.5 amps	12.0 amps
Suction line		15.875 mm (5/8")	15.875 mm (5/8")
Liquid line		9.525 mm(3/8")	9.525 mm (3/8")
Compressor type		Reciprocating	Reciprocating
Refrigerant		R-22	R-22
Weight (Kgs.)		12.5, 62.5	12.5, 64
Cooling capacity		18000 BTU/hr to 4500 Kcal/hr	24000 BTU/hr to 6000 Kcal/hr
RPM		930	930
HP		1/8	1/8
Type of bearing		Self lubricated ball bearing	Self lubricated ball bearing
Physical data	Width	760 mm	760 mm
	Height	540 mm	540 mm
	Depth	310 mm	310 mm
	Weight	53 kg.	61 kg.

The technical specifications of 2 ton units of reputed unit model given below (outdoor unit).

Model 2	5M 53024
Capacity	2.0 TR
BTU/hr	24000 BTU
Kcal/hr	6000 Kcal
	1350(RPM)

Fan motor	1/8 H.P.
Type of fan blade	Propeller
Refrigerant	R22
Running current	12.0 amps

TECHNICAL SPECIFICATIONS OF SPLIT AIR-CONDITIONER

Cooling capacity	T.R	1.0	1.5	2.0
	BTU/Hr.	12000	18000	24000
	Kcal/Hr.	3000	4500	6000
Power supply	Volt	230	230	230
	Phase	1	1	1
	Cycle	50	50	50
Power input	Watts	1140	1850	2470
Running current	Amps	6.0	8.5	11.0
Energy Efficient Ratio	BTU/W	10.5	9.7	9.7
Air circulation at high speed	M^3/min.	$10M^3$/min.	13	15
	CFM	350	450	525
Temperature control		Thermosensor	Theromostat	
Condenser & evaporator	H.P	1/6	1/5	1/4
fan motor/capacitor	Mfd	2.5	2.5	4
Compressor	Type	Rotary Reciprocating	Rotary Reciprocating	Reciprocating
Refrigerant		R22	R22	R22
Cooling unit fan speed-mode		3	3	3

TECHNICAL SPECIFICATIONS OF SPLIT AIR-CONDITIONER

Performance Data

Indoor unit							
Cooling capacity	kW		2	2.5	3.5	4.5	5
Cooling range (min. - max.)	kW		0.3 - 3.0	0.3 - 3.5	0.3 - 4.5	0.3 - 5.0	0.3 - 5.5
Power input (min.- rated - max.)	kW	Co	0.07- 0.35-0.680	07- 0.47-0.88	0.07- 0.77-1.25	0,07- 1.22-1.49	0.07- 1.49-1.75
EER	W/W		5.63 5.26	4.55	3.69	3.36	
Energy efficiency class		Co	A A	A A	A		
Annual energy consumption	kWh		177 237	385	610	745	
Heating capacity	kW		2.5 3	4 5,5	6		
Heating range (min.-max.)	kW		0.3-5.0	0.3-5.8	0.3-6.1	0.3-6.5	0.3-6.7
Power input (min.- rated - max.)	kW	HP	0.07-0.44-1.30	0.07-0.56-1.60	0.07-0.84-1.60	0.07-1.34-1.70	0.07-1.54-1.75
COP	W/W		5.68	5.36	4.76	4.1	3.9
Energy efficiency class		HP	A	A	A	A	A

Physical data indoor unit

Indoor unit							
Air flow (h/l)	M3/h-l/s	CO	612/288-170/80	624/306-173/85	696/318-193/88	744/372-207/103	804/408-223/113
Sound pressure level (h/l)	dB(A)	CO	42/26	43/27	45/27	47/30	49/31
Sound power level (h/l)	dB(A	CO	57/41	58/42	60/42	62/45	64/46
Air flow (h/l)	M3/h-l/s	HP	648/348-180/97	666/348-185/97	696/348-193/97	744/384-207/107	804/420-223/117
Sound pressure level (h/l)	dB(A	HP	42/26	43/27	45/27	47/30	49/31
Sound power level (h/l)	dB(A	HP	57/41	58/42	60/42	62/45	64/46
Dimensions (hxwxd)	Mm		295x790x242	295x790x242	295x790x242	295x790x242	295x790x242
Weight	kg		12	12	12	12	12

Physical data outdoor unit

Outdoor unit							
Air flow	M3/h-l/s	CO	1662-462	1800-500	2232-620	2232-620	2370-658
Sound pressure level	dB(A)	CO	46	48	50	50	52
Sound power level	dB(A)	CO	61	63	65	65	67
Operating range	°C	CO	-10 46	-10 46	-10 46	-10 46	-10 46
Air Flow	M^3/h-l/s	HP	1530-425	1662-462	2088-580	2088-580	2232-620
Sound pressure level	dB(A)	HP	46	48	50	50	52
Sound power level	dB(A)	HP	61	63	65	65	67
Operating range	°C	HP	-15 24	-15 24	-15 24	-15 24	-15 24
Dimensions (hxwxd)	Mm		550x780x290	550x780x290	550x780x290	550x780x290	550x780x290
Weight	Kg		39	39	40	40	40
Compressor type			Twin Rotary	Twin Rotary	Twin Rotary	Twin Rotary	Twin Rotary
Flare connections (gas-liquid)			3/8"-1/4"	3/8"-2/8"	3/8"-2/8"	4/8"-2/8"	1/2"-1/4"
Minimum pipe length	M		2	2	2	2	2
Maximum pipe length	M		20	20	20	20	20
Maximum height difference	M		10	10	10	10	10
Charge less pipe length	M		15	15	15	15	15
Power supply	V-ph-Hz		220/240-1-50	220/240-1-50	220/240-1-50	220/240-1-50	220/240-1-50

Condenser

The function of the condenser is to remove heat from the superheated high pressure refrigerant vapour and to condense the vapour into a sub-cooled high pressure refrigerant liquid. The cooling medium for domestic air-conditioner is air. (Fig 2)

Expansion devices

An expansion device is a link between condenser and evaporator. Capillary tube is an expansion device in domestic split units. Capillary tube allows the equalisation of suction and discharge side pressure during off cycle, it can be used with compressor working on CSR and PSC circuit, compressor motors which provide low starting torque.

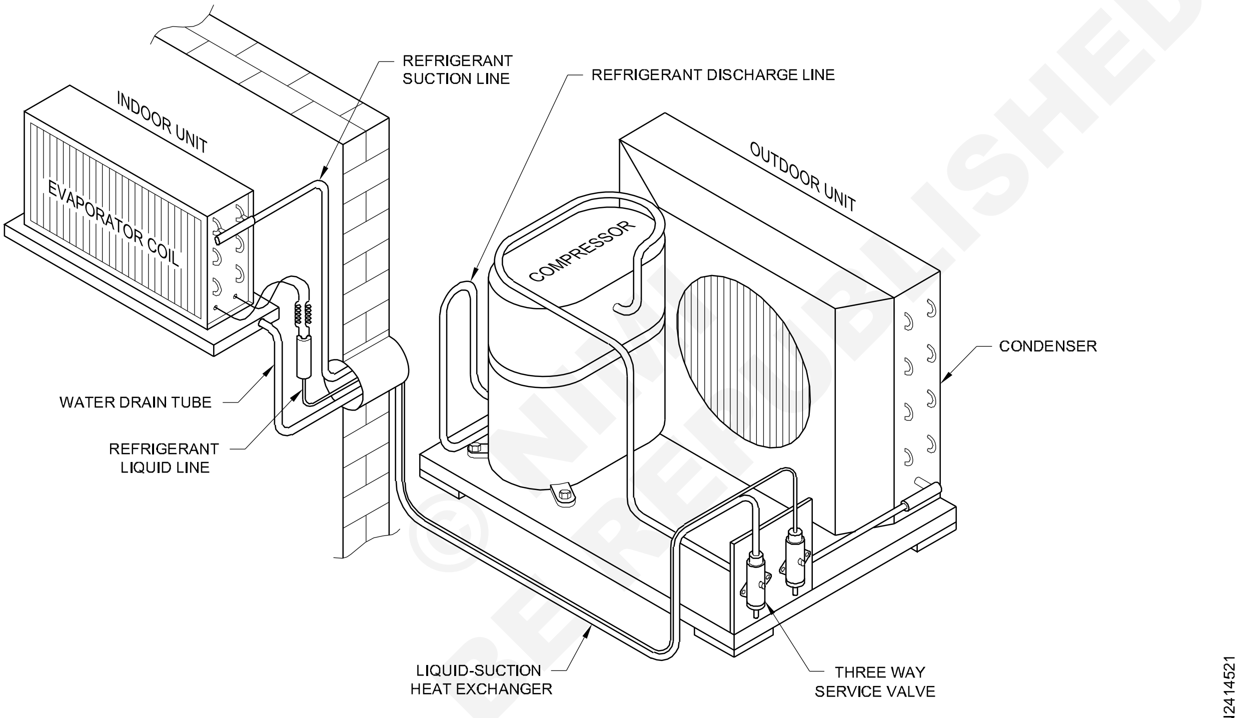
Liquid line drier filter

The function of a liquid line drier filter is to absorb moisture in the system. It also filters the foreign particles such as copper burr, dirt, dust, etc. This protects the expansion device from getting blocked due to ice (moisture) or other particles. It also protects the compressor from damage due to metal burr or dust etc.

Evaporator

The function of evaporator is to remove heat from the area to be cooled and to maintain it at desired temperature. Various types of constructions of the evaporator are in use in hermetic systems.

Fig 1



PARTS OF A SPLIT AIR CONDITIONER

Liquid suction heat exchanger

In a liquid suction heat exchanger the low temperature return gas picks up the heat from the higher temperature liquid, thereby increasing the sub-cooling and decreasing the flashing. This is expected to increase the capacity of the system. During this process super heat at compressor suction increases, also increasing the specific volume of gas.

Suction line accumulator

A suction line accumulator prevents liquid refrigerant from entering the compressor under low load condition.

Fan, Fan motor, Blower

The function of the fan, the fan motor and the blower is to provide the required amount of air flow on the condenser and the evaporator as per the design. The selection of these components is very important because any change in air flow over the fan cooled condenser or evaporator has a large effect on the capacity of these coils.

Refrigerant tubing

In split air conditioner the evaporator unit and condensing unit are connected by refrigerant tubings.

The condensing unit shall be kept as near as possible to minimise the pressure drop in the connecting tubings, bends, etc. Mounting the condensing unit at a higher level than the evaporator unit should be avoided, if other options are available, to make the oil return to compressor easier.

The distance between the units shall be normally horizontal distance:40 ft. (12 meters) vertical distance - 20 ft. (6 meters.)

The oil charged in all air-conditioner model compressors will be sufficient to operate upto 40 ft. long tubing (12 meters). When a typical installation for a much longer tubing than 40 ft. the compressor has to be charged with a specific quantity of extra oil as 90 ml. for every 10 ft. length after crossing the initial 40 ft. distance. The suction line shall be well insulated.

Suggested tube sizes for room mounted/ductable split A/Cs.

Capacity	Suction line		Liquid line
	Up flow	Down/Hori. flow	
1.0 TR	1/2" OD	5/8" OD	5/16" OD
1.5 TR	1/2" OD	5/8" OD	3/8" OD
1.7 TR	1/2" OD	3/4" OD	3/8" OD
2.0 TR	5/8" OD	3/4" OD	3/8" OD
3.0 TR	3/4" OD	7/8" OD	3/8" OD
3.75 TR	3/4" OD	$1\frac{1}{8}$" OD	1/2" OD
5.0 TR	7/8" OD	$1\frac{1}{8}$" OD	1/2" OD

Ventilation of room

Cooling unit of the split unit is mounted directly inside the room, normally do not have any built-in provision to supply fresh outside air for ventilation of the room. In certain applications while using split units, the need and quantity of fresh outside air required may be considered and suitable external provisions may be made.

Compressor motor circuits & accessories

Capacity	Compressor motor circuit	Run capacitor	Start capacitor
1 TR	PSC/CSR	25 mfd	60/80 mfd
1.5 TR	PSC/CSR	36 mfd	80/100 mfd
2.0 TR	PSC/CSR	45 mfd	150/200 mfd

Drainage of condensate water:

When the air around the evaporator is cooled, the moisture in the air accumulates as water under the evaporator. This water referred to as 'Condensate' is collected in a pan under the evaporator and must be removed from the conditioned space. Therefore, wherever indoor units are mounted, there must be a gently sloping drain tube to carry this condensate water away from the room. If the water is not drained properly, it may collect in the drain pan until it overflows and drops into the room.

Remote Controller (Fig 3)

Functions

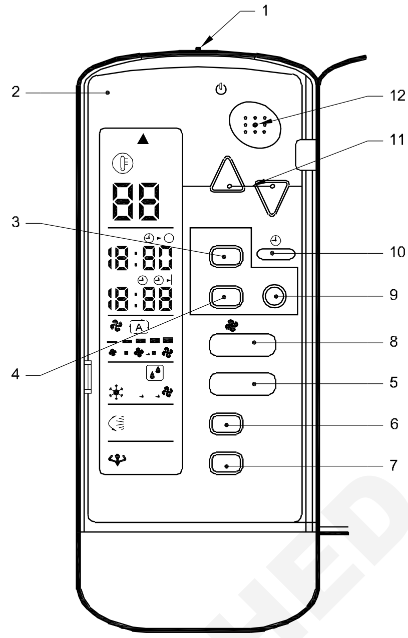
Transmitter

Sends signals to the indoor unit

Display: Displays the current settings. Each section is shown with all its displays ON for the purpose of explanation.

OFF timer operation: Timer functions are useful for automatically switching the air conditioner OFF. Press OFF timer while the air conditioner is operating 0:00 is displayed. Press up or down button and set the time. Press off timer once again. The timer lamp lights up.

Fig 2



1. TRANSMITTER
2. DISPLAY
3. OFF TIMER BUTTON
4. ON TIMER BUTTON
5. MODE SELECTOR BUTTON
6. SWING BUTTON
7. POWERFUL BUTTON
8. FAN SETTING BUTTON
9. TIMER CANCEL BUTTON
10. CLOCK BUTTON
11. TEMPERATURE/TIME ADJUSTMENT BUTTONS
12. ON/OFF BUTTON

REMOTE CONTROLLER

MRN2414522

ON timer operation: Check that the clock is correct. If not, set the clock to the present time. Press the ON timer button while the air conditioner is not in operation. The time is displayed. Press up or down buttons and set the time. Press ON timer again. To cancel the timer, press cancel, then the timer lamp goes off.

Mode selector button: Select a mode. Each pressing of the button advances the mode setting in sequence.

Swing: This can adjust the air flow direction. Every time the button is pressed the indicating lights appears or disappears to stop the flap at an angle, press the swing button and no display.

Powerful operation: Powerful operation quickly maximizes the cooling effect in any operation mode. Get the maximum capacity with this operation.

Fan setting: Selects the air flow rate setting.

Timer cancel: Cancels the timer setting.

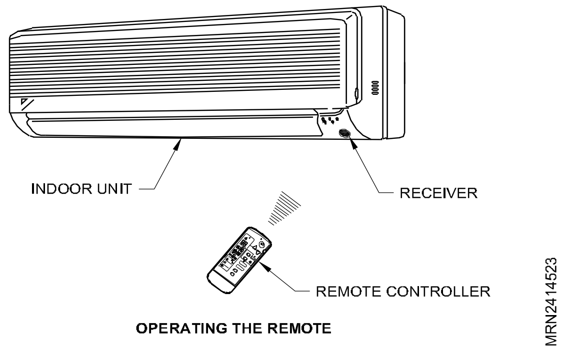
Clock: It is for setting the clock. To set the clock press up or down button.

Temperature/time adjustment: Change the temperature or time setting.

ON/OFF: To start operation press it once and to stop it press again.

To use the remote controller, aim the transmitter at the indoor unit (Fig 4). If there is anything to block signals between the unit and the remote controller, the unit will not operate.

Fig 4



OPERATING THE REMOTE

Caution: Do not drop the remote controller. Do not get it wet.

Only the split A/C cooling coil and blower will work inside the room, so the cool in the room feel very comfortable and will not be any noise.

The mounting of split A/C cooling coil is very easy with 2 clamp, where the window model A/C cannot be used. The split A/C can be fitted easily and the room can be decorated neatly.

Split A/C are available in 3 types:

1) Floor model 2) Wall mounting and

3) Ceiling mounting.

Important points for installation

The condensing unit can be fitted over evaporator. Also it can be mounted at the higher / lower (or) same level of the cooling coil.

Condensing unit to be kept very close to the cooling coil for minimising the gas quantity. The length of the pipe line also can be reduced.

The condensing unit should not be fixed above evaporator. Because there is no oil separator in sealed system for bringing back oil which travel in evaporator.

On condensing unit, sheet (shading) is provided for sun stroke.

Take care to avoid the air short cycling, otherwise compressor will trip with high condensation by OLP.

Specifications of split A/C

There are 3 types:

1) Direct mounted split A/C

2) Ductable split A/C

3) Multisplit

The outer unit of split A/C fan motor have single shaft with a capacity of 1/5 HP at 220V.

The indoor unit of cooling coil fan motor have double shaft with capacity of 1/32 HP at 220V.

There are 3 system in split A/C

1) Air flow system

2) Refrigeration system

3) Electrical system.

The Split A/C inner unit is covered with plastic and air louver for air direction.

The speed of fan motor is 800 rpm at 220V, 5 amps. for both indoor and outdoor unit.

The cooling capacity of 1 ton = 12000 BTU and for 1.5 ton is 18000 BTU. The compressor takes 8 to 9 amp. in full load at 220 volt. Refrigerant charge in split A/C is R 22.

Fan / blower motor bearing in split A/C

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

- **list the kind of bearing used in split AC blower motor**
- **explain in detail bush and ball bearing**
- **remove the existing bearing and fixing new bearing.**

Kind of bearing: There are two kinds of bearing used in split A/C.

- Bush (or sleeve) bearing
- Ball bearing

Bush bearing: Bush bearing usually made of bronze metal. Bush bearing used in window A/C in ½ " size with the motor shaft having ½" size. (ID ½" and O.D ½ " to 1")

Bush bearing has to be fixed manually by hand press method. Before fixing bearing to shaft, the shaft should be polished with fine emery. Absolute cleanliness is essential. Dirt and humidity are dangerous offenders. The type of manual fixing will give good result and eradicate bearing noise and increase bearing life.

Ball bearing: Ball bearing can be divided into 2 types Greasable and Non-greasable (sealed type). Ball bearing can be removed and refixed with bearing extractor of TMFT kit (Sleeve and impact rings). The most popular branded bearing comes in the name of SKF/NBC.

Detailed explanation of bush and ball bearing: Bush bearing (wick type): Bush bearing is usually made of bronze metal. Each individual bearing receives optimum heat treatment resulting in hardness between 59 to 63 HRC. There is a provision a the end shield to lubricate bearing with oil. Every 2 to 3 months, bush bearing should be oiled. Also while servicing fan motor bearing should be oiled to protect against corrosion to reduce wear.

When changing new bush bearing, readymade bushes are available which can installed manually when changing new bush bearing. Never use hammer to remove or fix bush bearing.

Ball bearing: Ball bearing comes in two types which commonly used in AK fan motor.

- Closed ball bearing (shield type)
- Open ball bearing

Closed ball bearing: this type of bearing has shield covered over bearing filled with grease for life time lubrications.

Open ball bearing: Both closed and open ball bearings are made in order to obtain desired structure, during heat treatment the structure of unhardened metal must confirm certain requirement. It is essential that in the annealed state the carbides are uniformly distributed as fine grains. This structure is also important for machining properties of material. Only high-grade greases, generally on a metal soap basis should be used to withstand extreme temperature. The high-grade greases used should be stable against deterioration and must not change in structure, besides to prevent inter-metallic contact between the rolling elements, race away and cage, to prevent corrosion of tear.

This type of bearing is used to stop worn out of bearing and have smooth performance of room A/C in the long run.

Removing old defective bearing and fixing new bearing: as explained earlier, bush bearing must be removed from shaft by hand or by using mallet (Never use iron hammer to remove ball bearing as it will damage the shaft of motor and the bush bearing will get damaged).

Ball bearing can be removed using puller.

Caution

- **Before removing bearing the end shield of motor should be marked with punch to get exact alignment.**
- **After fixing new bearing, Fix the end shield tightened the bolt and never use hammer to fix and shield as it will misalign the bearing or even damage the bearing.**

Wiring in split A/C system

Objectives: At the end of this lesson you shall be able to
- **describe the features of split A/C system**
- **explain the function of relay, thermostat**
- **explain about selector switch**
- **list the different models of wiring in split A/C.**

The working principle of split A/C: As you are aware of the working performance of window A/C, the functions of window A/C suits to this, one and only modified thing in that placement of units. In split A/C system low side/ high side in separated as outdoor and indoor unit duly connected with refrigerant lines with proper insulation.

In this system additional fan motor is provided in the indoor unit to provide evaporation and air (cold) through to the room/space required. In this split A/C system outdoor unit is fixed with single speed (high speed) motor (with propeller type blades). Indoor units are provided with blower model duly placed and lightened over shaft. The speed of fan motor will be 2 or more.

In this split units any mechanical repairs can be done without wasting gas in the system as unit is provided with service valve. Through that we can save the gas left by closing the service valves. After given all the wiring connections check once again for any improper connections (or) open up leads then correct it.

Use proper phased socket 15 amp/30 amp, connect the main chord with correct size plug. Use the socket with ON/OFF switch with indication lamp provision and correct hole. Insert the plug on the socket. Before switching on, check the Fan motor blade not touching the body (By hand movement, outdoor) and the blowers not touching the body (indoor).

After satisfied, with using and general check up start the unit initially and put the fan ON, wait and observe for few minutes, then change the switch of compressor to ON position. Check the ampere of the running unit and compare with supplier's manual.

Do not forget to connect the unit through voltage stabiliser (the capacity of the stabiliser should match the capacity or supplier's manual).

See that the feeler bulb of the thermostat properly clamped at correct location of feeler bulb clipping leads to A/C non stop running or short cycling.

The functions of the relay in the unit is to give extra energy needed through the starting winding of the (cuts the power supply at starting winding) compressor. Then compressor runs continuously with running winding.

The function of the starting capacitor is to give initial torque (extra energy) connected in series.

The function of the capacitor running is to increase the running torque and to create phase difference and power factor at the compressor.

The selector switch/master control used to switch OFF, ON the unit and to change the speeds of the indoor unit's fan motor low-medium-high.

Compressor line is connected through 'T' start. If the thermostat is found in OFF position/cut out position only, fan motor (indoor) will act along with turn off the selector switch, whenever compressor goes off/cut out the fan motor in the outdoor will not work in that way it is connected.

The filter is provided in the indoor unit is to filter the drawing air through the evaporator coil and in flushed out through the opening with cold air. As the draining area (evaporator area) is more, air collection will be more and is thrown out.

Filters used in advanced models are shown in Fig 1.

The wiring diagram of various split A/C units are given below (Fig 2a and Fig 2b)

Capacitors used for various units.

	1 ton	1.5 ton	2 ton
Start capacity	—	80/100mfd.	150/200 mfd.
Run capacity	25 mfd.	36 mfd.	45 mfd.

Fig 1

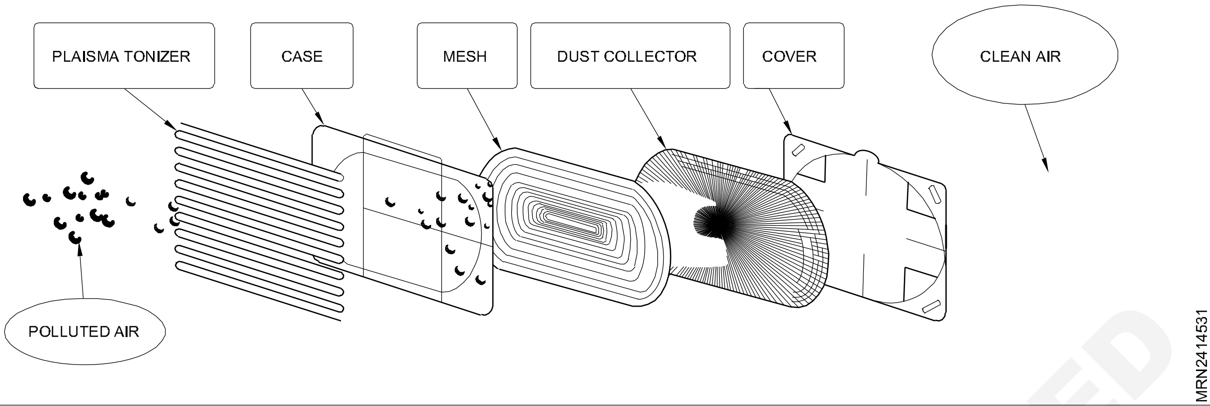
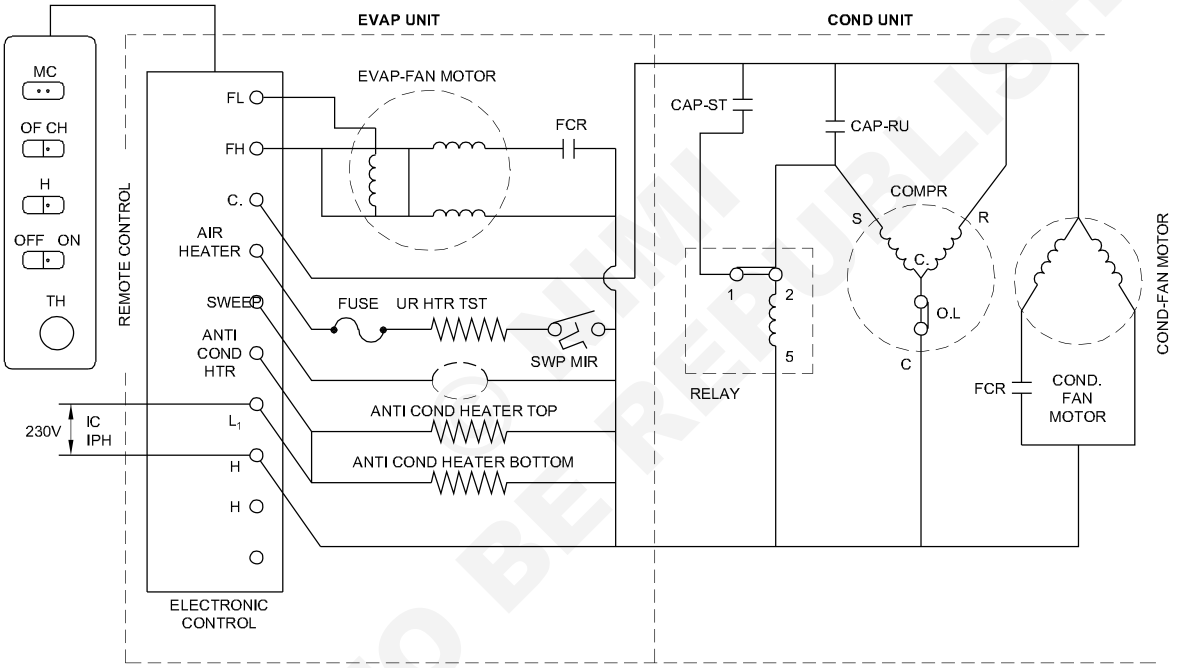
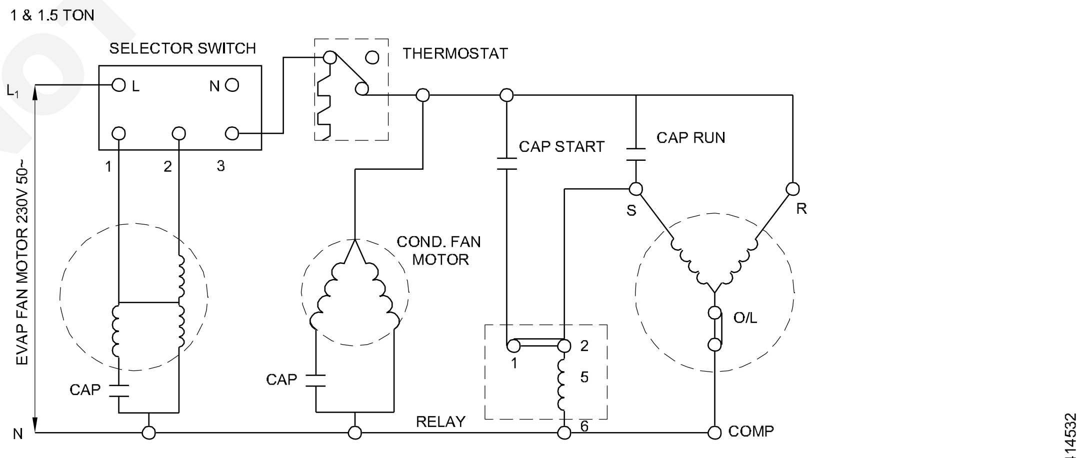


Fig 2



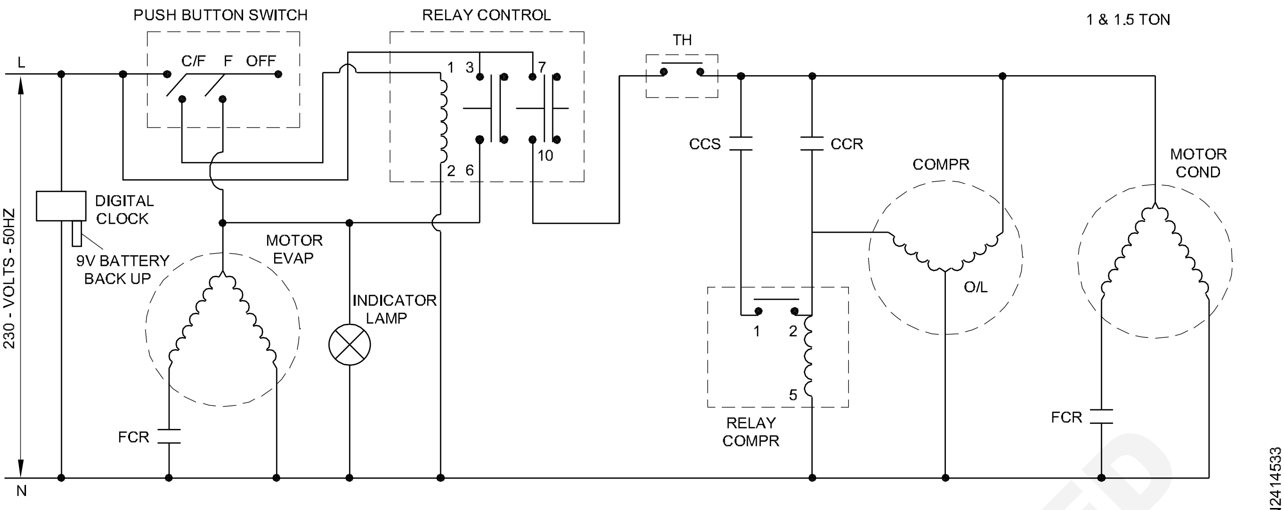
a) SPLIT UNIT AC 1.5 TON. CEILING MOUNTED



b) SPLIT ROOM AIR CONDITIONER(WIRING DIAGRAM)

Split A/C wiring diagram for 1 & 1.5 ton shown in Fig 3

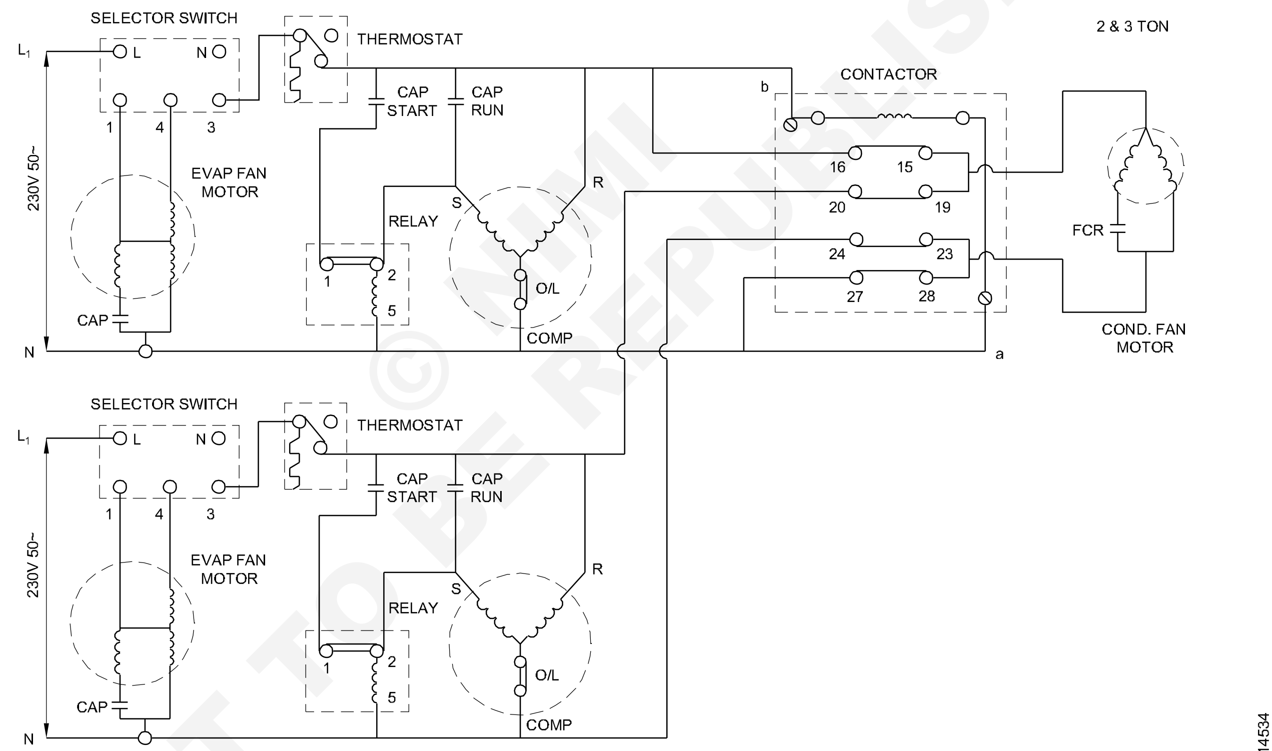
Fig 3



SPLIT A/C WIRING DIAGRAM

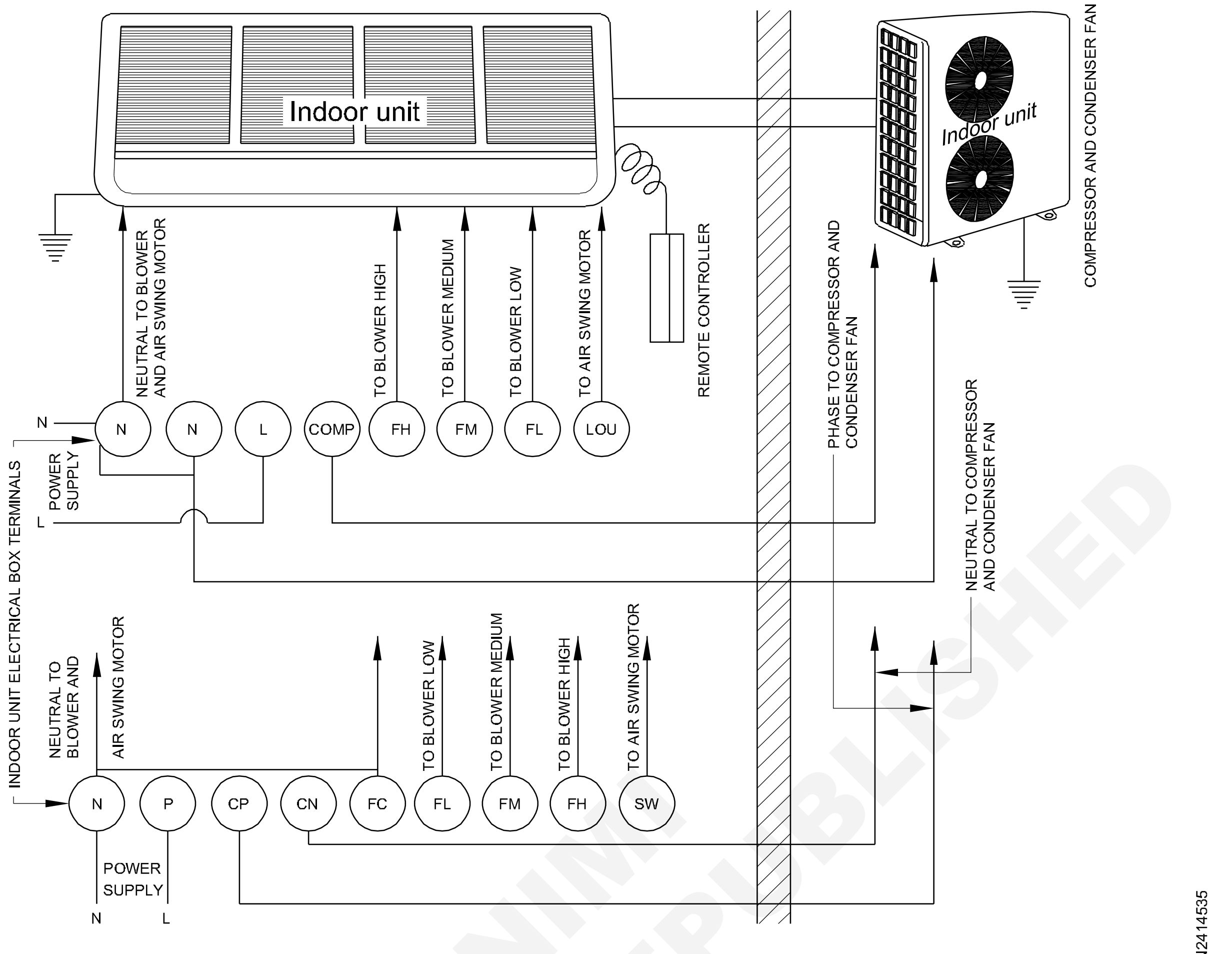
Split A/C wiring diagram for 2 & 3 ton shown in Fig 4

Fig 4



SPLIT A/C WIRING DIAGRAM

Fig 5



SPLIT A/C WIRING (DIFFERENT MODEL)

Tables (useful data)

	1 ton	1.5 ton	2 ton
Motor circuit	P.S.C	C.S.R	C.S.R.
Capacitor start	—	80/100mfd.	150/200mfd.

Capacitor run	25/440V	36/440V	45/440V
Running current	7 amp.	10 amp.	12.6 amp.

Split air-conditioner indoor unit (evaporators)

Objectives: At the end of this lesson you shall be able to
- **explain the features of outdoor unit of split A/C**
- **list the specification of indoor unit**
- **list the sizes of indoor unit (room unit).**

Indoor unit is the part of the split A/c system which consists of low side system. Indoor unit is placed inside the room where the area to be cooled.

Indoor units comes in various types depends on its positioning.

i) Wall mounted

ii) Floor mounted

iii) Ceiling type

All the indoor units are provided with fan having 2 or more speeds such as low, medium, high, three levels differentiate the speeds of increase in revolution of fan motor. Mostly all the indoor unit provided with blower(s).

Indoor unit works as recycling of air inside the room. It also controls the humidity contents of air. All the indoor units will be mounted where the air throw will not go out of the room (i.e. facing the door/entrance area).

Filters were placed in the front side of the unit covering the evaporator. This will be in easily movable position to clean it up/change periodically. The air inside the room was sucked through the evaporator fan motor and thrown back to the room depending on the throw of the model differs.

Indoor unit will be mounted inside the room at the corner near to wall or window so that the drainage line can be provided easily. Also the refrigerant line both suction/ liquid will be clamped on the wall. Suction line will be insulated for better refrigeration.

The motor inside the unit will be suspected and lubricated properly. Also the fan blower's cleaned/ serviced properly.

Rubber pads will have to be provided to avoid vibration of overall unit. If the unit runs with vibration, it will lead to pipe crack and leakage of refrigerant.

All the places should be insulated well to avoid air leak at the indoor unit. The I.D.unit should be installed in slight slope towards drain line side to facilitate the disposal of dehumidified water.

Clean the external surface of the evaporator coil with detergent water and insulate. If the refrigerant line connecting outdoor unit and indoor unit exceeds 40 ft, Add 90ml of oil extra to the compressor.

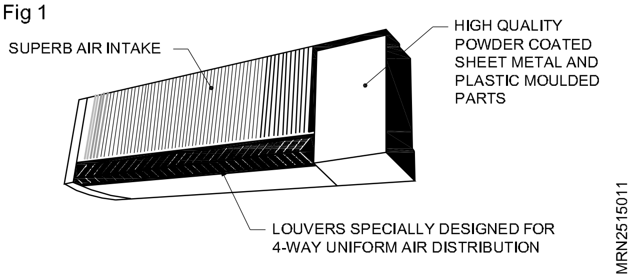
Thermostat will be positioned properly at the evaporator coil which will sense and cut the compressor after the unit reaches sufficient temperature. Insulating the room will have advantage of the unit working for shorter period.

Specification of Indoor unit

Indoor unit is shown in Fig 1.

Room unit sizes

Fig 1



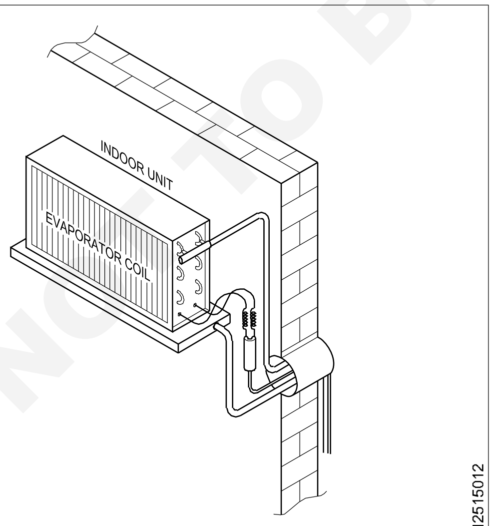
	1.5 TR	**3 TR**
L (mm)	600	936
D (mm)	388	440
H (mm)	574	580
W (mm)	33	48

MODEL	BTU/HR	Cooling coil size	Impeller motor	Blower of DLF	Apl.No.	R.P.M.	Air flow CFM	Suitable capacity	Size of unit L. H. D.
WM120	12,000	26"x 10" 2 Row	9"x4" 2 Nos	1/30 HP	CO41 3 speed	900/1000/1100	400	1.0 ton	34"x14"x 8.1/2" 864x356x 216 mm
WM180	18,000	26"x10" 3 Row	9"x4" 2 Nos	1/30 HP	CO41 3 speed	900/1000/1100	450	1.5 ton	34"x14"x 8.1/2" 864x356x 216 mm
WM200	20,000	37"x10" 2 Row	15"x4" 2 Nos	1/30 HP 3 speed	CO40	1000/1100/1200	500	1.75 ton	46"x14"x 8.1/2" 1169x356x 216 mm
WM240	24,000	37"x10" 3 Row	15"x4" 2 Nos.	1/30 HP	CO40 3 speed	1000/1100/1200	550	2.0 ton	46"x14"x 8.1/2" 1169x356x 216 mm

All specifications are approximate and are subject to change without notice due to a continuous R&D programme.

View of Installed Indoor unit is shown in Fig 2.

Fig 2



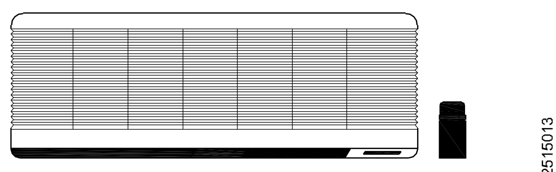
INSTALLED INDOOR UNIT

Some of the unit details (Indoor unit) are given below:

	1.5 ton	**2 ton**
Capacity	18,000 BTU/Hr.	24000 BTU/Hr.
	4,500 Kcal/Hr.	6,000 KCal/Hr.
Power supply	230V/50Hz/1 ph.	2301/50Hz/1 ph.
Power consumption	65 W	90 W
Fan motor	3 speed	3 speed
Current	0.3 amp	0.4 amps.
Air flow Ft/mm	450	550
M^2/hrs	765	950

The wall mounted indoor unit is shown in Fig 3.

Fig 3



THE WALL MOUNTED INDOOR UNIT

Outdoor/indoor unit of split AC system (floor/ceiling mounted)

Objectives: At the end of this lesson you shall be able to
- **explain the pump down the system**
- **explain the removal of indoor/outdoor unit's of split A/C**
- **explain the types of split A/C system**
- **explain the advantages of the system.**

As you all know split A/C system in the combination of the indoor unit and outdoor unit connected through refrigerant line (upper) are duly insulated.

The Outdoor unit is mounted at the top of the (floor) building, balcony, even mounted on the angle frames duly grounded in the wall. Outdoor unit consists of condenser, service valves (inlet and outlet) fan motor and propeller (for air throw). Some outdoor units mounted along with compressor, discharge line mounting frame. Outdoor units provided with fan motor(s) (two) according to the capacity of the unit.

The Indoor unit is always mounted inside the insulated room where cold air is needed. It comes of with cooling coil (evaporator), fan motor with blower (s) (scroll assembly) differs in air throw (top throw, side throw) and filter provision is made before the cooling coil to prevent moisture/dirt from the air which is drawn through.

Before removal of both the units, gas must be saved through storing at one of thfe unit by pump down the system. The main advantage of the pump down system is savage of refrigerant and also can be used the same refrigerant lines (copper) if possible.

Pump down system is the simple work by closing the outlet of condenser (provided with condenser outlet service valve) and run the unit. No possibility of gas (rest) passing over the condenser outlet all the refrigerant stand with in the condenser.

The pump down system can be checked by measuring through compound gauge mounted on the service valve. After completion of the pump down (to the satisfaction of the technician) stop the unit lines from the service valve connections by removing clamps (if any) for easy removal of pipes.

Cleaning and removing the copper lines will be an advantage of using the same for the installation (possibly). This removal of units (explained brief) is to reinstall or to use at some other position without much cost. Improper removal of indoor unit/outdoor units will create major problems in reinstallation also to change of electrical aspects.

During installing the unit, always maintain the distance between the indoor unit and outdoor units as follows,

Horizontal distance	40ft.	(12 mts.)
Vertical	20ft.	(6 mts.)

The oil charged is sufficient to operate upto the rated level (above). If the tubing is longer, compressor has to be charged with extra oil (i.e. 90ml. of every extra 3 ft.)

Now-a-days split A/C units becomes popular and comes out in many types as follows,

(A) Direct room mounted split unit

The evaporator unit of this type is available in three patterns suitable for:

i) Floor mounting

ii) Wall mounting

iii) Ceiling mounting

B Ductable split unit

In this type the evaporator is concealed and normally mounted above false ceiling and the cold air is supplied through ducting (G.I.) and delivered through the outlets (diffuser's in various models) located at the selected places.

C Multi split unit

This system offers the features of having individual room temperature controls. Now-a-days it is developed to maintain cool temperature at different (2 or 3) rooms simultaneously by having as many individual compressor and separate refrigerant circuits with single condenser at the outdoor unit (single),

Separate thermostat(s) is used to control the room temperature and is connected to the respective circuits for cutout, cut in operation.

Advantages of the split A/C units

In the recent years the split systems have been very popular because of their designs and latest developments etc. There are many advantages using the split units as follows:

i) They are an alternative for air-conditioning partition rooms (various rooms) where window models cannot be used or over cost.

ii) They are very silent in operation.

iii) The room side units can be tailor made or specifically selected to match the interior decorations of the room.

There are some disadvantages too which are,

i) Cost will be more.

ii) Extra care should be taken.

iii) Servicing of both the units will be done periodically.

iv) Wear and tear of the unit (outdoor unit) will be more as the unit is positioned to open atmosphere.

Various models of split units in use:

1	Outdoor unit with one fan motor/one compressor	> <	One indoor unit
2	One outdoor unit different rooms)	> <	Two indoor unit (for the one fan motor and two compressors
3	One outdoor unit/ two fan motor and two or three compressor (two fan motors connected in series) (Mostly ductable type)	> <	Two or Three indoor unit (For different rooms) Rest line given respectively.

Remote control

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

- **explain the working principle of remote**
- **know the technology of remote.**

Generally there are two types of remote controls: infrared (R), and radio frequency (RF). Infrared remote controls work by sending pulses of infrared light to a device, while RF remote controls use radio waves in much the same way. Pragmatically, the biggest difference between the two is range. IR remote controls require a clear line of sight to the receiving device and their range maxes out at about 30 feet (9.14 meters). RF remote controls can go through walls and around corners, with a range of roughly 100 feet (30.48meters). Most home entertainment components such as stereos, television and home entertainment centres use IR remote controls. The remote contain an internal circuit board, processor, and one or two light emitting diodes (LEDs).

When you push a button on a remote control, it transmits a corresponding code to the receiving device by way of LED infrared pulses. The idea is somewhat akin to flashing an SOS signal, but instead of letters, the flossing LED light is transmitting a series of 1s,and 0s. The “1” might be represented by a long flash, while “0”, a short flash. A receiver, built into the component, receives the pulses of light and a processor decodes the flashes into the digital bits required to activate the function.

Along with the desired function, remote controls must also piggyback other data. Firstly they transmit the code for the device they are controlling. This lets the IR receiver in the component know that the IR signals it is picking up are intended for it. It essentially tells the component to start listening. The function data follows, capped by a stop command to tell the IR device go back into passive mode.

Technology: The upto components, circuits and mathematics

Most control remotes for electronic appliances use a near infrared diode to emit a beam of light that reaches the device. A 940 nm wavelength LED is typical. This infrared light is invisible to the human eye, but picked up by sensors on the receiving device. Video cameras see the diode as if it produces visible purple light.

With a single channel (single-function, one button) remote control the presence of a carrier signal can be used to trigger a function. For multi-channel (normal multi-function)remote controls more sophisticated procedures are necessary, one consists of modulating the carrier with signal of different frequency. After the demodulation of the received signal, the appropriate frequency filters are applied to separate the respective signals. Now a days digital procedures are more commonly used. One can often hear the signals being modulated on the infrared carrier by operating a remote control in very close proximity to an AM ratio not tuned to a station.

Remote controller: Remote controller (The remote controller transmits signal to the system)

ON/OFF button

The appliance will be switched on or OFF on pressing this button

Mode button

Press this button to select the operation mode

FAN BUTTON

Used to select fan speed in sequence auto, high medium or low.

ROOM TEMPERATURE SETTING BUTTONS

Used to adjust the room temperature and the timer, also real time.

6th SENSE BUTTON

Used to enter fuzzy logic operation directly, regardless of the unit is on or off.

SWING BUTTON

Used to stop or start vertical adjustment louver swinging and set the desired up/down airflow direction.

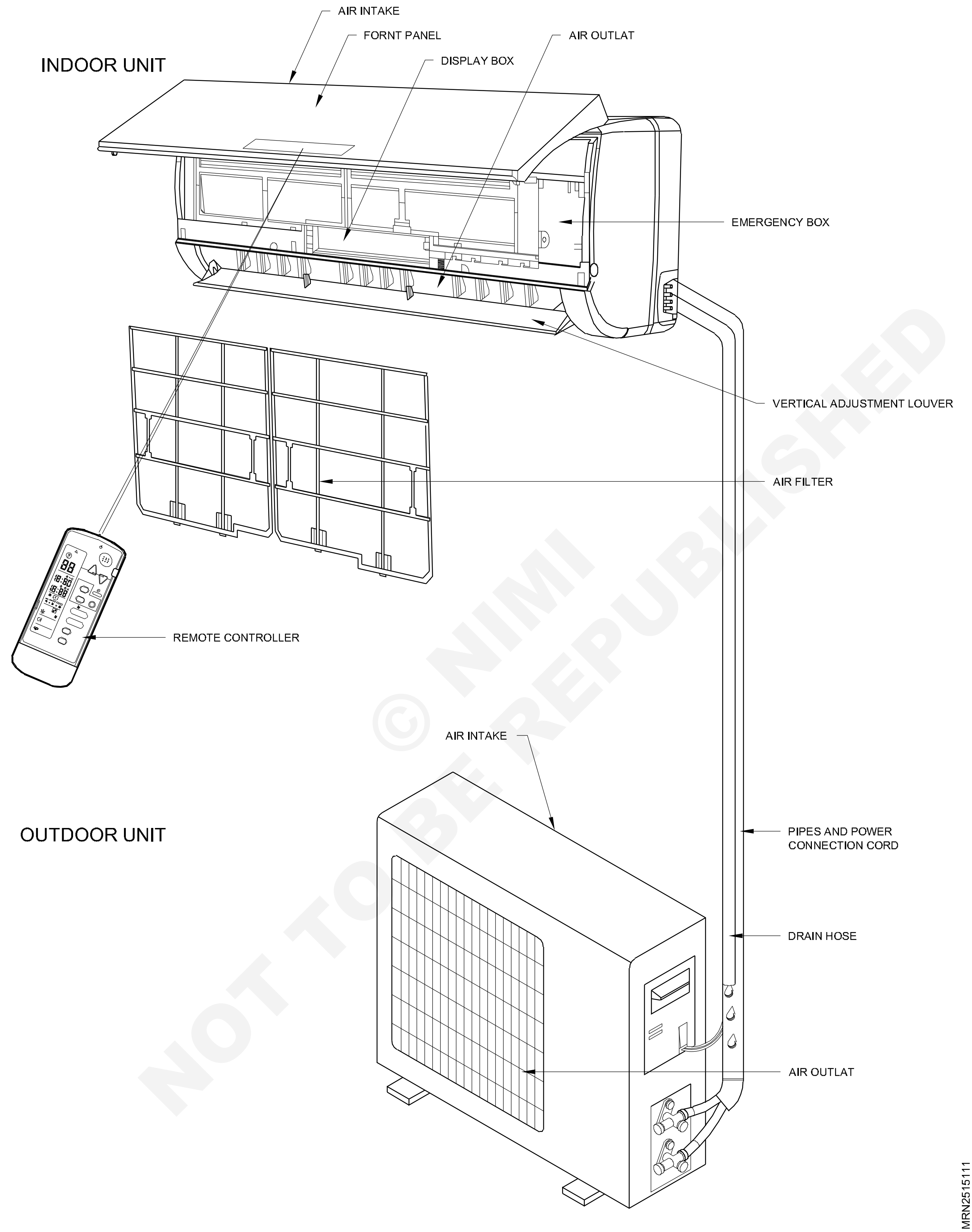
SLEEP BUTTON

Used to set or cancel Sleep Mode operation.

AROUND U BUTTON

Used to set or cancel AROUND U Mode operation.

Fig 1



POWER SAVER BUTTON

Used to enter or quit POWER SAVER mode

TIMER OFF BUTTON

Used to cancel the timer operation.

TURBO BUTTON

Used to start or stop the fast cooling

TIMER ON/CLOCK BUTTON

Used to set timer operation and clock.

Emergency button: ON/OFF to let the AC run or stop by pressing the button. The symbols may be different from these models, but the functions are similar.

DIM BUTTON

When you press this button, all the display of indoor unit will be switched off. Press any button to resume display.

Operation mode and temperature are determined by indoor temperature

Fig 2

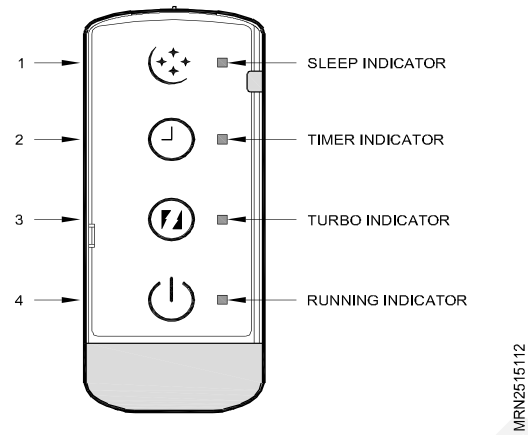
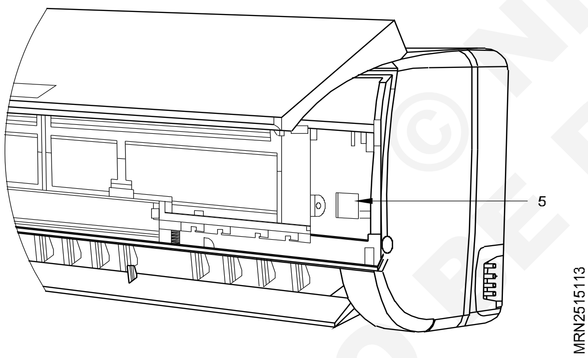


Fig 3



Cooling only models

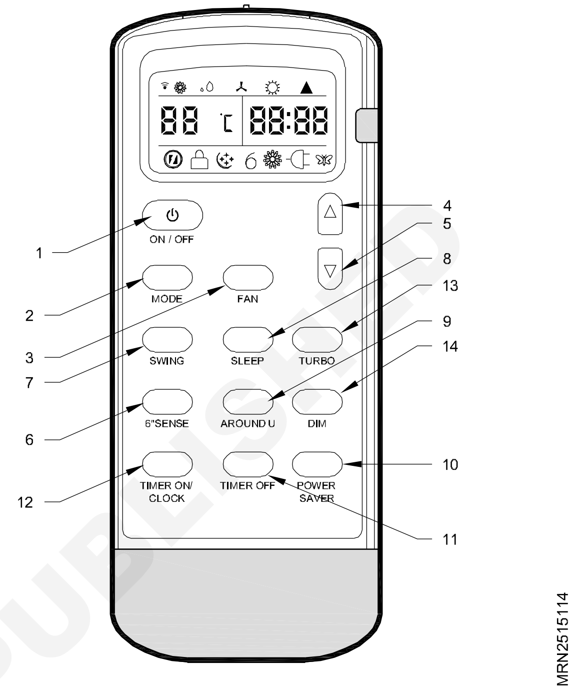
Indoor temperature Operation mode Target temperature

23°C or below FAN ONLY

23°C - 26°C DRY Room temperature decrease by 1.5°C after operate for 3 minutes

Over 26°C COOLING   26°C

Fig 4



Cassette mounted split AC

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

- **description of cassette A/C**
- **explain the parts of cassette A/C**
- **selection of location of indoor and outdoor units.**

Ceiling cassette A/C units are mounted as name suggests, in ceiling. This is most effective in a suspended (or) floating ceiling where there is room to accommodate the units. Since cold air falls towards the floor. It contains adjustable thermostats and variable speed fans, purification filters can also be used with then to filter the air of pollutants and other harmful particulate meaning the A/C can pull double duty as an air purifier.

The ceiling cassette A/C unit needs to have to be professionally installed. Lines need to be run from the condenser outside the building to the cassette in the ceiling, no more than 50 feet away.

Selection of location of indoor and outdoor units

Ensure the installation complies with the installation minimum dimensions and meets the minimum and maximum connecting piping length and maximum change in elevation.

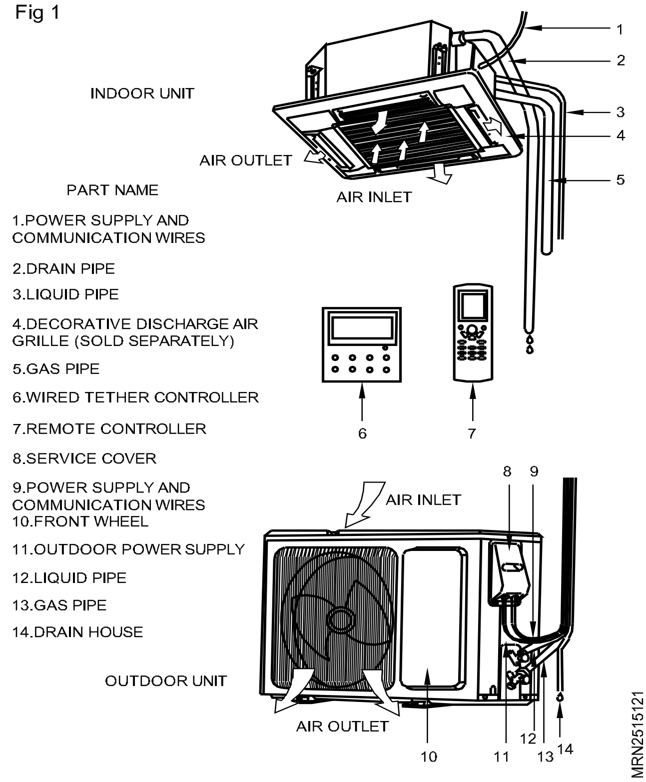
Air inlet and outlet should be clear of obstructions, ensuring proper airflow throughout the room.

Condensate can be easily and safely drained.

All connections can be easily made to outdoor unit.

Indoor unit is out of reach of children.

Fig 1



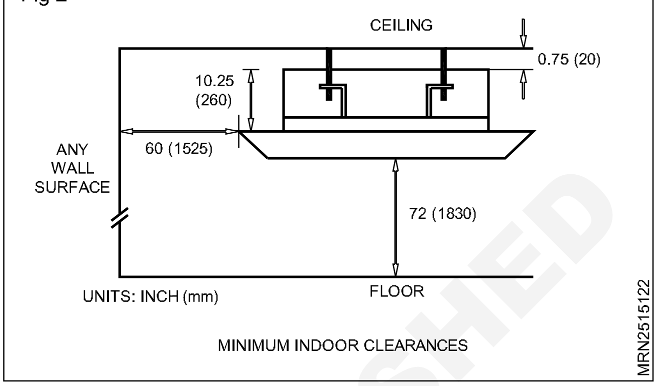
A structure strong enough to withstand four (4) times the full weight and vibration of the unit.

Filter can be easily accessed for cleaning.

Leave enough free space to allow for routine maintenance.

Do not install in a laundry room or by a swimming pool due to chemicals corroding cassette coil.

Fig 2



System Requirements

Pipe Size in (mm)

Unit Size (BtuH)	Liquid Line	Suction/Gas Line	Net/ Gross Weight
12,000	1/4 (6)	3/8 (9.5)	44/51 lbs
18,000	1/4 (6)	1/ (12)	48/55 lbs
24,000	3/8 (9.5)	5/8 (16)	64/84 lbs

Nomenclature

Examples: CAS18HP230V1AC

Series Designation

Cooling Capacity
12 - 12,000 BTUH
18 - 18,000 BTUH

Model Type
AC - Cooling Only
HP - Heat Pump

Product Type
S - System
O - Outdoor units
H - Indoor High Wall
D - Indoor Duct
C - Indoor Cassette

Revision Level

Style/Color Designation

Electrical Rating
230V - 208/230V 60Hz 1PH

Trouble shooting

Problem	Cause/Solution
System does not restart	**Cause:** The system has a built-in three minute delay to prevent short and/or rapid cycling of the compressor. **Solution:** Wait three minutes for the protection delay to expire.
Indoor unit emits unpleasant odor when started	**Cause:** Typically unpleasant odors are the result of mold or mildew forming on the coil surfaces or the air filter. **Solution:** Wash indoor air filter in warm water with mild cleaner. If odors persist, contact a qualified service professional to clean the coil surfaces.
You hear a “water flowing” sound	**Cause:** It is normal for the system to male “water flowing” or “gurgling” sounds from refrigerant pressures equalizing when the compressor starts and stops. **Solution:** The noises should discontinue as the refrigerant system equalizes after two or three minutes.
A thin fog or vapour coming out of the discharge register when system is running	**Cause:** It is normal for the system to emit a slight fog or water vapour when cooling extremely humid warm air. **Solution:** The fog or water vapour will disappear as the system cools and dehumidifies the room space.
You hear a slight cracking sound when the system stops or starts.	**Cause:** It is normal for the system to male “sounds from parts expanding and contracting during system starts and stops. **Solution:** The noises will discontinue as temperature after two or three minutes.
The system will not run	**Cause:** There are a number of situations that will prevent the system from running. **Solution:** Check for the following: • Circuit breaker is “tripped” or “turned off”
Problem	**Cause/Solution** • Power button of controller is not turned on • Controller is in sleep mode or timer mode • Otherwise, contact a qualified service professional for assistance.
The unit is not heating or cooling adequately	**Cause:** There are a number of reasons for inadequate cooling or heating. **Solution:** Check the following • Remove obstructions blocking airflow into the room • Clean dirty or blocked air filter that is restricting airflow into the system • Seal around door or windows to prevent air infiltration into the room • Relocate or remove heat sources from the room.

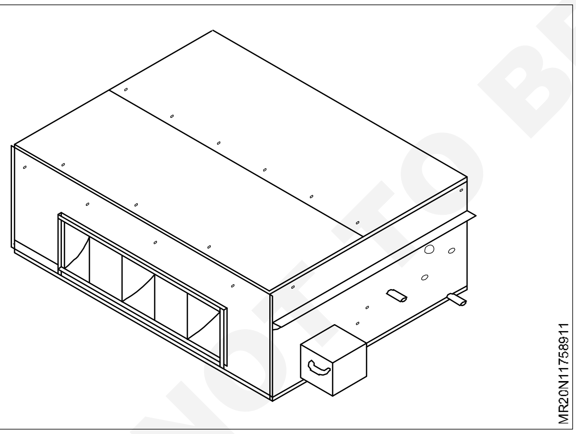
Problem	Cause/Solution
Water leaking from the indoor unit into the room	**Cause:** While it is normal for the system to generate condensate water in cooling mode, it is designed to drain this water via condensate drain system to a safe location. **Solution:** If water is leaking into the room, it may indicate one of the following: • The indoor unit is not level right to left. Level indoor unit • The condensate drain pipe is restricted or plugged. All restrictions must be removed to allow continuous drainage by gravity. • If problem persists, contact a qualified service professional for assistance
The unit will not deliver air	**Cause:** There are a number of system functions that will prevent air flow. **Solution:** Check for the following: • In heating mode, the indoor fan may not start for three minutes if the room

Description of the indoor unit

The indoor unit is a front discharge cabinet unit for installation in false ceilings, lofts and ventilation spaces. It is designed for horizontal installation with discharge via a duct (see selection catalogue for the available static pressure).

The unit's structure consists of powder coated insulated steel panels.

Fig 1



Description of the outdoor unit

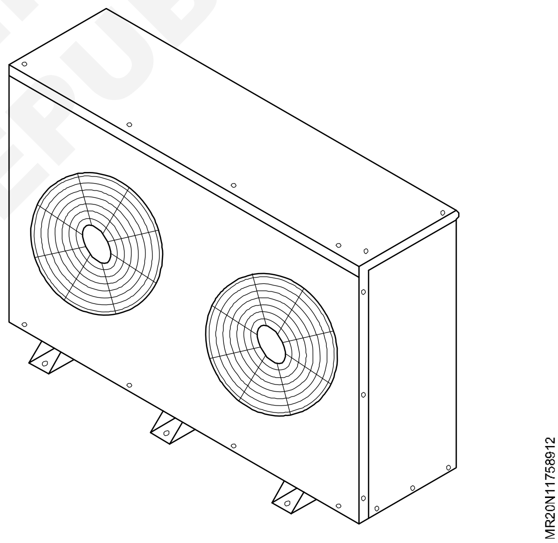
The outdoor unit is a front discharge cabinet unit for installation in open area like terrace parapet, etc. It is designed for horizontal installation with front discharge.

Installation

The Ductable unit6s are self-contained, assembled and pre-wired at Voltas Factory.

Water cooled units need field piping connection to the cooling water system. Main electric supply is to be connected to the unit condenser water pumps, cooling

Fig 2



tower fans etc. the air-cooled Ductable & package units are to be used in conjunction with matching remote air-cooled condensers.

Fieldwork includes interconnecting refrigerant piping, electrical power connection to the ductable & package units and the outdoor condenser units.

Air-cooled split units are supplied as a separate indoor unit and outdoor unit together with electric control box. Fieldwork involves interconnecting refrigerant piping, electrical connection to the outdoor condensing unit and the indoor evaporator unit.

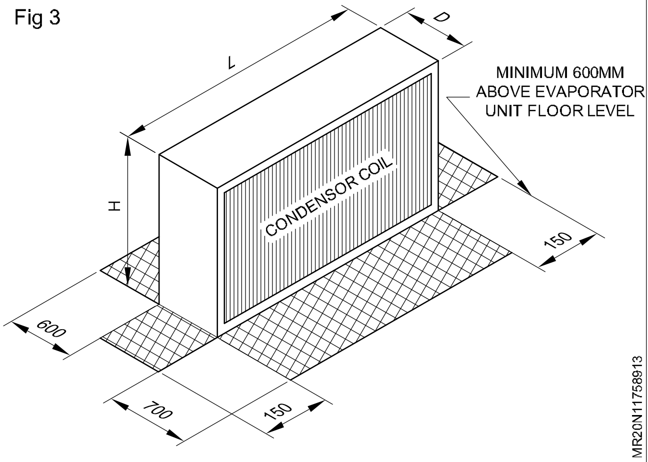
All ductable & package units need to be connected to the field ductwork with a canvass connection at the fan outlet.

Receiving and placement of the unit

Inspect the unit on arrival at site for transit damages. In case of damages, file claim immediately with transporter/ insurance company.

Ensure that the intimation of such damages are reported to voltas office/ dadra factory. Install the unit as per drawing, ensuring that adequate space is provided around for servicing filter and access to piping connections. Recommended clearance for the various units shown in figure below.

Fig 3



Service Clearance for condensing unit

To ensure proper functioning of air cooled condenser/outdoor unit, place the condenser unit such that

a) Adequate access is available for intake of fresh air and warm air to be thrown away without re-circulation.

b) Bottom of condenser coil is slightly above the expansion valve in the evaporator unit.

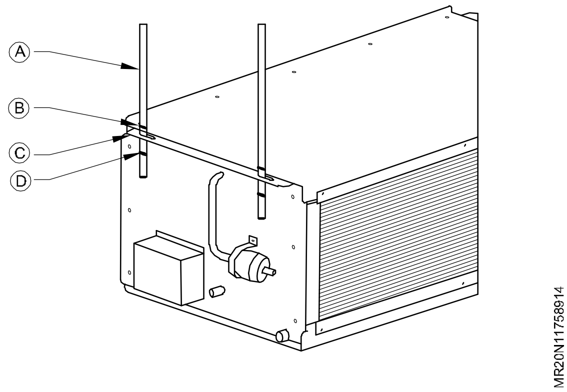
Ceiling installation

Preparation of the ceiling and installation of the unit

The angle on can be used to determine the drilling hole distances. Access must be provided on the pipe connection end to facilitate installation, maintenance and access to the cabinet. Four 8mm diam. Threaded rods (A) must be securely fixed into the building's slab or structure. Screw a nut (B) as shown in below figure sufficiently high onto each threaded rod. Put the unit angle (C) in place by holding those using a second nut D. make sure the unit is in level in both directions using the bottom nuts D. once they are perfectly level. Use the top nuts to tighten the unit.

In case the units are installed before completion of the ductwork, cover the supply air opening and protect filter from any dirt. If the units are to be stored for some reasons, move the units to a store and keep them in an upright position and cover the units with polythene sheets for protection.

Fig 4



Electrical connection

Electric power supply should be 415V 4 wire, 50 Hz AC supply complete with earthing as per local electricity rule, follow the control wiring schematic for the entire installation for local up different ductable units, condenser units,

Caution

a) Check the electrical characteristics on the unit's name plate. Make sure the wiring corresponds to the manufacturer's electrical diagram and local standards.

b) Power up the units using one or more lines protected by a disconnect switch and fuses.

c) Earth each unit.

d) The wires must not touch the refrigerant lines, the motors or other moving parts.

e) The manufacturer does not assume any liability for problems caused by modifications to the unit's internal wiring.

f) Tighten the terminals securely.

g) For the electrical connections, refer to the interconnection diagrams supplied with the device.

Ducting connection

Carry out ductwork as per drawing. Ensure all duct joints are properly made and adequate supports are provided to the ductwork. For installation where return air is taken back through RA ducts, ensure that entire ductwork (supply as well as return air ducts) is thermally insulated. Where return air is taken back around SA ducts, ensure adequate area around SA ducts for passage of return air is provided as required in the drawing. Check various RA opening in walls, partitions, etc. Check provision of the thermal and acoustic insulation on SA ducts as per drawing. Where false ceiling is to be provided, care should be taken to avoid supporting ducts on the false ceiling and vice versa.

Ensure that all grills, diffusers, dampers, etc. are provided as intended in the drawings. Ensure adequate provision of access door for duct dampers.

Air cooled units

In case of air-cooled ductable units, the room units must be connected to the outdoor condenser unit by adequately sized copper refrigerant piping. The piping route must be kept short and free from bends, as much as possible. Adequate protections must be provided to the pipes to avoid any mechanical damage, especially while running on the roof. A receiver should be installed in the liquid line immediately after the condenser installations where evaporator is located above the condenser. See below table for recommended copper refrigerant pipe sizes. A relief valve (400 psig) must be installed on the hot gas line near the air-cooled condenser or on receiver (if installed). In case of any doubt, manufacturer recommendation should be sought for proper sizing and routing of pipes.

"Model"	Connections Sizes OD		Equivalent Length of Line (m)*							
	(Inches)		7		15		25		35	
	L	S	L	S	L	S	L	S	L	S
5.5 TR	½	¾	½	¾	5/8	7/8	5/8	1-1/8	5/8	1-1/8
8.75 TR	5/8	1-1/8	5/8	1-1/8	5/8	1-1/8	5/8	1-3/8	5/8	1-3/8
11.00 TR	1/2x2	3/4x2	1/2x2	3/4x2	5/8x2	7/8x2	1/2x2	7/8x2	1/2x2	7/8x2
17.00 TR	5/8x2	1-1/8x2	5/8x2	1-1/8x2	5/8x2	1-1/8x2	5/8x2	1-3/8x2	5/8x2	1-3/8x2
22.00 TR	5/8x2	1-1/8x2	5/8x2	1-1/8x2	5/8x2	1-1/8x2	5/8x2	1-3/8x2	5/8x2	1-3/8x2

Drain Piping

Condensate from evaporator coil is collected in the drain tray provided underneath. Connect suitable size drain piping to the drain tray on convenient side of the unit and ensure that the other drain connection provided in the opposite side of drain tray is plugged. Provide adequate slope in the horizontal run of the drainpipe. PVC pipe can be used for disposal of the condensate drain but utmost care is to be taken to ensure that the pipes are supported at close intervals at 4 Ft. or so, so as to avoid sagging of pipes between supports. Though the sagged drain header may continue to allow condensate to flow over a period of time, fungus is likely to collect in the trapped water which will ultimately clog the drain. To ensure satisfactory condensate drainage, the drainage tube must be sloped 10°. If the pipe passes through a room, insulate it with nitrile rubber insulation to prevent damage caused by condensation.

Fig 5

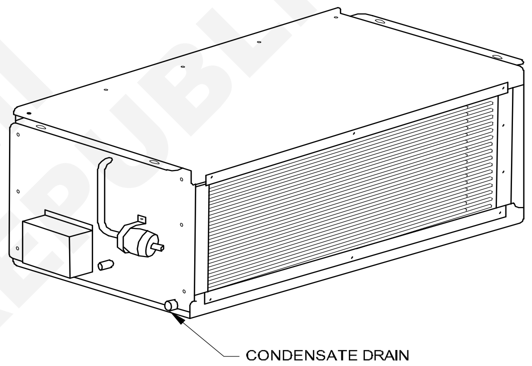
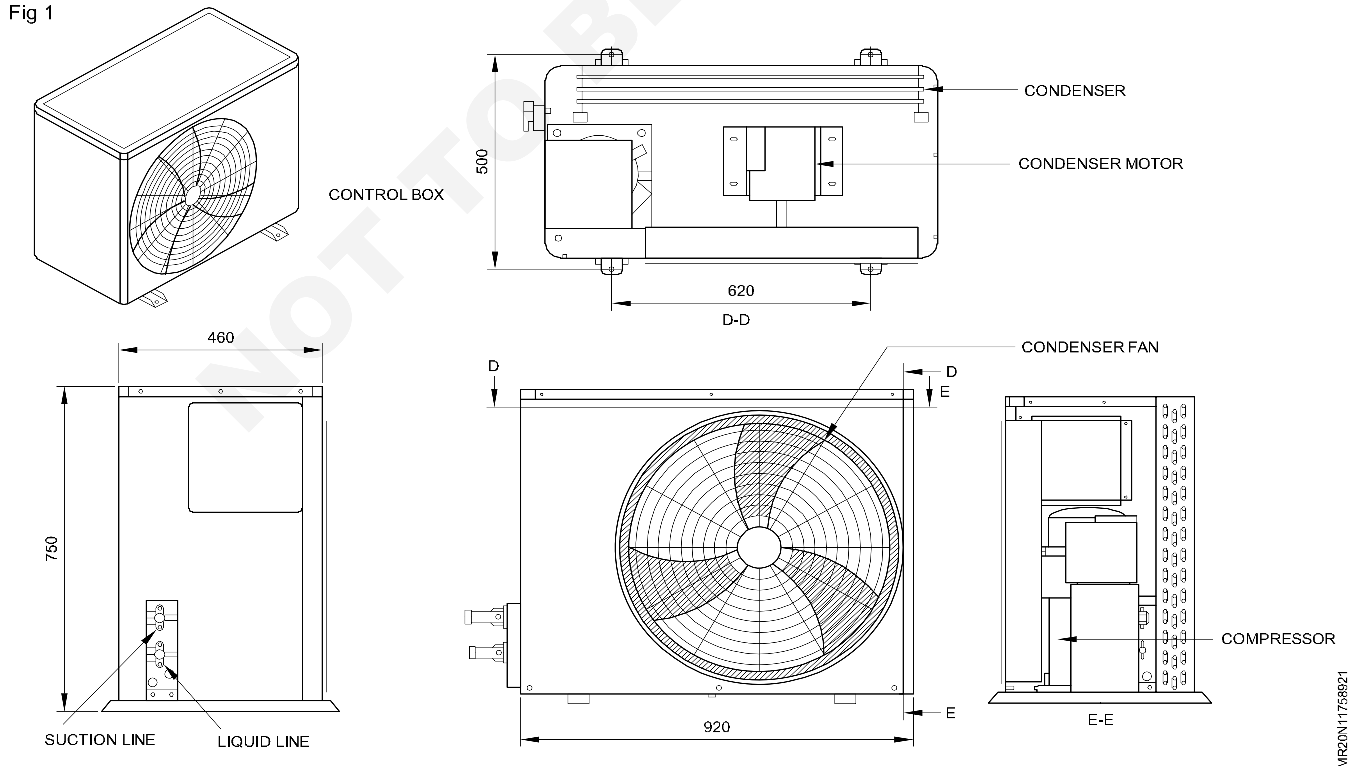


Fig 1



Safety provisions

The Ductable & package units are provided with following safety devices:

1 Refrigerant HP/LP pressure switch, LP is self-resetting type. (LP switch is provided for scroll compressors

2 Compressor motor winding thermostat, internal for compressors.

Where ductable units are installed with equipment such as heater, humidifier, etc additional hearter safety switches, level switches ect must be used.

Filtering: Important to ensure the unit runs smoothly.

No filters are supplied with the unit, they can be ordered as accessories.

A Pressure testing

Pressure testing (followed by vacuum test) a refrigerant circuit is essential: before refrigerant is charged in the system either initially or for up gas after a suspected leak. It is advisable to locate the leak, rectify and than charge gas after pressure testing (before pressure testing the remaining FREON gas should be removed into an empty cylinder. In case of a compressor winding burnout, the system should be thoroughly flushed with dry N2 to drive out contaminants generated in the system, before the compressor is replaced. It is imperative that a new catchall drier is fitted in circuit (after a burnout).

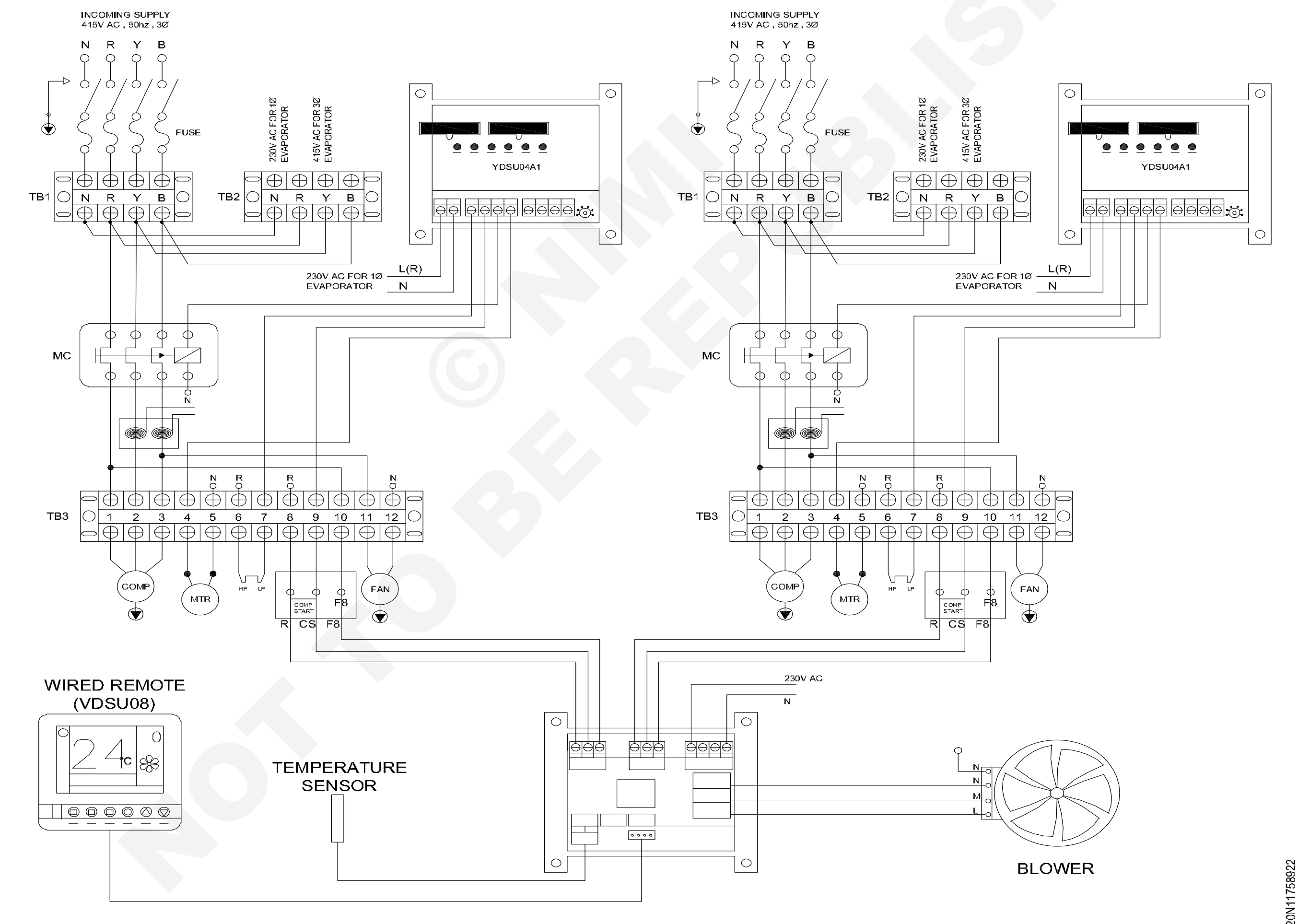
1 Charge dry nitrogen in the system by connecting cylinder at the compressor service valve and check pressure in the system. Charge nitrogen up to a pressure of 3 to 4 Kg/cm2.

2 Check all joints with soap solution. Locate all leaks.

3 If no leaks are found, increase pressure upto 10.5 kg/cm2 adding more nitrogen. Check for leaks

4 After all leaks are located, remove nitrogen completely by opening charging line. Repair leaks and retest. Do not start work unless entire nitrogen is removed from system.

Fig 2



WIRING OF 11.0TR,17.0TR & 22.0TR (TWIN CONDENSER)

Caution

Never use oxygen gas for pressure testing as fatal explosion may occur. Avoid use of CO2 for pressure test as CO2 gas may contain excessive moisture, which might remain in system. Do not use compressor to build pressure for leak test as overheating might damage the compressor.

Note

Minor leak suspected during operation can be located by using halide leak detector.

B Vacuumising and Charging of refrigerant

Evacuating the system by pulling deep vacuum enable dehydrating the system and removing of air (non-condensable)

1 In the event of a compressor burnout, it helps to remove carbon deposits and smoke that is generated. A good 2 stage vacuum pump should be employed to get vacuum down to5 microns (1 microns = 0.001 mm) of Hg absolute. A vacuum gauge for reading vacuum should be used.

2 Put a jumper line (1/4'' OD) to equalise high and low side on the compressor connect vacuum pump and vacuum gauge to the system. Open compressor services valves and start the pump.

3 Run pump till vacuum the boiling point of moisture (water) which will be about 0 Deg C. hence for normal ambient temperature (10 Deg C and above pulling a deeper vacuum

Trouble shooting chart

Symptoms	Possible Cause	Remedy
A Compressor fan or pump motor not working.	Power off.	Check and Restore supply.
	Blown fuses (s)	Replace fuses (s).
	Thermostat switch open	Check thermostat setting.
	Interlock not complete	Check control wiring and see that auxiliary equipment like pump, fans are running.
	Loose power connection.	Tighten connections.
	Improper wiring	Check and correct.
	Lower voltage	Provide adequate voltage.
	Motor winding open.	Disconnect power supply disconnect terminals at motor. Check resistance of winding. If resistance is infinite motor windings are open. Rewind stator, refit on compressor.
	Starter defective	Check starter contacts, plunger movement. Replace coil if burnt, with correct voltage coil.
	Tripped pressure switch or overload.	Reset switch, restart and observe operating pressure and current.
B Compressor short cycle on low pressure.	Low refrigerant charge restricted air flow over evaporator/ filter clogged.	Check and add charge clean or replace filters, check for closed dampers and fan motor drive.
	Expansion valve bulb/ capillary broken.	Replace power Element/Expansion Valves.
	Compressor service valves not fully open.	Open valves.
	Clogged refrigerant strainer or suction lines.	Clean strainer/line.
C Compressor OFF on high pressure.	Low condenser water (or air) flow and high water temp.	Provide adequate water/air flow to condenser. Check cooling tower performance.
	Fouled condenser tubes.	Descale/clean condensers.
	Air in system.	Purge system.
	Overcharges gas.	Remove excess charge.
	Faulty condenser pump (or fan). Condenser air short cycling.	Check and repair. Prevent by using suitable baffles. Service at proper intervals.
D Excessive noise in unit.	Inadequate lubrication	Service at proper intervals.
	Loose fan belt.	Tighten or replace entire set of belt.
	Damaged or loose components.	Tighten all bolts, compressor and fan mounts. Check compressor for broken parts. Check fan bearings.

	Loose fan section panel.	Fix properly.
E Unit operates continuously or far too long.	Shortage or refrigerant.	Check leak/repair and charge.
	Unit undersized.	Recheck design and accrual loads.
	Leaking suction.	Check compressor and repair.
	Defective thermostat.	Replace thermostat.
F High suction pressure	Excess load	Reduce load on system.
	Damaged compressor valve plates	Check/repair
G Frost on evaporator, distributor or suction line.	Lack of refrigerant.	Check leaks/repair and charge refrigerant.
	Clogged expansion valve.	Clean or replace.
	Low evaporator air flow.	Clean filters, coil check. V-belt drive and open dampers.
H Air conditioned space too warm.	Inadequate cooling.	Check above symptoms
	Excessive load on unit.	Recheck actual and design load, reduce load or install unit for additional capacity.
		Check air balancing.
I Air-conditioned space too warm.	Defective thermostat.	Check thermostat & control circuit.
	Compressor starter stuck in "ON" position.	Check starter and replace if necessary.
J Discomfort in air conditioned space.	Lack of air movement	Check fan belts, dampers and air filters.
	High humidity	Check fresh air infiltration, draw fresh air through unit.
	Inadequate cooling.	As per (H).

Air-distribution balancing in ducts

Objectives: At the end of this lesson you shall be able to
- **describe static pressure & air velocity**
- **explain air-distribution balancing in ducts**
- **reading the mechanical drawing of the plan**
- **explain common faults & remedy**
- **describe the safety requirements of duct system.**

Static pressure and Air velocity: Static pressure is the air pressure in a duct exerted by the air at its rest position. It has equal pressure in all the sides of the duct, while the velocity pressure is the air pressure above the static pressure in a duct exerted by the motion of air from the air supply source to the direction it is required to flow the sum of static pressure and velocity pressure is called the total pressure in a duct.

A pivot tube nano-meter is used for measuring total pressure and static pressure, velocity pressure is found out by subtracting static pressure from the total pressure.

Air velocity is the speed of air at which it leaves the fan or blower. It is measured by a voltmeter or anemometer.

Duck works: Ducts are like pipes and used to carry conditioned air to room supply and bring back the used air to the fan or blower of the air-condition plant.

They are distinguished as per its function as:

- Supply-duct
- Return duct
- Fresh air-duct

with respect to the shape, the ducts may be of three types.

- Round duct,
- Square or rectangular duct,
- Flexible duct,

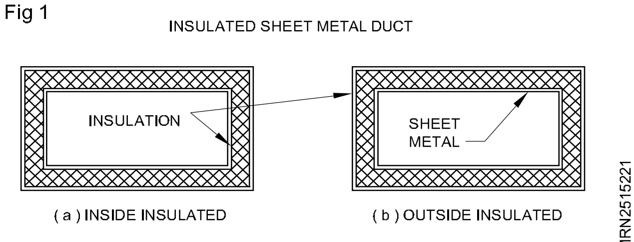
the other details of the ducts are explained in Related theory of Ex.

Duct insulations: When there is no change of moisture condensation on the duct, glass wool can be used, since it is economical and fire resistant. However if moisture condensation can occur, greater care should be taken in case of glass wool.

First a uniform coat of bitumen is applied to the duct surface and the glass wool is stuck to the bitumen. These insulation, then covered with a polythene sheet, which acts as a vapour barrier. The surface can be plastered after spreading chicken - wire mesh. But the insulation should be covered with fibre glass cloth to prevent the flying off of the fibres due to the air-velocity.

The insulations can be finished with covering by metal cladding. Many ducts are insulated either inside or outside to reduce noise, as well as heat transfer. (Fig 1a,b.)

Fig 1



Glass fibre ducting, which is self-insulating is often used in domestic and other small installations, where air velocities does not exceed 10 m/s and duct dimensions are not so large, to require structural supports.

In commercial and industrial, supply and return ducts are fabricated is galvanised steel or aluminium sheets.

The insulation is fastened to the duct with adhesives, in some cases metal clips hold the insulation in place.

Some standard sizes round duct branch elbows made of sheet metals with insulated inside. The elbows used in round & rectangular ducts are shown in Fig 2a,b,c.

The blowers out let connected to the duct, to avoid vibration a canvass covering is provided. In that canvass a zip arrangement also may provided, to measure the air temperature by thermometer.

The sheet metal which is covering the duct may tightened with self threaded screws or with proper rivets. The riveting method and the instrument used to rivet such joints are shown in Fig 3 a,b.

Diffusers & Grilles: The controlled air distributed to the rooms through the grilles or ceiling mounted diffusers.

Dampers: If controls the air flow in forced air systems. If not some spaces would receive too much of air, while others would not get enough air throw.

The method of getting even, air distribution through the use of duct dampers. The different types of dampers are used in air-conditioning plants.

Three types of duct air-flow controls are:

1 Butterfly damper

2 Multiple vane damper

3 Spliter damper

The adjustment handle which mentioned 'D' helps the opening and closing of the dampers. Fig 4.

Fig 2

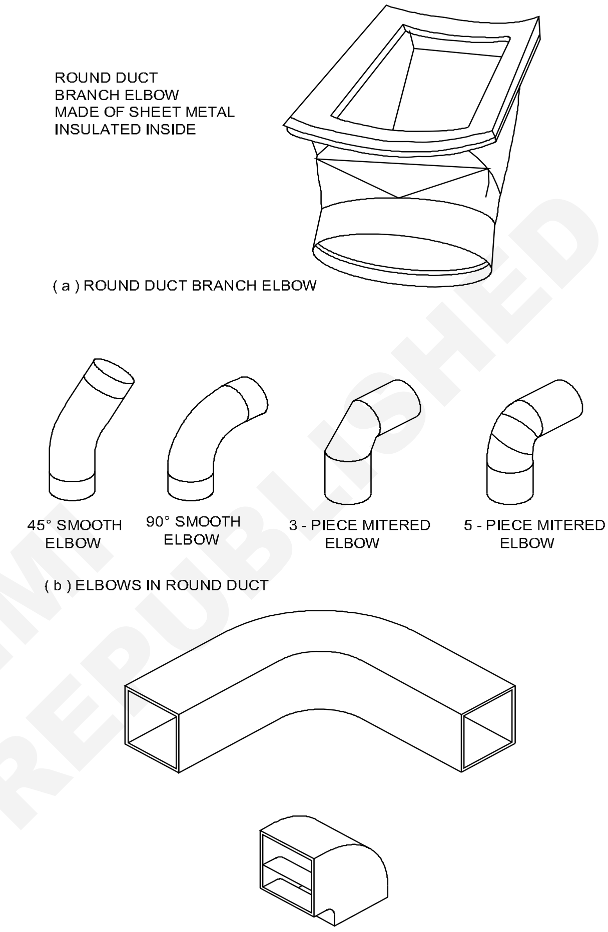
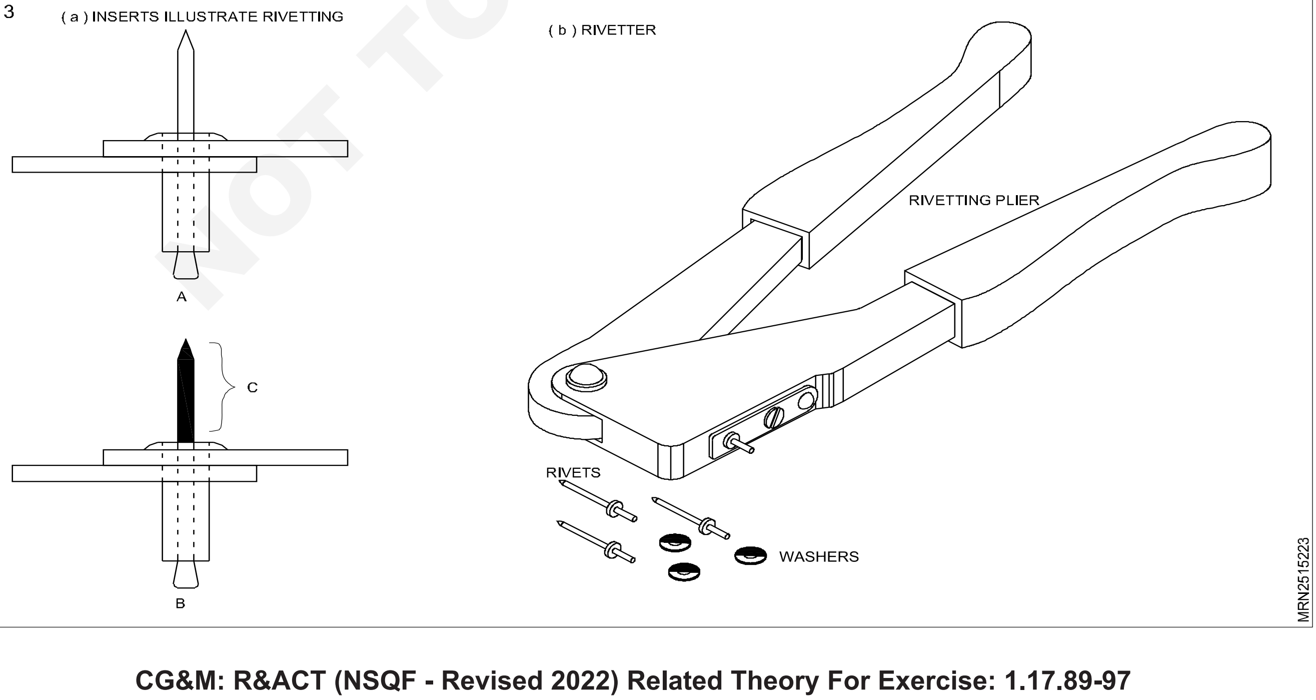


Fig 3



The damper balance the air flows or they can cut off or open certain ducts for zone control. Some are located in the diffusers or grilles and some are in the duct itself.

For accurate air control these dampers should be tight fitting with minimum leakage. Many are automatically controlled for cooling zones. Automatic controllers also used to mix two air flows for either fresh air and re-circulated air mixes, for humidity control or temperature control.

Reading the mechanical drawings: The most common is the plan view, which draws the equipment as if you were looking down from direct above. The elevation is the view looking from the side. Fig 5a,b.

The isometric drawing is the three-dimensional sketches used throughout the isometric drawings. They are the most easiest to visualize. But they are not accurate dimensionally.

The scales which given to the drawings, each section will be reduced scale of actual, for the convenient to draw.

Example: In a drawing a scale of 10 mm = 1m, means, that for each 10 mm length shown on the drawing, an actual real-life length of 1 m is represented.

Calculation: A room in 50 mm long on a drawing that has a 10 mm = 1 m. scale.

How long is the actual room?

Solution: You must determine how many 10 mm are there in the 50 mm, in length on the drawing.

(50 mm ÷ 10 mm = 5mm)

The actual room length is 5 m.

Another types of view that can be represented is section drawing. As if the equipment had been cut with a knife along the section line and every thing behind the section line stripped away. These kind of drawings are most useful to the manufacturer's level.

Common faults and remedies

The noise in an air-conditioning duct-system, sound emanates from the machinery such as fans, fan motors, air flow through ducts and diffusers.

The solution are:

1 Reduce the original source of the sound by using well designed equipment

2 Enclose the source in well insulated space

3 To absorb the sound using absorbing materials.

Fig 4 DIFFERENT TYPES OF DAMPERS

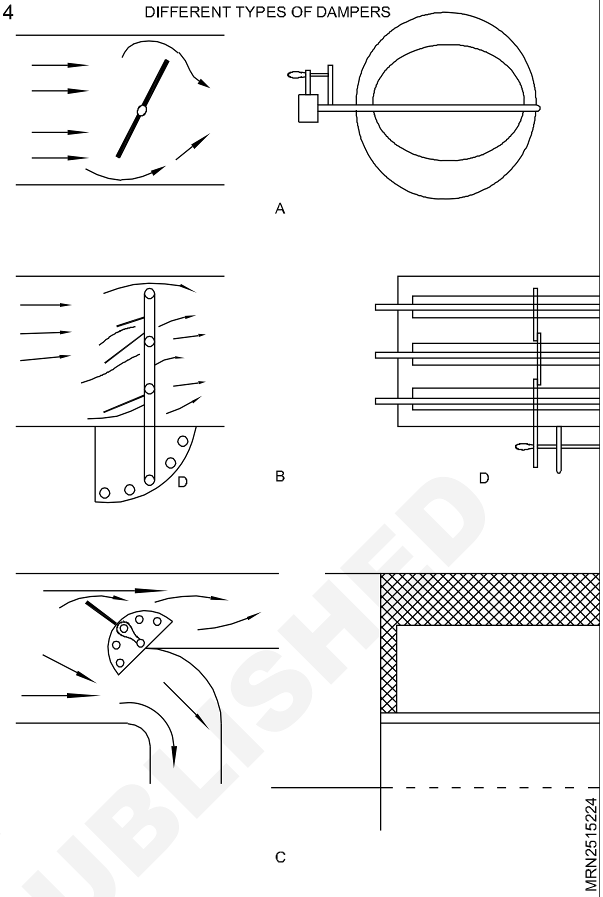


Fig 5a

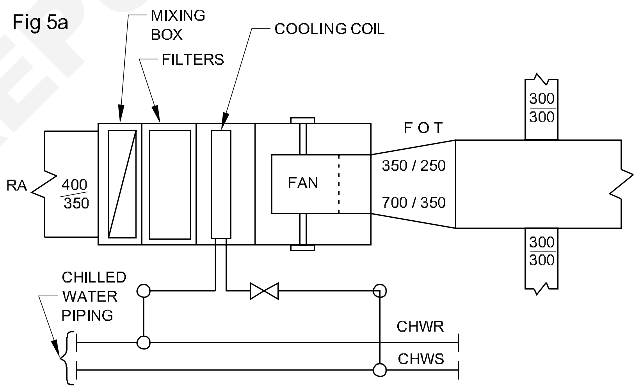
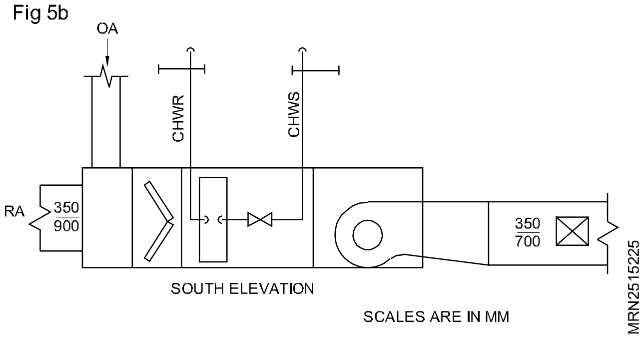


Fig 5b



Multi-split AC systems

Objectives: At the end of this lesson you shall be able to
- **multi-split systems**
- **advantages & draw backs**
- **how multi-split air conditioning works**
- **prons & cons of multi-split air conditioning**
- **system layout.**

Multi-Split Systems

A multi-type air conditioning system operates on the same principles as split type air-conditioning system however in this case there are multiple evaporator units connected to one external condensing unit. These simple systems were designed mainly for small to medium commercial applications where the installation of ductwork was either too expensive, or aesthetically unacceptable. The small-bore refrigerant piping, which connects the indoor and outdoor units requires much lower space and is easier to install than the metal ducting. Each indoor unit has its own set of refrigerant pipe work connecting it to the outdoor unit.

Advantage of Multi splits

The fact that one large condenser can be connected to multiple evaporators within the building reduces and/or eliminates the need for ductwork installation completely.

Multi-splits are suitable for single thermal zone (defined below) applications with very similar heat gains/losses.

Drawbacks

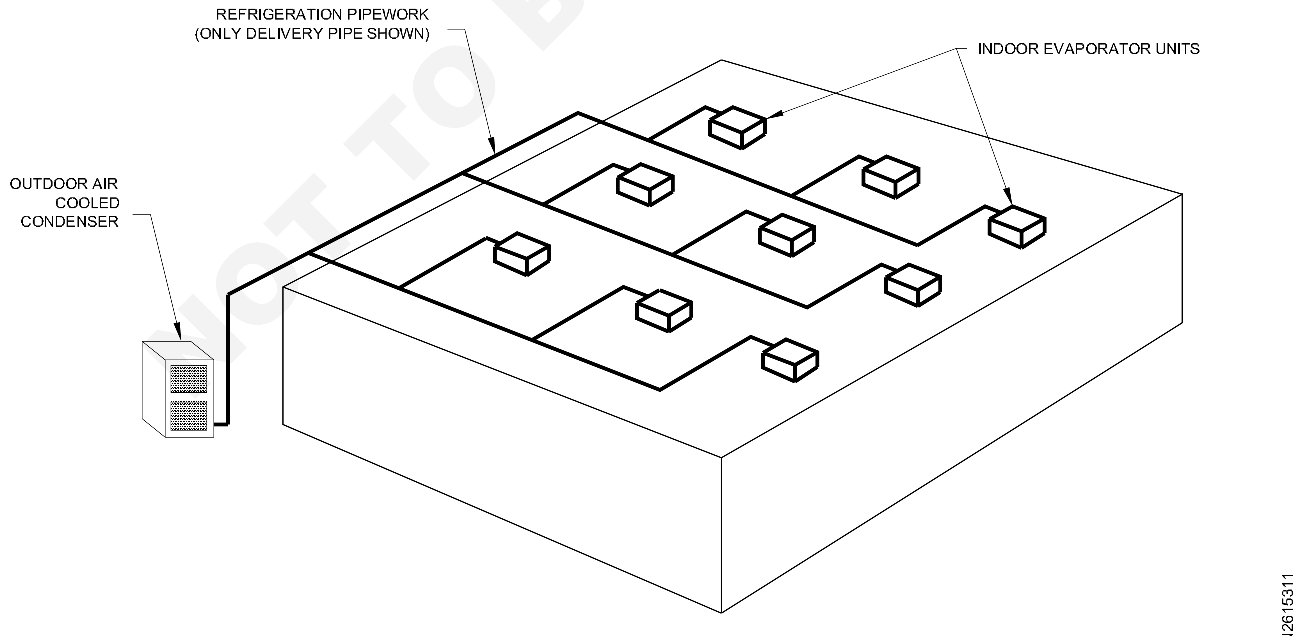
Inability to provide individual control;

There are many multi split air conditioners on the market today, and a variety of features is available.

Internal Technology - If you have ever used a regular forced air heating and cooling system, you know how frequently such equipment starts and stops. When the thermostat senses that more heated or cooled air is needed, the compressor kicks on. When the thermostat senses that the correct temperature has been achieved, the compressor kicks off. Significant amounts of energy are consumed every time the compressor turns off and on. Inverter technology, which is also known as variable-speed technology, eliminates this issue by allowing the compressor to operator at variable speeds. Equipment slows down and speeds up as needed to maintain a constant, comfortable temperature.

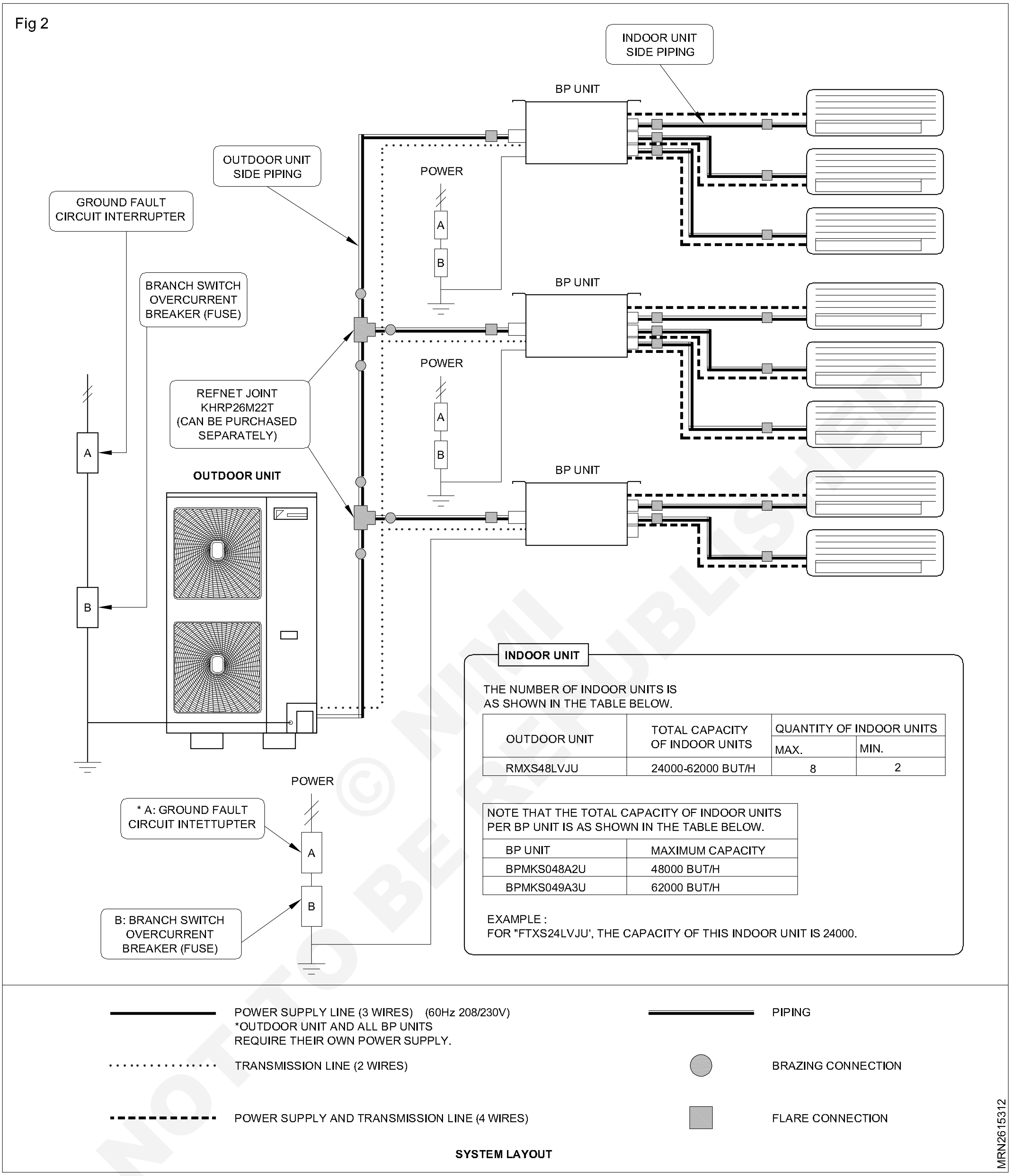
Heat pumps- while considering a multi split air conditioner vs. mini split air conditioner, you will notice that both options have plenty of similarities. For instance, they both rely on heat pumps to heat and cool the air. Heat pumps are prized for their energy-efficient operations. They use a lot less energy than traditional furnaces and air conditioners because they work with heat's natural tendency to move from warm areas to cool ones. A small amount of electricity is needed to move the process along. The heat pumps that are used in Mitsubishi Electric air conditioners are reversible models, which means they reverse the process using small amounts of extra energy, which allows them to both heat and cool a room.

Fig 1



TYPICAL MULTI SPLIT SYSTEM

Fig 2



OUTDOOR UNIT	TOTAL CAPACITY OF INDOOR UNITS	QUANTITY OF INDOOR UNITS	
		MAX.	MIN.
RMXS48LVJU	24000-62000 BUT/H	8	2

BP UNIT	MAXIMUM CAPACITY
BPMKS048A2U	48000 BUT/H
BPMKS049A3U	62000 BUT/H

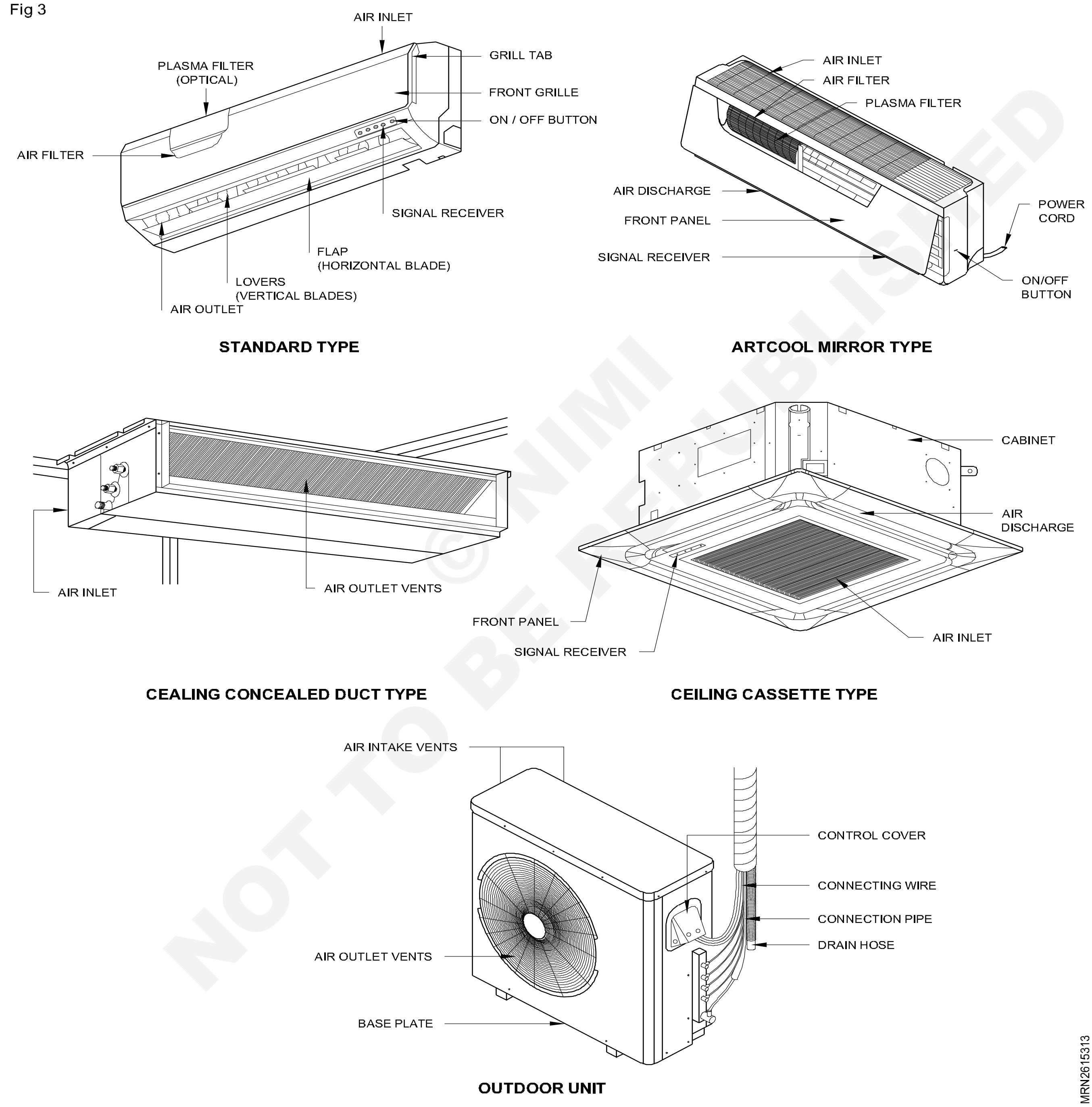
Sensors - Inverter technology goes a long way toward maintaining a consistent temperature. Specialized sensors improve upon this even more. They detect small changes in temperature and automatically make adjustments accordingly. In multi split systems, these sensors are located in each room, which ensures that the correct temperature is maintained in every zone.

Multi Split Air Conditioner vs. Mini Split Air Conditioner: Both multi split air conditioners and mini split air conditioners can heat and cool multiple rooms or areas in a home. The key difference between the two is that you can set different temperature for different rooms with a multi split system while the same temperature applies to all rooms with a mini split system.

Multi Split Unit Air conditioning systems: During the British summer, high air temperature and high relative humidity outdoors can sometimes combine to produce uncomfortably high temperatures - higher than 27°C or so - indoors. In these situations, air conditioning can cool, dehumidify band filter the air in your home or office creating a comfortable hygienic environment in which to live and work. Given the vagaries of the British weather, however and similar comments apply if you rent your home or likely to move home soon- you may not be able to justify the expenses of a fixed central air conditioning system. A split air conditioning system on the other hand is unexpensive in comparison and can be transferred from property to property as you desire. A split unit air conditioning system is capable of cooling your home unobtrusively via one, two, or more indoor sections connected to a single outdoor unit.

How Multi split unit Air conditioning works: Like any form of air conditioning multi split unit air conditioning works by extracting heat from the air of a room and discharging it outdoors. A multi split unit air conditioning, however, is so called because it "splits" the cold unit- the "evaporator" coil which is located indoors - from the hot unit- the condenser and compressor which are located outdoors, usually in a weather proof metal cabinet - for greater efficiency and less noise.

Fig 3



A chemical-known as a "refrigerant" which is easily transformed from liquid to gas, and back again, is pumped through the evaporator coil where it absorbs heat energy as well as moisture from the air in a room. The cool, dehumidified, air is circulated back into the room and the heat is carried away by the refrigerant to the outdoor unit where it is discharged. The refrigerant itself is compressed so that it once again becomes a low pressure liquid and the cycle is repeated until optimum air temperature is attained.

Pros & cons of multi split unit air conditioning

The fact that the outdoor unit of multi split unit air conditioning system can be located outdoors up to 50 or so away from the indoor unit- constraints on the size of components are less likely and the noise that is audible indoors. Split unit air conditioning systems also typically provide powerful outputs and good air distribution and so are suitable for cooling large areas. They also offer flexibility in interior design with all mounted. ceiling mounted or floor standing air handlers and the convenience of remote control, if indoor units are positioned out of reach.

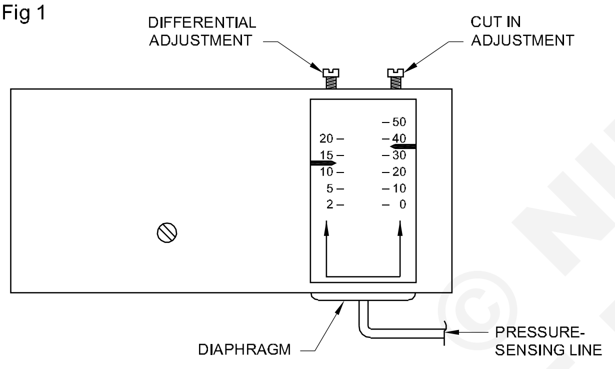
Split unit air conditioning systems do, of course, require the internal and external units to be connected together- usually via copper pipe - through an external wall. This may need to be done professionally but, in some cases, the drilling of a 3" hole is all that is required. Another consideration is the condensate drain pan- a feature of all multi split unit air conditioning systems- which may be susceptible to mould growth and bacteria which can be carried into the air stream passing over the pan. Special films are available to prevent any potentially hazardous micro-organisms from being circulated through your home.

Multi split system's controls

Objectives: At the end of this lesson you shall be able to
- **explain the function of all the electrical components of multi split system**
- **wiring diagram for indoor units combination with dual system kit.**

Low pressure cutout switch: When the suction pressure or evaporator pressure falls, the low pressure switch opens it's contact and stops the compressor motor. (Fig 1)

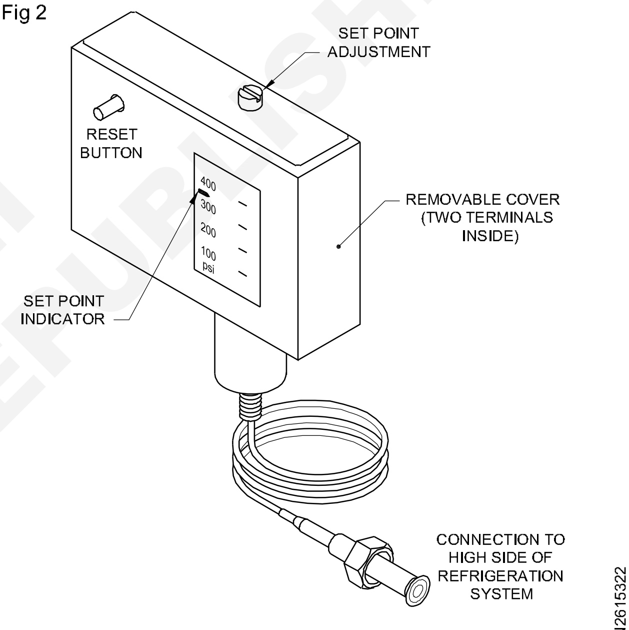
Fig 1



LOW PRESSURE CUT OUT

High pressure cutout switch: When the discharge pressure of the compressor exceeds a certain point, the high pressure switch opens its contact and stops the compressor motor. It is a manual reset. (Fig 2)

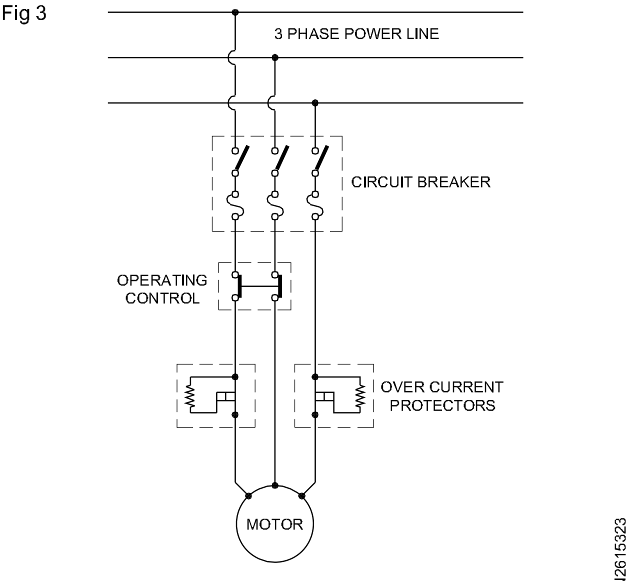
Fig 2



HIGH PRESSURE CUT OUT

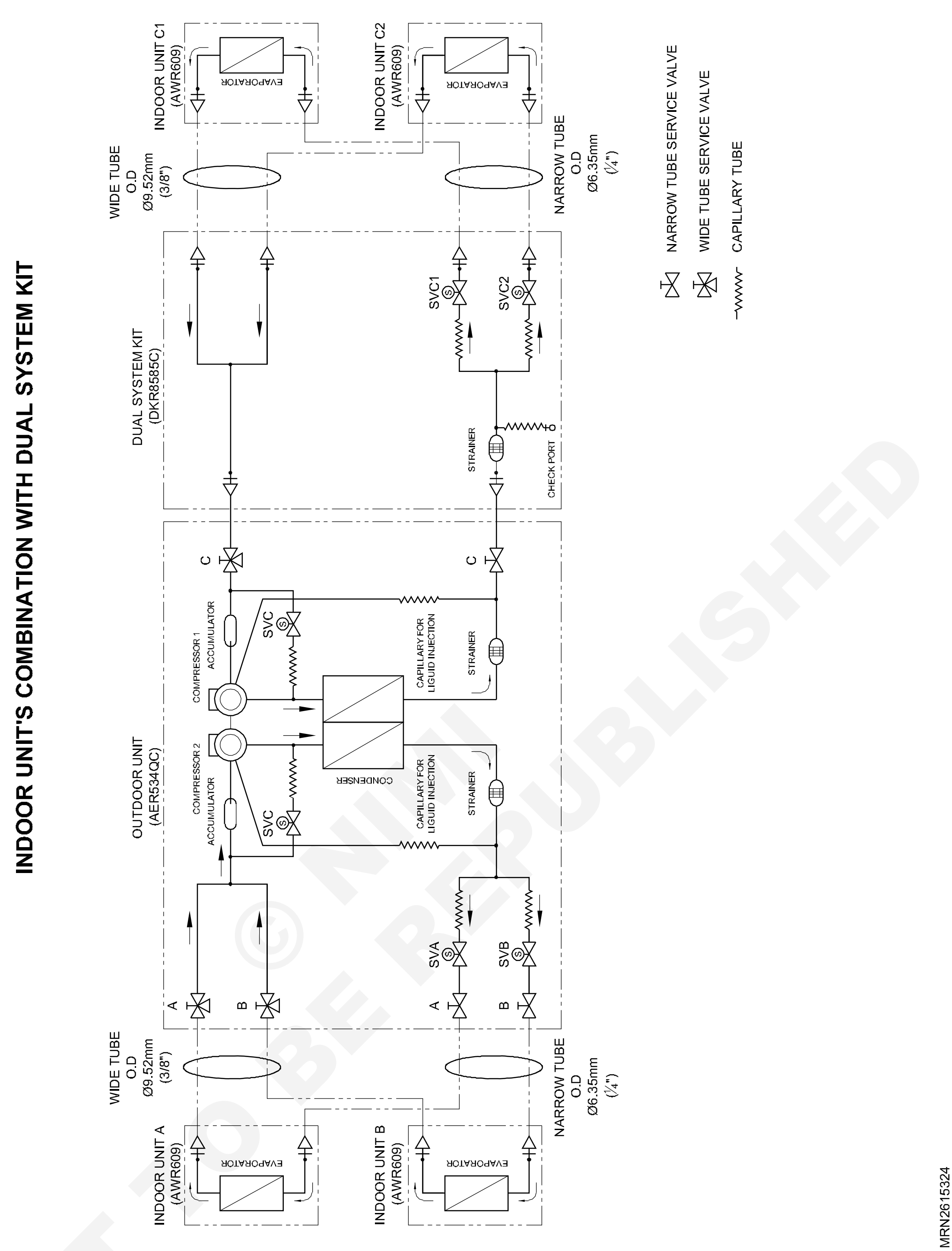
Electrical overload (over current protector): All air-conditioning units probably to be connected to separate circuits from the control panel. This applies to both domestic units and commercial units. The fuse or circuit breaker in the individual circuit should have enough capacity to provide a continuous flow of current under normal operating conditions. But they should open the circuit in the event of continuous overload of over 25 percent. (Fig 3)

Fig 3



OVER CURRENT PROTECTION 3-PHASE

Fig 4


INDOOR UNIT'S COMBINATION WITH DUAL SYSTEM KIT
INDOOR UNIT C1 (AWR609)
INDOOR UNIT C2 (AWR609)
EVAPORATOR
WIDE TUBE O.D Ø9.52mm (3/8")
NARROW TUBE O.D Ø6.35mm (¼")
DUAL SYSTEM KIT (DKR8585C)
SVC1
SVC2
STRAINER
CHECK PORT
NARROW TUBE SERVICE VALVE
WIDE TUBE SERVICE VALVE
CAPILLARY TUBE
OUTDOOR UNIT (AER534QC)
C
COMPRESSOR 1
COMPRESSOR 2
ACCUMULATOR
SVC
CAPILLARY FOR LIQUID INJECTION
CONDENSER
A
B
SVA
SVB
INDOOR UNIT A (AWR609)
INDOOR UNIT B (AWR609)
MRN2615324

Specifications

Unit specifications

Outdoor unit

Symbol of indoor unit				A,B:AWR609		C:AWR518
	Power source				220-240 v - 50HZ	
Performance					Cooling	
	Max.Capacity		kW		980	
			BTU/h		33800	
	Indoor unit(s)			A+B	C	A+B+C
	Capacity		kW	5.50	4.3	9.8
			BTU/H	19000	15000	33800
Electrical rating	Voltage rating		V		230	
	Available voltage range		V		198 to 264	
	Running amperes		A	10.9	9.5	19
	Power input		W	2350	2000	4050
	Power factor		%	94	92	93
	C.O.P		W/W	2.4	2.2	2.4
	Compressor locked rotor amperes		A	45/46/48	41/43/45	86/89/93
Features	Fan speed				2	
	Compressor				Rotary (Hermetic)	
	Refrigerant/Amount charged at shipment		g		R407c/A+B:1,300 C:1200	
	Refrigerant control				Capilary tube	
	Operation sound		dB-A		54	
	Refrigerant tubing connections					Flare type
	Max.allownce tubing length at shipment		m		A+B:15	C :7.5
	Refrigerant tube	Narrow tube	mm(in.)		A,B,C:6:36(1/4)	
	diameter	Wide tube	mm(in.)		A,B:9:52(3/8)	C : 12.7(1/2)
	Refrigerant tube kit				Optional	
	Dual system kit				Non	
Dimensions & weight	Unit dimensions	Height	mm		1,235	
		Width	mm		940	
		Depth	mm		340	
	Package dimensions	Height	mm		1343	
		Width	mm		1036	
		Depth	mm		421	
	Weight	Net	kg		108.0	
		Shipping	kg		116.0	
	Shipping volume		m^3		0.59	

DATA SUBJECT TO CHANGE WITHOUT NOTICE

Remarks: Rating conditions are:
Indoor air temperature 27° C D.B/19°C W.B.
Outdoor air temperature 35°C D.B./24°C W.B.

Major Component Secifications

Outdoor unit

Symbol of indoor unit		A,B:AWR609 C:AWR518 or C1,C2: AWR609	
Compressor	Type	Rotary (Hermetic)	Rotary(Hermetic)
	Compressor Model name Qty	C-2RN170H5W...1(CM1)	-2RN150H5W...1(CM2)
	Code No.	80807045E	80805045C
	Nominal output W	1700 1500	
	Compressor oil cc	750 750	
	Coil resistance (ambient temp.25°c) Ω		C-R:1:35 C-R:1:42
		C-S:3.42	C-S:4.12
	Safety devices Type	Internal protector	Internal protector
	Overload relay ..Q'ty	-	-
	Open °C	160±5 170±5	
	Operating temp Close	°C 100±11	105±11
	Operating amp.(Ambient temp.25°C)	Trip in 6 to 16 sec.at35A	Trip in 6 to 16 sec.at35A
	Run capacitor...Qt'y	µF 40	35
	VAC	450	450
Fan & Fan Motor	Type	Propeller	
	Q'ty...Dia mm		2... 460
	Fan motor model...Q'ty	KFC6T-91C5P...1(upper)	KFC6T-9K5P...1(lower)
	No.of poles...rpm (230V,High)	6...778	6...778
	Nominal output W	66	66
	Coil resistance (Ambient temp.20°C) Ω	WHT-BRN:127.3	WHT-Violet:56.73
		Violet-YEL.15.04	YEL-PNK.23
	Safety devices type	Internal protector	Internal protector
	operating temp. open	°C 130 ± 8	130 ± 8
	close	79 ± 15	79 ± 15
	Run capacitor µF	5.0	6.0
	VAC	400	400
Heat Exch coil	Coil	Aluminimum plate fin/copper tube	
	Rows	1	
	Fin pitch mm	1.3	
	Face area m^2	0.456 x 2	
External finish		Acrylic baked-on enamel finish	

DATA SUBJECT TO CHANGE WITHOUT NOTICE

Other component specifications

Outdoor unit

Relay	**MCS24A2F1**
Coil rating AC 240V Coil resistance kΩ (at 20°C) Contact rating AC 250V, 5A	15.5±15%
Power Relay (PR1,PR2)	**G7L-2A-TUB**
Coil rating Coil resistance kΩ (at 23°C) Contact rating	AC 220/230/240V, Single Phase 50Hz 21±15% AC 250V, 25A
Thermostat (Fan speed control)	**YTB-4U201F**
Switching temp. °C	high LOW $24°C^{+1.5}_{-0.5}$ low HIGH 26°C± 1.5
Timer (T)	**H3Y-2**
Rating Operating time	AC 220V,50/60Hz 3 minutes
Solenoid valve	**NEV-MOAJ503BO(Coil), NEV202DXF (Valve)**
Rating Coil reistance kΩ (at20°C)	AC 240V,50/60Hz 7/6W,45/35mA 1.15±7%
Relay (R1,R2)	**MY2-02-US-TS**
Coil rating Coil resistance Ω (at 20°C) Contact rating	AC 240V 650±15% AC 240V, 4.4A
Solenoid Valve (SVC1,C2)	**NEV-MOAJ503BO (Coil), NEV202XF (Valve)**
Rating Coil resistance kΩ (at 20°C)	AC 240V,50/60Hz 7/6W,45/35mA 1.15±7%
Timer(T)	**H3Y-2-0**
Rating Operating time	AC 200-230V, 50/60Hz 3 minutes

Multi - split AC system compressor

Objectives: At the end of this lesson you shall be able to
- **explain about replacing compressor**
- **explain refrigerant in leaking**
- **describe about charging additional refrigerant.**

In case of compressor malfunction

Should be compressor malfunction, be sure to replace compressor as quickly as possible.

Use only the tools indicated exclusively for R407C. Tools specifically for R407C".

Procedure for replacing compressor

1. Recovering refrigerant

↓ ok

2. Replacing compressor

↓ ok

3. Checking for sealing

↓ ok

4. Evacuation

↓ ok

5. Recharging

Recovering refrigerant

Any remaining refrigerant inside the unit should not be released to the atmosphere, but recovered using the refrigerant recovery unit for R407C.

Do not reuse the recovered refrigerant, since will contain impurities.

Replacing compressor

Soon after removing pinched pipes of both discharge and suction tubes of the new compressor, replace it quickly.

Checking for sealing

Use nitrogen gas for the pressurized gas, and never use a refrigerant other than R407C. Also do not use oxygen or any flammable gas.

Evacuation

Use a solenoid valve-installed vacuum pump so that even if power is cut off in the middle of evacuation of air due to a power interruption, the valve will prevent the pump oil from flowing back.

The equipment may be damaged if moisture remains in the tubing, thus carry out the evacuation thoroughly.

When using a vaccum pump with exhaust air volume more than 25L/min. and ultimate vaccum pressure rate of 0.05T or:

Standard time of evacuation

Length of tubing Less than 10m
More than 10m

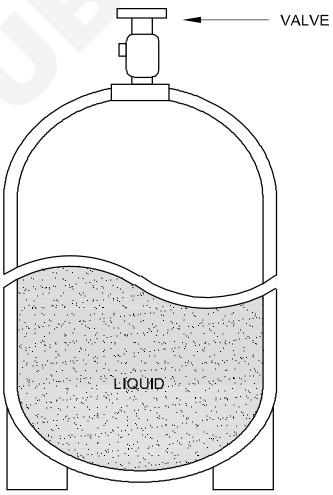
Time More than 10 min More than 15 min.

Recharging

Be sure to charge the specified amount of refrigerant in liquid state using the service port of wide tube service valve. The proper amount is listed on the unit's nameplate.

When the entire amount cannot be charged all at once, charge gradually while operating the unit in cooling operation.

Fig 1



MRN2615331

Never charge a large amount of liquid refrigerant at one to the unit. This may cause damage to the compressor.

When charged with a refrigerant cylinder, use the electronic scale for charging refrigerant. In this case, if the volume of refrigerant in the cylinder become less than 20% of the fully-charged amount, the composition of the refrigerant starts to change. Thus, do not use the refrigerant if the amount in the refrigerant cylinder is less than 20%.

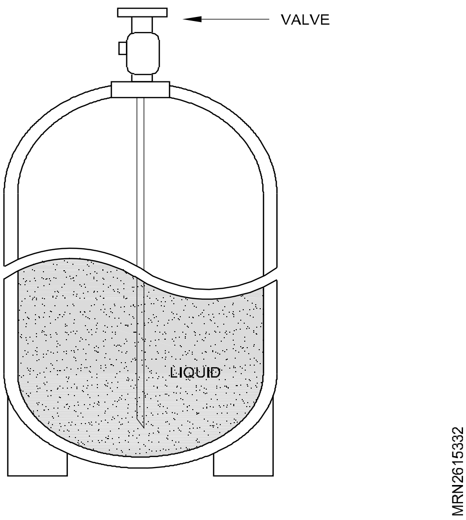
Also, charge the minimum necessary amount to the cylinder before using it for charging the air conditioning unit.

Example:

In case of charging refrigerant to a unit requiring 0.76kg using a capacity of 10kg-cylinder, the minimum necessary amount for the cylinder is :

0.76+10x0.20=2.76kg

Fig 2



For the remaining refrigerant, refer to the instructions of the refrigerant manufacturer.

If using a charging cylinder, transfer the specified amount of liquid refrigerant from the refrigerant cylinder to the charging cylinder.

Prepare an evacuated charging cylinder before hand.

> **To prevent the composition of R407C from changing, never bleed the refrigerant gas into the atmosphere while transferring the refrigerant.**
>
> **Do not use the refrigerant if the amount in the charging cylinder is less than 20%.**

Single valve

Charge the liquid refrigerant with the cylinder in the up-side down position.

Single valve (with siphon tube)

Charge with the cylinder in the normal position.

Configuration and characteristics of cylinders

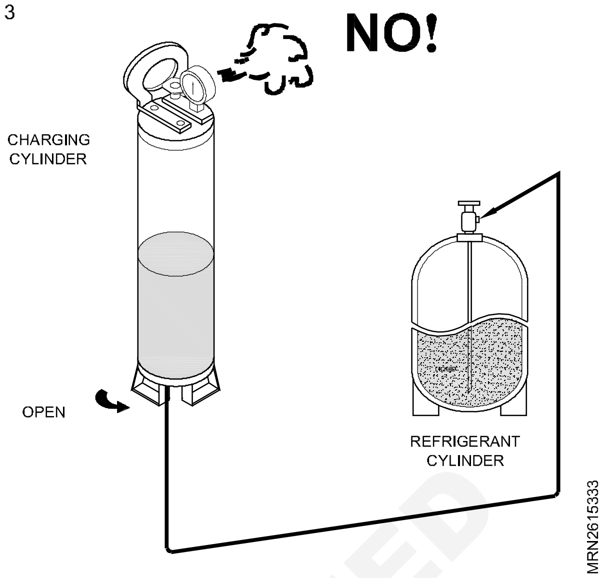
Refrigerant is leaking: Never attempt to charge additional refrigerant when refrigerant has been leaking from the unit. Follow the procedure described below to locate points of leaks and carry out repairs, then recharge the refrigerant.

Detecting leaks: Use the detector for R407C to locate refrigerant leak points.

Recovering refrigerant: Never release the gas to the atmosphere, recover residual refrigerant using the refrigerant recover unit for R407C, instead.

Do not reuse the recovered refrigerant because its composition will have been altered.

Fig 3



Welding leaking points

Confirm again that no residual refrigerant exists in the unit before starting welding.

Weld securely using flux and wax for R407C.

Prevent oxide film from forming inside the tubes utilizing subsition with nitrogen (N2)in the refrigerant circuit of the unit. Leave ends of tubes open during welding.

Checking for sealing

Use nitrogen gas for the pressurized gas, and never use a refrigerant other than R407C. Also do not use oxygen or any flammable gas.

1. Detecting leaks

↓ ok

2. Recovering refrigerant

↓ ok

3. Welding leaking points

↓ ok

4. Checking for sealing

↓ ok

5. Evaciation

↓

6. Recharging

Evacuation

Use a solenoid valve-installed vaccum pump so that even if power is cut off in the middle of evacuation of air due to a power interruption, the valve will prevent the pump oil from flowing back.

The equipment may be damaged if moisture remains in the tubing, thus carry out the evacuation thoroughly.

When using a vaccum pump with exhaust air volume more than 25L/min and ultimate vacuum pressure rate of 0.05Tor

Standard time of evacuation

Length of tubing Less than 10m
More than 10m

Time More than 10 min   More than 15 min.

Charging additional refrigerant

When tubes are extended

Observe the proper amount of refrigerant as stated in the service manual or the installation manual that came with the indoor unit. Charge additional refrigerant in liquid state.

Never charge additional refrigerant is leaking from the unit. Follow instructions given in “10-6. In case refrigerant is leaking” and completely carry out repairs. Only then should you recharge the refrigerant.

Retro-fitting existing systems

Use of existing units

Never use new refrigerant R407C for existing units which use R22. This will cause the air conditioner to operate improperly and may result ina hazardous condition.

Use of existing tubing

If replacing an older unit that used refrigerant R22 with a R407C unit, do not use its existing tubing. Instead, completely new tubing must be used.

Leak testing and gas charging of multi - split AC systems

Objectives: At the end of this lesson you shall be able to
- **air purging and evacuation**
- **describe about leak checking, evacuation, charging.**

Air purging and evacuation

Air and moisture remaining in the refrigerant system have undesirable effects as indicated below.

Pressure in the system rises.

Operating current rises

Cooling (or heating)efficiency drops

Moisture in the refrigerant circuit may freeze and block capillary tubing

Water may lead to corrosion of parts in the refrigeration system.

Therefore, the indoor/outdoor unit and connecting tube must be checked for leaks, and vacuumed to remove in condensible gas and moisture in the system.

Leak checking

Preparation

Check that each tube(both liquid and gas side tubes) between the indoor and outdoor units have been properly connected and all wiring for the test run has been completed. Remove the service valve caps from both the gas and the liquid sides on the outdoor unit. Check that both the liquid and the gas side service valves on the outdoor unit are kept closed at this stage.

Leakage test

Connect the manifold valve (with pressure gauges) and dry nitrogen gas cylinder to this service port with charge hoses.

Caution: Be sure to use a manifold valve for leak testing. The high side manifold valve must always be kept closed.

Pressurize the system to no more than 150 P.S.I.G with dry nitrogen gas close the cylinder valve when the gauge reading reached 150 P.S.I.G. Next, test for leaks with liquid soap.

Caution: To avoid nitrogen entering the refrigerant system in a liquid state, the top of the cylinder must be higher than its bottom when you pressurize the system. Usually, the cylinder must be higher than its bottom when you pressurize the system. Usually, the cylinder is used in a vertical standing position.

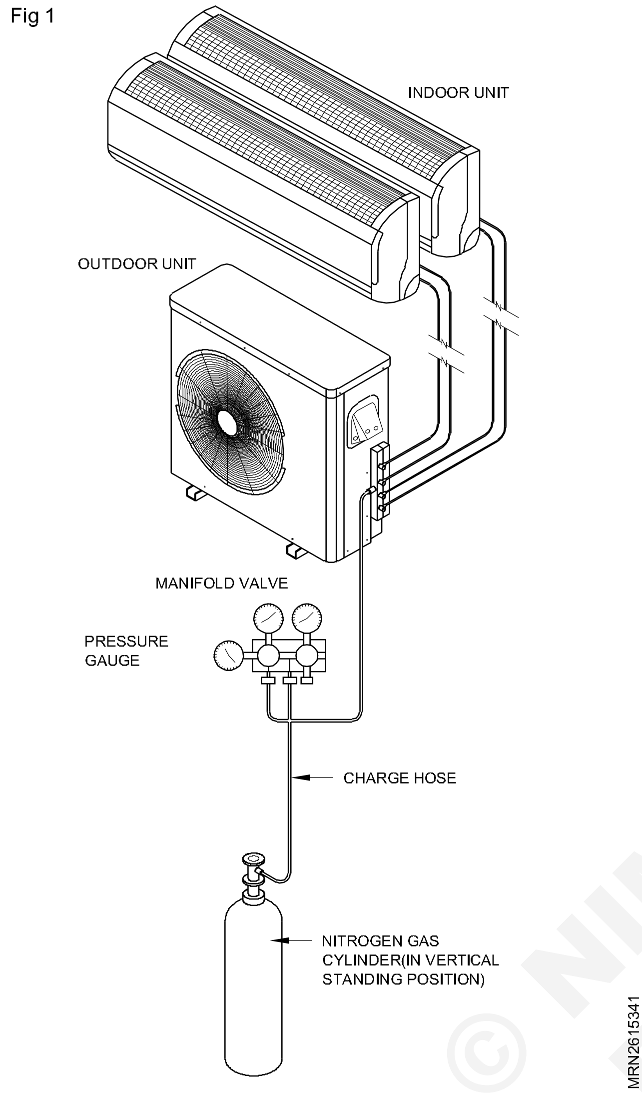
Leakage testing should be done for each indoor unit connection set, separately.

Do a leakage test of all joints of the tubing (both indoor and outdoor)and both gas and liquid side service valves with soap bubbles.

Bubbles indicate a leak. Be sure to wipe off the soap with a clean cloth.

After the system is found to be free of leaks, relieve the nitrogen pressure by loosening the charge hose connector at the nitrogen cylinder. When the system pressure is reduced to normal, disconnect the hose from the cylinder.

Fig 1



Evacuation

Connect the charge hose end described in the preceding steps to the vacuum pump to evacuate the tubing and indoor unit.

Confirm the “Lo” knob of the manifold valve is open. Then, run the vacuum pump.

The operation time for evacuation varies with tubing length and capacity of the pump.

Each room the vacuum pump must be operated less than 0.8 torr of the gage pressure.

When the desired vacuum is reached, close the “Lo” knob of the manifold valve and stop the vacuum pump.

Finishing the job

With a service valve wrench, turn the valve stem of liquid side valve counter-clockwise to fully open the valve.

Turn the valve stem of gas side valve counter-clockwise to fully open the valve.

Loosen the charge hose connected to the gas side service port slightly to release the pressure, then remove the hose.

Replace the flare nut and its bonnet on the gas side service port and fasten the flare nut securely with an adjustable wrench. This process is very high important to prevent leakage from the system.

Replace the valve caps at both gas and liquid side service valves and fasten them tight.

This completes air purging with a vacuum pump.

The air conditioner is now ready for test running.

Repeat evacuation procedure for each indoor unit.

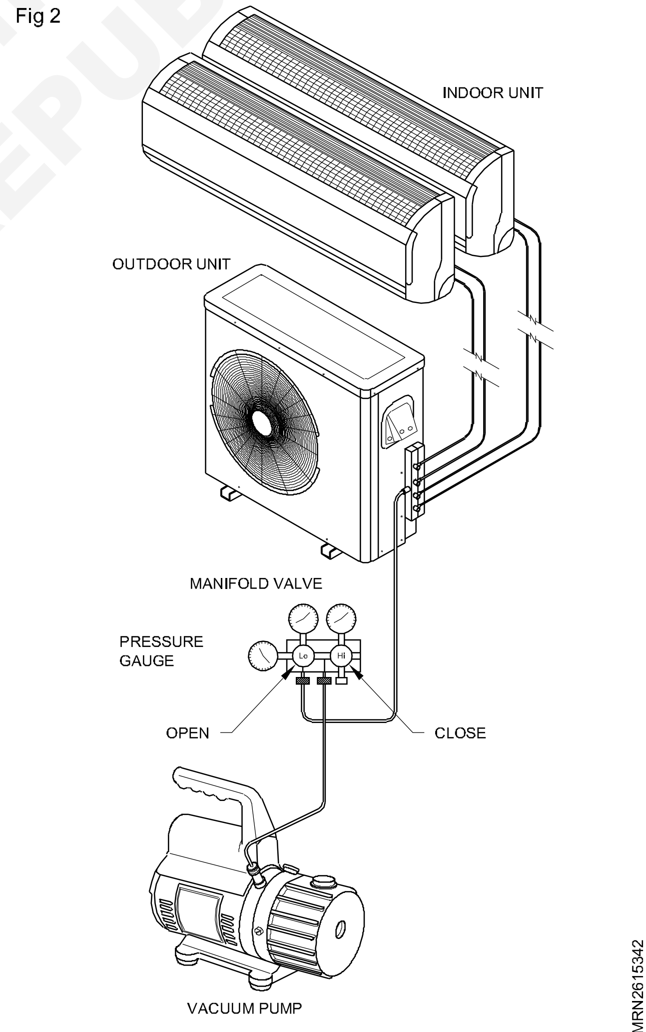
Charging

Each outdoor unit is factory charged (see rating plate)for the evaporator as well as a 7.5m (25ft) line set for each indoor line.

Any time total line set is used either shorter or longer than the nominal 7.5 ID No.m (25 ID No. ft) line set length the refrigerant charge has to be adjusted.

Whether the line set is made shorter or longer you must adjust the charge based on how many ft of tubing are either added or removed based on 20g/m (0.220z/ft) of R-410 A per meter (foot).

Fig 2



Outdoor Unit Capacity (Btu/h class)	Max.total length of all pipes (A+B)(A+B+C)/(A+B+C+D)	Max length of each pipe (A/B/C/D)	Min length of each pipe (A/B/C/D)	Max elevation between each indoor unit and outdoor unit (h1)	Max elevation between indoor units	Additional refrigerant unit:g/m(oz/ft)	Piping Length (no add'l refrigerant)
18k	50(164)	25(82)	3 (10)	15 (49)	7.5 (25)	18k	22.5(74)
24k	75(246)	25(82)	3 (10)	15 (49)	7.5 (25)	24k	37.5(128)
36k	75()246	25(82)	3 (10)	15 (49)	7.5 (25)	36k	37.5(128)

Important

If you are ever uncertain of the unit charge, reclaim, evacuate and weigh in the correct charge using the charge amount specified on the rating plate, adjusting for line sets longer or shorter than 7.5m(25ft) for each indoor unit.

Additional charge(g)= [(A room installation length - Standard length) x 0.22 oz/ft

+ (B room installation length - standard length) x 0.22 oz/ft +..]

-CF (correction factor)x 1.61 oz

CF = Max number of connectable indoor unit-Total number of connected indoor unit

Each branch pipe

= (82.25)x0.22

+ (16-25)x0.22

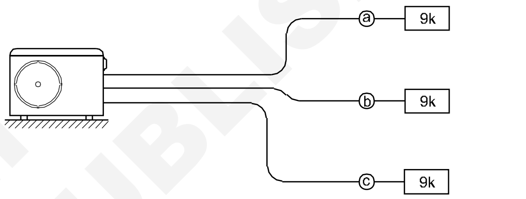
+ (49-25)x0.22

- (4-3)x1.61

= 12.54-1.98+5.28-1.61=14.23 oz

If the total additional charge value after calculation comes out to be negative, then do not consider additional charge.

Fig 3



Servicing and trouble shooting in multi - split AC systems

Objectives: At the end of this lesson you shall be able to
- **describe the importance of air filtration**
- **adjusting the direction of air circulating**
- **cleaning and care.**

Importance of air filtration: The recirculated air within the air conditioned area acts as a carries of bacteria and dust brought in by the movement of the people, materials etc. The functions of areas like industrial, operation theatres and ICU's. Air conditioning systems are to provide clean, filtered air that is often essential to trouble-free operation and to the production of quality products.

The air it is passed through filters that remove the dust particles from air and ensure delivery of clean air to the conditional space. The air filters are interfere with performance of the air-conditioning system.

1 Open the intake grille and remove the air filters

2 Replace them by two new air cleaning filters

   Remove the old air cleaning filters in reverse order of their installation.

   Install in the same way as for installation of the air cleaning filter set.

3 Install the two air filters and close the intake grille

   In regard to the Air cleaning filters

   The air cleaning filters are disposable filters. They cannot be washed and reused

However, the filter frame is used again.

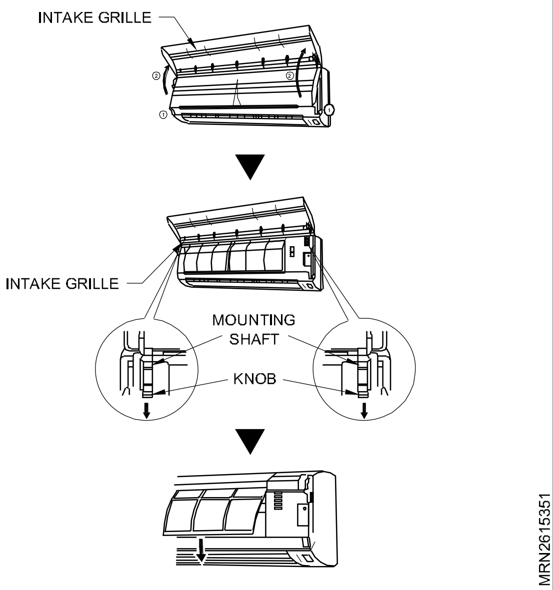
For storage of the air cleaning filters, avoid places with high temperature and high humidity, and use the filters as soon as possible after the package has been opened. (The air cleaning effect decreases when the filters are left in the opened package)

Generally the filters should be exchanged about every three months.

Adjusting the direction of air circulation

Instruction relating to heating are applicable only to "Heat & Cool model"

Fig 1



Vertical (up-down) direction of airflow is adjusted by pressing the Remote Control Unit's AIR FLOW DIRECTION button. Horizontal (right-left) airflow direction is adjusted manually, by moving the Air Flow Direction Louvers. Whenever making a horizontal airflow adjustments, start air conditioner operation and be sure that the vertical air direction louvers are stopped.

Fig 2

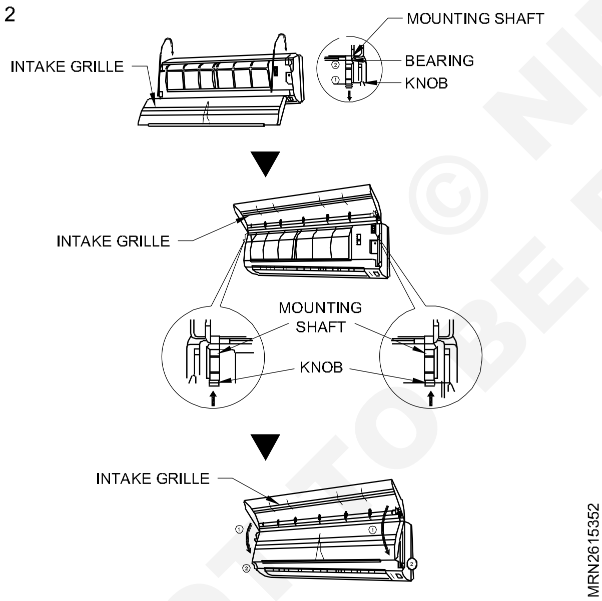
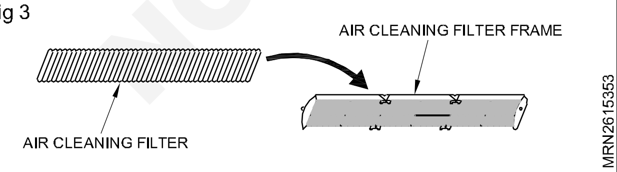


Fig 3

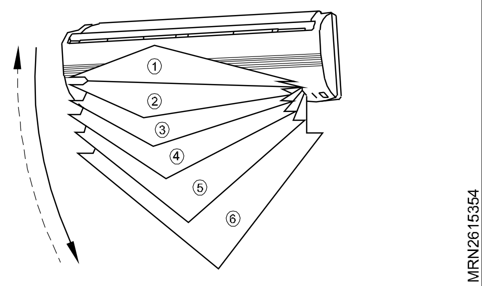


Vertical Air Direction Adjustment

Press the AIR FLOW DIRECTION button (Fig 4)

Each time the button is pressed, the air direction range will change as follows:

Fig 4



Types of Air flow direction setting

During cooling/dry modes

During heating mode

The remote control unit's display does not change.

Use the air direction adjustments within the ranges shown above

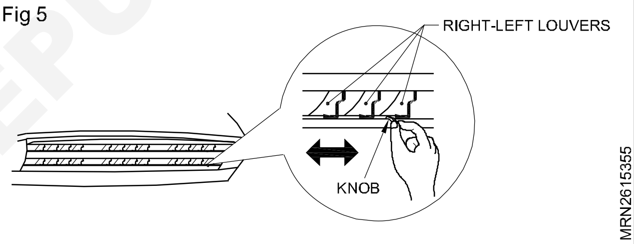
The vertical air flow direction is set automatically as shown, in accordance with the type of operation selected.

During cooling/dry modes : Horizontal flow

During heating mode: downward flow

During AUTO mode operation for the first minute after beginning operation, airflow will be horizontal : the air direction cannot be adjusted during this period.

Fig 5



Right-left adjustment

Adjust the right left louvers

Move the right-left louvers to adjust air flow in the direction you prefer.

Never place fingers or foreign objects inside the outlet ports, since the internal fan operates at high speed and could cause personal injury.

Always use the remote control unit's AIR FLOW DIRECTION button to adjust the vertical air flow louvers. Attempting to move them manually could result in improper operation: in this case stop operation and restart. The louvers should begin to operate properly again.

During use of the cooling and dry modes, do not set the Air Flow direction louvers in the heating range for long periods of time, since water vapor may condense near the outlet louvers and drops of water may drip from the air conditioner. During the cooling and dry modes, if the heating range for more than 30 minutes, they will automatically return to position.

When used in a room with infants, children, elderly or sick persons, the air direction and room temperature should be considered carefully when making settings.

Cleaning and care

Before cleaning the air conditioner be sure to turn it off and disconnect the power supply cord.

Be sure the intake grille is installed securely.

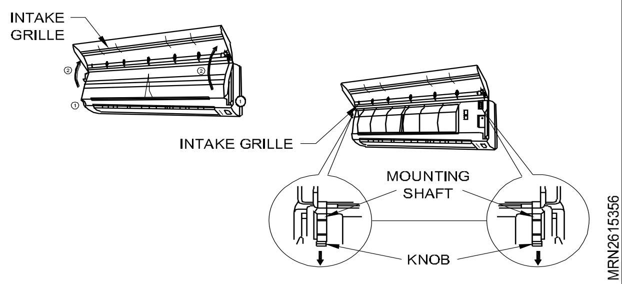
When removing and replacing the air filters, be sure not to touch the heat exchanger as personal injury may result.

Cleaning the intake grille

Place your fingers at both lower ends of the grille panel, and lift forward if the grille seems to catch party through its movement, continue lifting upward to remove.

Pull past the intermediate catch and open the intake grille wide so that it become horizontal.

Fig 6



Clean with water

Remove dust with a vacuum cleaner: wipe the unit with warm water, then dry with a clean, soft cloth.

Replace the intake grille

Pull the knobs all the way

Hold the grille horizontal and set the left and right mounting shafts into the bearings at the top of the panel.

Cleaning the Air Filter

Open the intake grille, and remove the air filter.

Lift up the air filter's handle, disconnect the two lower tabs, and pull out.

Air filter handle

Hooks (two places)

Fig 7

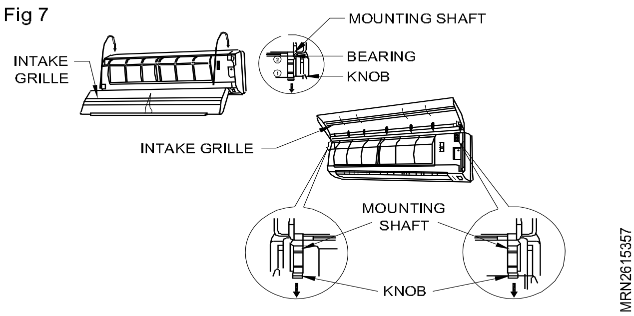
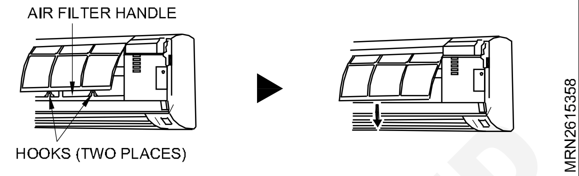


Fig 8



Remove dust with a vacuum cleaner or by washing

After washing, allow to dry thoroughly in a shaded place.

Replace the air filter and close the intake grille

Align the sides of the air filter with the panel, and push in fully, making sure the two lower tabs are returned properly to their holes in the panel.

Close the intake grille.

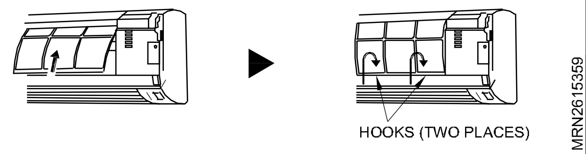
For purpose of example, the illustration shows the unit without intake grille installed.

Dust can be cleaned from the air filter either with a vacuum cleaner, or by washing the filter in a solution of mild detergent and warm water. If you wash the filter, be sure to allow it to dry thoroughly in a shady place before reinstalling.

If dirt is allowed to accumulate on the air filter, air flow will be reduced, lowering operating efficiency and increasing noise.

During periods of normal use, the air filters should be cleaned every two weeks.

Fig 9



Precaution for the installation of multi split AC systems

Objectives: At the end of this lesson you shall be able to
- **explain preparations before installation**
- **explain about preparation during installation.**

Preparation before installation

Relation of the unit to the suspension bolt positions.

Install the inspection opening on the control box side where maintenance and inspection of the control box are easy. Install the inspection opening also in the lower part of the unit.

Make sure the range of the unit's external static pressure is not exceeded

(See the technical documentation for the range of the external static pressure setting.)

Open the installation hole (Pre-set ceilings)

Once the installation hole is opened in the ceiling where the unit is to be installed, pass refrigerant piping, drain piping, transmission wiring, and remote controller wiring (unneeded if using a wireless remote controller) to the unit's piping and wiring holes. See **"Refrigerant piping work", "Drain piping work", and Wiring".**

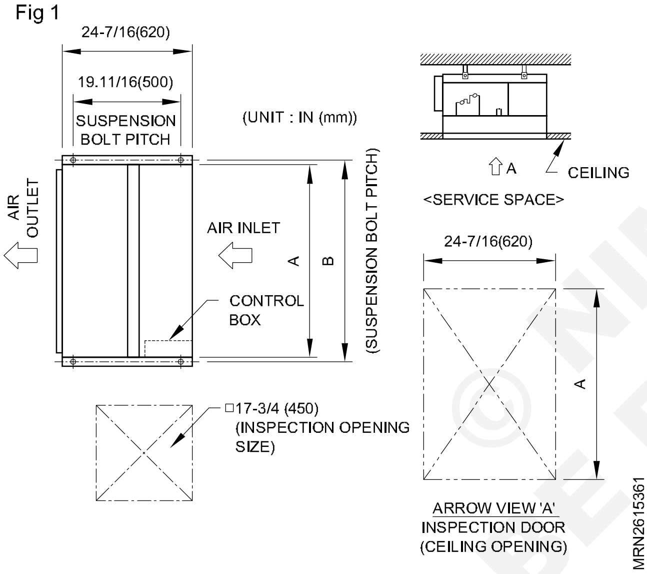
After opening the ceiling hole, make sure ceiling is level if needed, It might be necessary to reinforce the ceiling frame to prevent shaking. Consult an architect or carpenter for details.

Install the suspension bolts

(Use W3/8 to M10 suspension bolts)

Use a hole-in-anchor, sunken insert, sunken anchor for existing ceilings, and a sunken insert, sunken anchor or other part to be procured in the field to reinforce the ceiling to bearing the weight of the unit.

Fig 1



Mount chamber cover and air filter (accessory)

For bottom intake, replace the chamber cover and the protection net in the procedure listed in Fig.

1 Remove the protection net (6 locations) Remove the chamber cover (7 locations)

2 Reattach the removed chamber cover in the orientation shown in Fig (7 locations) Reattach the removed protection net in the orientation shown in Fig (6 locations) Refer to fig for the direction of the protection net.

3 Attach sealing pad as shown in the right figures (stored in outlet vent) (only for CDXS) (In order to take in the air inside the ceiling and when not taking in air from outdoor air, it is not necessary to stick.)

Attach the sealing pad (accessory to the plate metal sections which are not covered by anti-sweat material.

Make sure there are no gaps between the different pieces of sealing pad.

4 Attach the hanger (right) insulation to the right hanger (stored in outlet vent (see the below figure for the sticking base line)

5 Attach the air filter (accessory) in the manner shown in the diagram

In case of bottom side

In case of back side

When two indoor units are installed in one room, one of the two wireless remote controllers can be easily set for another addresses.

Fig 2

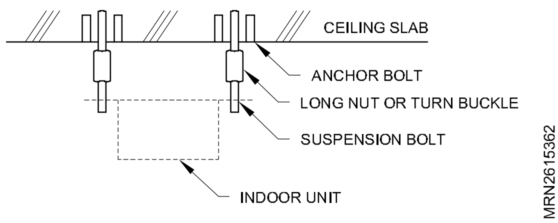


Fig 3

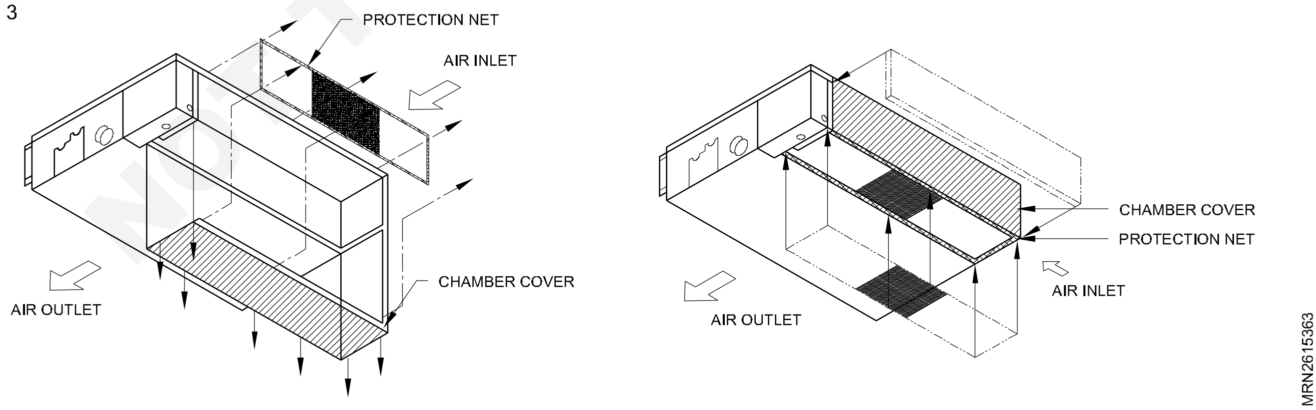


Fig 4

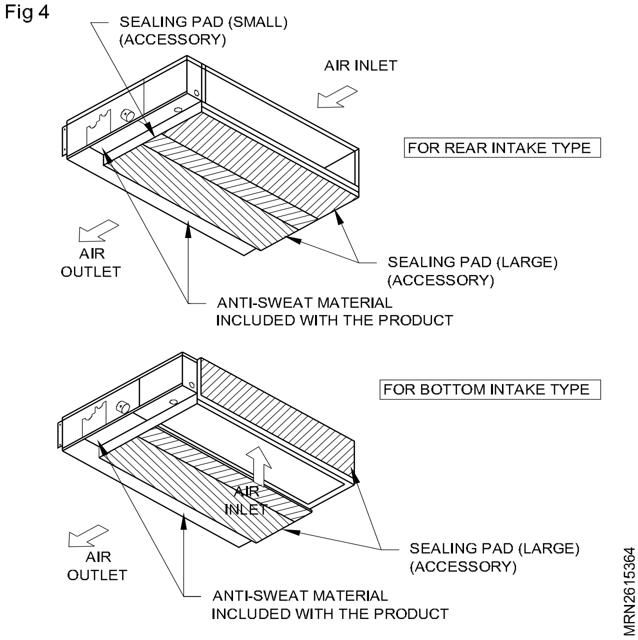


Fig 5

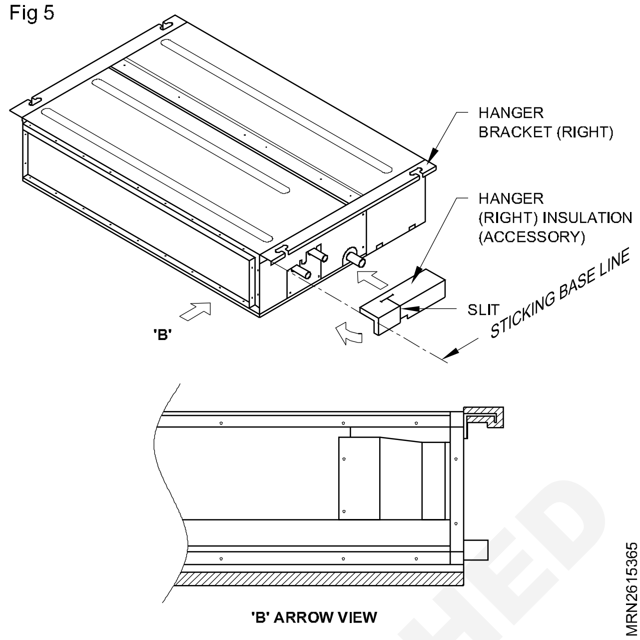


Fig 6

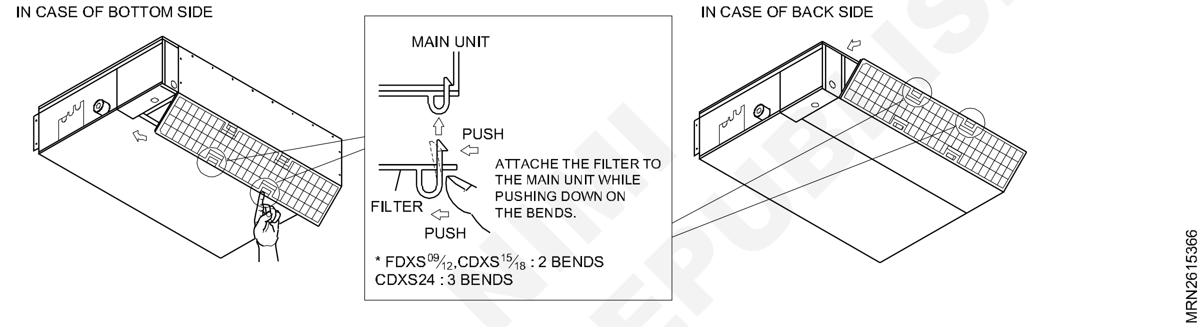
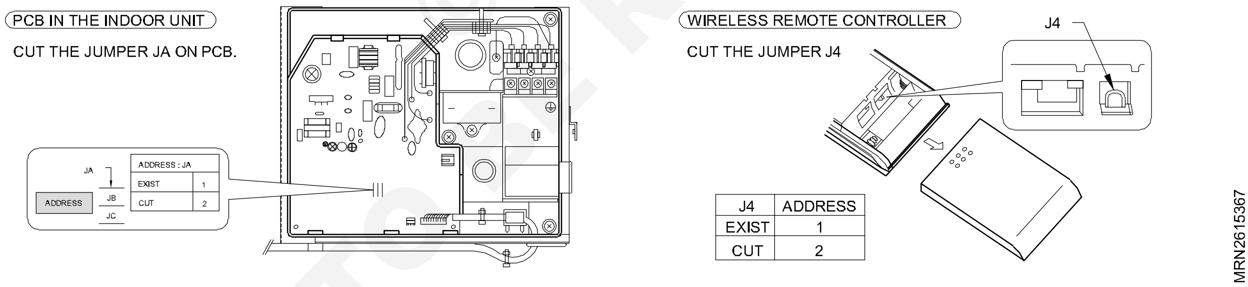


Fig 7



Installation of indoor, outdoor unit

Select the best location

Indoor unit

1 Do not have any heat or steam near the unit.

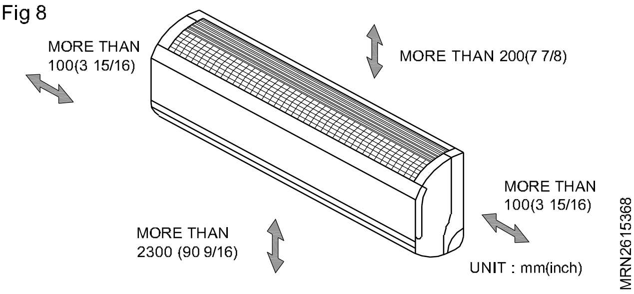
2 Select a place where there are no obstacles in front of the unit.

3 Make sure that condensation drainage can be conveniently routed away.

4 Do not install near a doorway

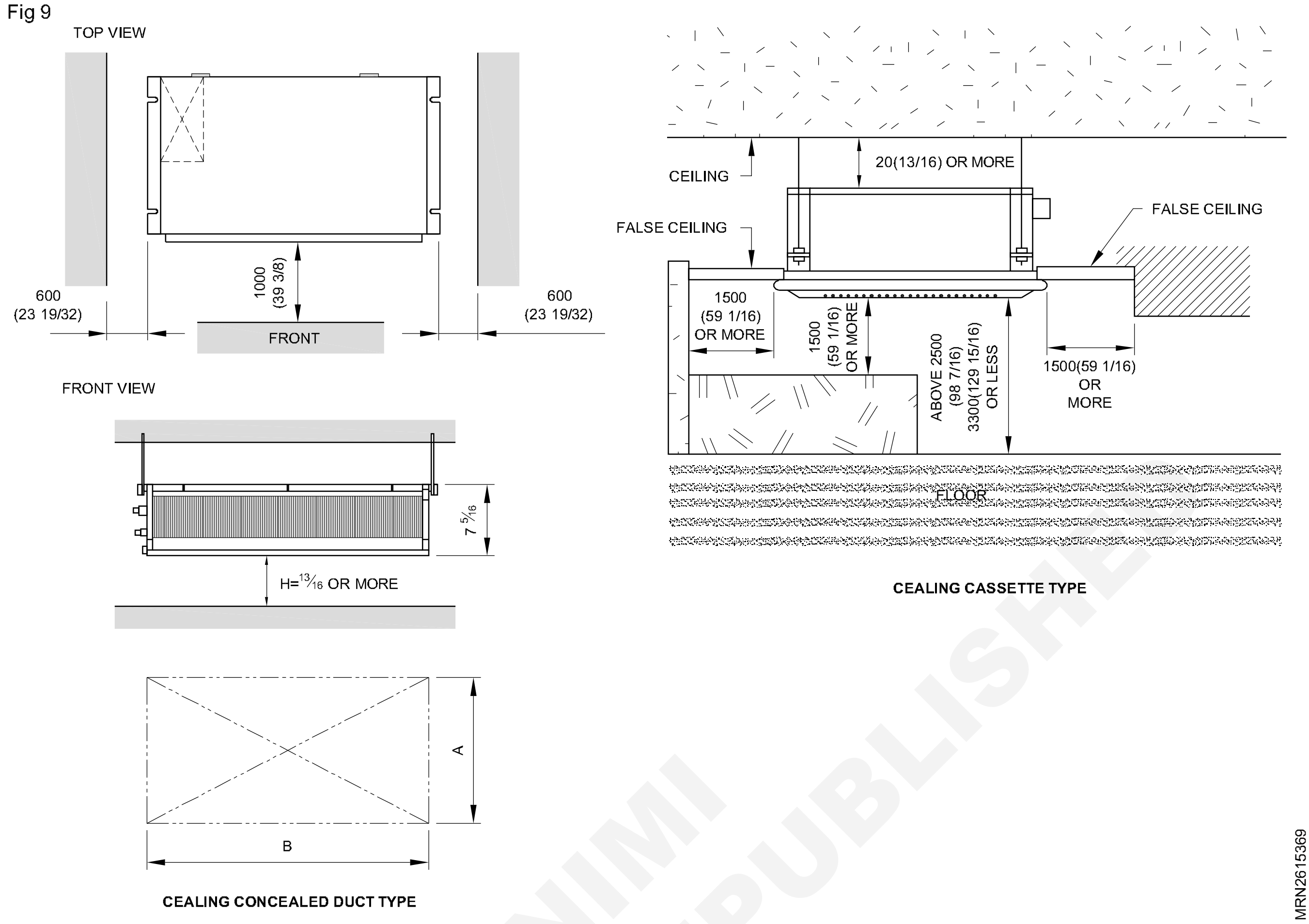
5 Ensure the unit is unobstructed, allow proper space on all sides according to the arrows and distance measurement in the figures

Fig 8



6 Use a metal detector or metal scanner to locate studs to prevent unnecessary damage to the wall.

Fig 9



Outdoor unit

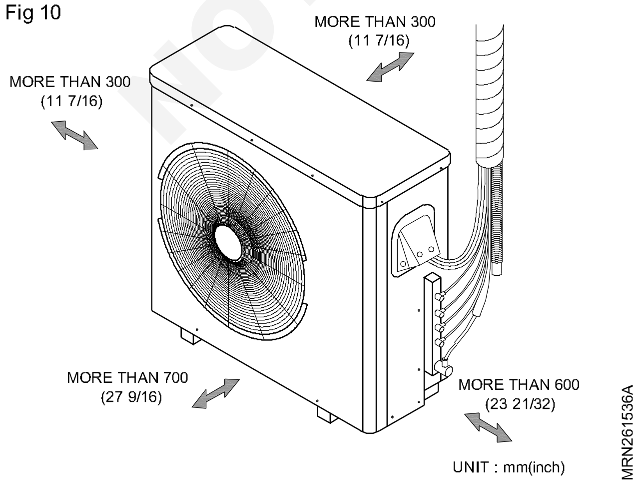
1 If an awning is built over the unit to prevent direct sunlight or rain exposure, make sure that heat radiation from the condenser is not restricted.

2 Ensure the unit is unobstructed, allow proper space on all sides according to the arrows and distance measurement in the figures.

3 Do not place animals and plants, in the path of the warm air.

4 Take the air conditioner weight into account and select a place where noise and vibration are minimum.

Fig 10



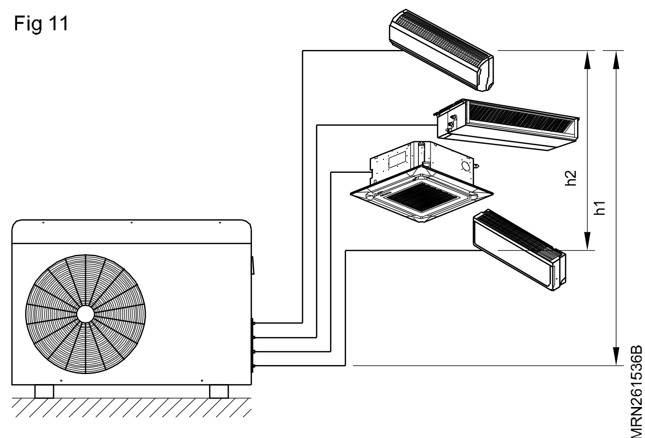
5 Select a place so that the warm air and sound from the air conditioner does not disturb neighbors.

Roof top installations

If the outdoor unit is installed on a roof structure, be sure to level the unit. Ensure the roof structure and anchoring method are adequate for the unit location. Consult local codes regarding rooftop mounting.

> **Caution: Capacity is based on standard length and maximum allowance length is on the basis of reliability**

Fig 11



Piping length and elevation

Multi piping type
Unit :m(ft)

Outdoor Unit Capacity (Btu/h class)	Max.total length of all pipes (A+B)(A+B+C)/(A+B+C+D)	Max length of each pipe (A/B/C/D)	Min length of each pipe (A/B/C/D)	Max elevation between each indoor unit and outdoor unit (h1)	Max elevation between indoor units (h2)	Max.combination of indoor unit (Blu/h class)
18k	50(164)	25(82)	3 (10)	15 (49)	7.5 (25)	18k
24k	75(246)	25(82)	3 (10)	15 (49)	7.5 (25)	24k
36k	75()246	25(82)	3 (10)	15 (49)	7.5 (25)	36k

Indoor Unit Capacity (Btu/h class)	Pipe Diameter Unit : mm(inch)		Standard Pipe Length Unit :m(ft)	Max.combination of indoor unit (Blu/h class)
	Gas	Liquid		
9k	9.52 (3/8)	6.35 (1/4)	7.5 (25)	20(0.22)
12k	9.52(3/8)	6.35 (1/4)	7.5(25)	20(0.22)
18k	12.7(1/2)	6.35 (1/4)	7.5(25)	20(0.22)

Installation

[Standard/ Art cool Mirror Type]

Connecting the piping

1 Prepare the indoor unit's piping and drain hose for installation through the wall.

2 Remove the plastic tubing retainer (see the illustration on the right) and pull the tubing and drain hose away from chassis.

3 Route the indoor tubing and the drain hose to the required piping hole position.

4 Insert the piping, drain hose, and the connecting cable into the piping hole.

5 Insert the connecting cable into the indoor unit.

Don't connect the cable to the indoor unit.

Make a small loop with the cable for easy connection later.

6 Tape the drain hose and the connecting cables.

7 Indoor unit installation

Hang the indoor unit from the hooks at the top of the installation plate.

Insert the spacer etc, between the indoor unit and the installation plate and separate the bottom of the indoor unit from the wall.

8 Connecting the piping to the indoor unit and drain hose to drain pipe.

Align the centre of the pipes and sufficiently tighten the flare nut by hand.

Tighten the flare nut with a wrench.

Outside diameter		Torque
mm	**inch**	**kgf.m(lbf.ft)**
6.35	1/4	1.8-2.5 (13-18)
9.52	3/8	3.4-4.2 (24-30)
12.7	1/2	5.5-6.6 (24-30)

Next, extend the indoor unit's drain hose. Then attach the drain pipe.

Fig 1

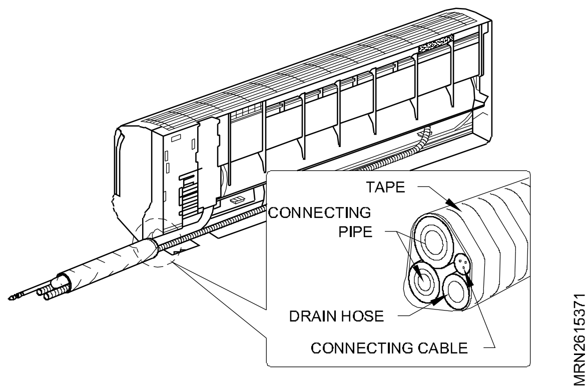


Fig 2

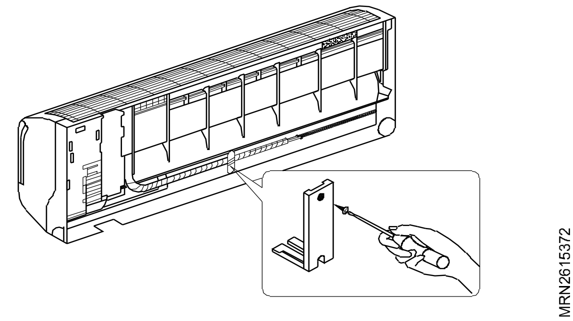


Fig 3

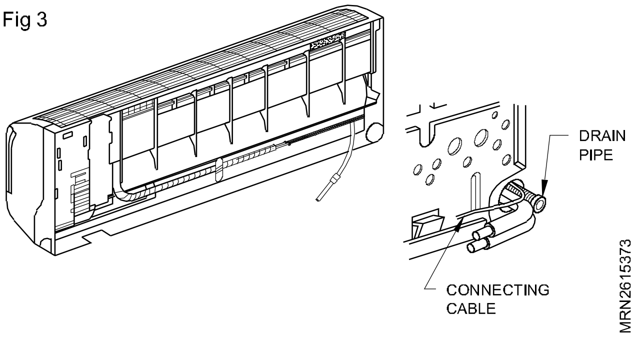


Fig 4

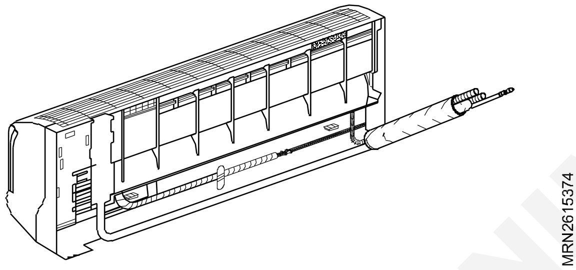


Fig 5

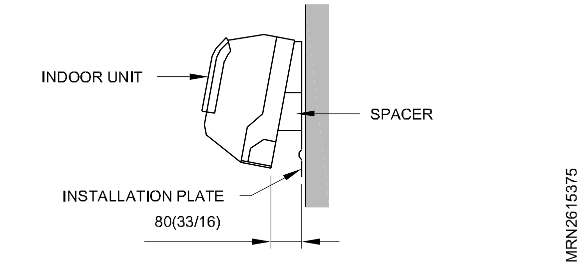


Fig 6

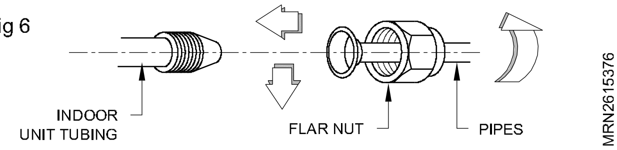


Fig 7

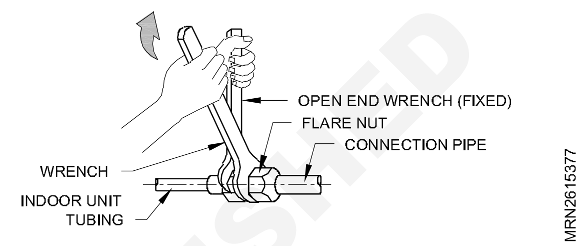
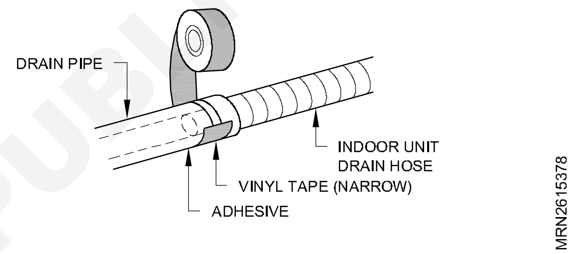


Fig 8



Commissioning of multi split AC systems

Objectives: At the end of this lesson you shall be able to
- **explain the operating tips**
- **describe trial operation and testing.**

Operating Tips

Multi-type air conditioner

This indoor unit can be connected to a multi-type outdoor unit. The multi-type air conditioner allows multiple indoor units to be operated in multiple locations. The indoor units may be operated simultaneously, in accordance with their respective output.

Simultaneous Use of Multiple units

Instructions relating to inverter are applicable only to INVERTER MODER"

When using a multi-type air conditioner, the multiple indoor units can be operated simultaneously, but when two or more indoor unit of the same group are operated simultaneously, the heating and cooling efficiency will be less than when a single indoor unit is used alone. Accordingly, when you wish to use more than one in door unit for cooling at the same time, the use should be concentrated at night and other times when less output is required. In the same way, when multiple units are used simultaneously for heating, it is recommended that they be used in conjunction with other auxiliary space heaters, as required.

Seasonal and outdoor temperature conditions, the structure of the rooms and the number of persons present may also result in difference of operating efficiency. We recommended that you try various operating efficiency. We recommend that you try various operating patterns in order to confirm the level of heating and cooling output provided by your units, and use the units in the way that best matches your family's lifestyle.

If you discover that one or more units delivers a low level of cooling or heating during simultaneous operation, we recommend that you stop simultaneous operation of the multiple units.

Operation cannot be done in the following different operating modes.

If the indoor unit is instructed to do an operating mode that it cannot perform, the OPERATION indicator lamp (red) on the indoor unit will flash (1 second on, i second off)and the unit will go into the standby mode.

Heating mode and cooling mode (for dry mode)

Heating mode and fan mode.

Operation can be done in the following different operating modes.

Cooling mode an dry mode

Cooling mode and fan mode

Dry mode and fan mode

The operating mode (heating mode or cooling (dry) mode of the outdoor unit will be determined by the operating mode of the indoor unit that was operated first. If the indoor unit was started in fan mode, the operating mode of the outdoor unit will not be determined.

For example, if indoor unit (A) was started in fan mode and then indoor unit (B) was then operated in heating mode, indoor unit (A) would temporarily start operation in fan mode but when indoor unit(B) started operating in heating mode, the OPERATION indicator lamp (red) for indoor unit (A) would begin to flash(1 second on, 1 second off) and it would go into standby mode. Indoor unit (B) would continue to operate in heating mode.

Notice

Instructions relating to heating (*) are applicable only to “HEAT & COOL MODEL” (Reverse cycle).

During use of the heating mode, the outdoor unit will occasionally commence the defrost operation for brief periods. During the defrosting operation, if the user sets the indoor unit for heating again, the defrosting mode will continue, and the heating operation will begin after completion of defrosting, with the result that some time.

During use of the heating mode, the top of the indoor unit may become warm, but this is due to the fact that coolant is circulated through the indoor unit even when it is stopped; it is not a malfunction.

	Symptoms	Items to check
Check once more	Doesn’t operate at all	Has the circuit breaker been turn off? Has there been a power failure? Has a fuse blown out, or a circuit breaker been tripped?
		Is the timer operating?
	Poor cooling or heating performance	Is the air filter dirty? Are the air conditioner’s intake grille or outlet port blocked? Did you adjust the room temperature settings (thermostat)correctly? Is there a window or door open? In the case of cooling operation, is a window allowing bright sunlight to enter? (close the curtains) In the case of cooling operation, are there heating apparatus and computers inside the room, or are there too many people inthe room?
		Is the unit set for SUPER QUIET operation?
	The unit operates differently from the remote control unit’s setting	Are the remote control unit’s batteries dead? Are the remote control unit’s batteries loaded properly?

If the problem persists after performing these checks, or if you notice bring smells, or the TIMER indicator Lamp (Fig) flashes, immediately stop operation, turn off the circuit breaker, and consult authorized service personnel.

Operating tips

Instruction relating to heating(*) are applicable only to “HEAT & COOL MODEL”

Operation and Performance

Heating performance

This air conditioner operates on the heat-pump principle, absorbing heat from outdoor air and transferring that heat indoors. As a result, the operating performance is reduced as outdoor air temperature drops. If you feel that insufficient heating performance is being produced, we recommend you use this air conditioner in conjunction with another kind of heating appliances.

Heat-pump air conditioner heat your entire room by recirculating air throughout the room, with the result that some time may be required after first starting the air conditioner until the room is heated.

When indoor and outdoor temperature are high

When both indoor and outdoor temperatures are high during use of the heating mode, the outdoor unit's fan may stop at times.

Microcomputers-controlled automatic defrosting

When using the heating mode under conditions of low outdoor air temperature high humidity, frost may form on the outdoor unit, resulting in reduced operating performance.

In order to prevent this kind of reduced performance, this unit is equipped with a microcomputer-controlled automatic. Defrosting function. If frost forms, the air conditioner will temporarily stop, and the defrosting circuit will operate briefly (for about 7 to 15 minutes).

During Automatic Defrosting operation, the OPERATION indicator lamp (red)will flash slowly.

Auto Restart

In event of power interruption

The air conditioner power has been interrupted by a power failure. The air conditioner will then restart automatically in its previous mode when the power is restored.

Operated by setting before the power failure.

If a power failure occurs during TIMER operation, the timer will be reset and the unit will being (or stop)operation at the new time setting. In the event that this kind of timer fault occurs the TIMER Indicator Lamp (green) will flash.

Use of other electrical appliances (electric shaver, etc.)or nearby use of a wireless radio transmitter may cause the air conditioner to malfunction. In this event, temporarily disconnect the Power Supply Plug, reconnect it, and then use the remote control unit to resume operation.

Trial Operation and testing

Measure the supply voltage and make sure that it falls in the specified range.

Trial operation should be carried out in either cooling or heating mode.

Trial operation from remote controller

Press ON/OFF button to turn on the system.

Simultaneously press center of TEMP button and MODE button.

Press MODE button twice

("–" will appear on the display to indicate that Trial Operation mode is selected)

Trial operation mode terminate in approx. 30 minutes and switches into normal mode. To quit the trial operation, press ON/OFF button.

In cooling mode, select the lowest programmable temperature, in heating mode, select the highest programmable temperature.

Trial operation may be disabled in either mode depending on the room temperature.

After trial operation is complete, set the temperature to a normal level (79°F (26°C) in cooling mode, 68°F (20°C) to 75°F(24°C)in heating mode).

For protection, the system disables restart operation for 3 minutes after it is turned off.

Carry out the test operation in accordance with the operation manual to ensure that all functions and parts, are working properly.

The air conditioner requires a small amount of power in its standby mode. If the system is not to be used for some time after installation, shut off the circuit breaker to eliminate unnecessary power consumption.

If the circuit breaker trips to shut off the power to the air conditioner, the system will restore the original operation mode when the circuit breaker is turned on again.

Test items

Test items	Symptom (diagnostic display on RC)
Indoor and outdoor units are installed properly on solid bases.	Fall, vibration, noise
No refrigerant gas leaks.	Incomplete cooling/heating function
Refrigerant gas and liquid pipes and indoor drain hose extension are thermally insulated.	Water leakage
Drain pipe is properly installed.	Water leakage
System is properly grounded	Electrical leakage
The specified wires are used for interconnecting wire connections.	Inoperative or burn damage
Indoor or outdoor unit's air inlet or discharge has clear path of air. Shut-off valves are opened.	Incomplete cooling/heating function
Indoor unit properly receives remote controller commands.	Inoperative

Drain test

The air conditioner uses a drain pump to drain water. Use the following procedure to test the drain pump operation:

Connect the main drain to the exterior and leave it provisionally until the test comes to an end.

Feed water to the flexible drain hose and check the piping for leakage

Be sure to check the drain pump for normal operating and noise when electrical wiring is complete.

When the tst is complete, connect the flexible drain hose to the drain port on the indoor unit.

Caution: The supplied flexible drain hose should not be curved, neither screwed. The curved or screwed hose may cause a leakage of water.

Trouble shooting of multi split AC system

Objective: At the end of this lesson you shall be able to
- **trouble shooting of Multi split AC system.**

Instructions relating to heating (*) are applicable only to "HEAT & COOL MODEL" (Reverse Cycle).

In the event of a malfunctions (burning smell, etc.) immediately stop operation disconnect the power supply plug or turn off the circuit breaker, and consult authorized service personnel. Merely turning off the unit's power switch will not completely disconnect the unit from the power source. Always be sure to turn off your circuit breaker to ensure that power is completely off.

Before requesting service, perform the following checks:

	Symptom	Problem
Normal function	Doesn't operate immediately	If the unit is stopped and then immediately started again, the compressor will not operate for about 3 minutes, in order to -prevent fuse blowouts. Whenever the power supply plug is disconnected and then reconnected to a power outlet, the protection circuit will operate for about 3 minutes, prevailing unit operation during that period.
	Noise is heard	During operation and immediately after stopping the unit, the sound of water flowing in the air conditioner's piping may be heard. Also, noise may be particularly noticeable for about 2 to 3 minutes after starting operation (sound of coolant flowing) During operation, slight squeaking sound may be heard. This is the result of minute expansion and contraction of the front cover due to temperature changes. During heating operation, a sizzling sound may be heard occasionally. This sound is produced by the Automatic Defrosting operation.
	Smells	Some smell may be emitted from the indoor unit. This smell is the result of room smells (furniture, tobacco, etc) which have been taken into the air conditioner.
	Mist or steam are emitted	During cooling or dry operation, a thin mist may be seen emitted from the indoor unit. This results from the sudden cooling of room air by the air emitted from the air conditioner, resulting in condensation and missing. During heating operation, the outdoor unit's fan may stop, and steam may be rising from the unit. This is due to the automatic defrosting operation.

	Symptom	Item to check
	Air flow is weak or stops	When heating operation is started, fan speed is temporarily very low to allow internal parts to warm up.
		During heating operation, if the room temperature rises above the thermostat setting, the outdoor unit will stop, and the indoor unit will operate at very low fan speed. If you wish to warm the room further, set the thermostat to higher setting.
		During heating operation, the unit will temporarily stop operation (between 7 and 15 minutes) as the automatic defrosting mode operates. During the automatic defrosting operation, the operation indicator lamp will flash.
		The fan may operate at very low speed during dry operation or when the unit is monitoring the room's temperature.
		During SUPER QUIET operation the fan will operate at very low speed.
		In the monitor AUTO operation, the fan will operate at very low speed.
	Water is produced from the outdoor unit	During heating operation, water may be produced from the outdoor unit due to the automatic defrosting operation.
Check once more	Doesn't operate at all	Has the circuit breaker been turn off Has there been a power failure Has a fuse blown out, or a circuit breaker been tripped? Is the timer operating?
	Poor cooling (or heating performance)	Is the air filter dirty? Are the air conditioner's intake grille or outlet port blocked? Did you adjust the room temperature settings thermostat correctly? Is there a window or door open? In the case of cooling operation, is a window allowing bright sunlight to enter? close the curtains. In the case of cooling operation, are there heating apparatus and computers inside the room, or are there too many people in the room?
	The unit operates differently from the remote control unit's setting	Is the unit set for super quiet operation? Are the remote control unit's batteries dead? Are the remote control unit's batteries loaded properly?

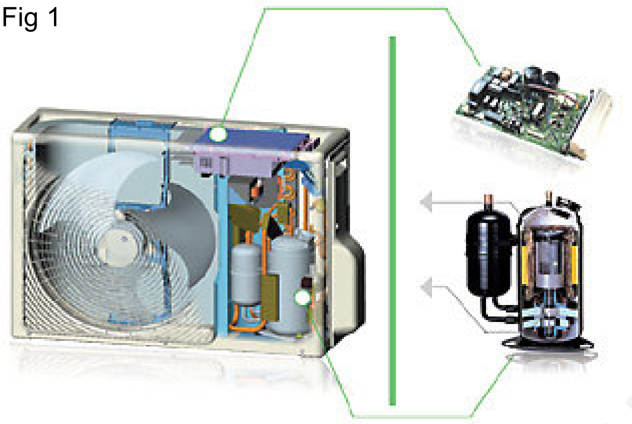
If the problem persists after performing these checks, or if you notice burning smells, or the TIMER indicator Lamp flashes, immediately stop operation, turn off the circuit breaker, and consult authorized service personnel.

Air conditioning units with inverter technology

Objective: At the end of this lesson you shall be able to
- **explain the working principle of inverter technology.**

Split air conditioning systems with inverter technology provide a good way to save space, buying cost and electricity cost in smaller offices. These air conditioners have multiple indoor units connected with a single outdoor unit as shown in the picture below. The temperature control is available at every indoor unit and the outdoor unit adjusts the compressor load based on the heat load coming in from various units.

Fig 1



It saves space: as there is only one outdoor unit instead of many.

It saves buying cost: the combined cost of buying several single split units is more than buying one single multi split unit.

It saves electricity cost: The compressor load is adjusted on the heat load coming in from various indoor units by the inverter technology. Thus electricity consumption is less. To know more about inverter technology read our article: Air conditioners with inverter technology can help save electricity.

These systems are available in sizes of 2 tons and more with 2 to 8 units connected with single outdoor unit. Smaller units can also be used for residential purposes in case air conditioning is required in multiple rooms. Using multi split system; one just has to make sure that the refrigerant tubing is not long so that there are energy losses during the refrigerant flow. Also a multi split system without inverter technology may not be very useful as the individual room control is not possible without inverter technology.

- Explain VFD
- Advantages of VFD

How inverter air conditioner work

The inverter technology (DC) is the latest evolution of technology concerning the electro motors of the compressors. An inverter is used to control the speed of the compressor motor, so as to continuously regulate the temperature. The DC inverter units have a variable frequency drive that comprises an adjustable electrical inverter to control the speed of the electro motor, which means the compressor and the cooling/ heating output. The drive converts the incoming AC current to DC and then through a modulation in an electrical inverter produces current of desired frequency. A micro controller can sample each ambient air temperature and adjust accordingly the speed of the compressor. The inverter air conditioning units have increased efficiency in contraction to traditional air conditioners, extended life of their parts and the sharp fluctuations in the load are eliminated. This makes the inverter AC unit quieter with lower operating coat and with less broke downs. The inverter AC unit might be more expensive than the constant speed air conditioners, but this is balanced by lower energy bills. The payback time is approximately two years depending on the usage.

DC inverter control circuitry

The electronics control is the most complicated part of a DC inverter system hence making it one of the most costly components of the air conditioner, the other part being the compressor.

Let us look at the control circuit for the DC compressor that takes its supply from a single phase power supply. There are many variation of design and we will look at a design that uses power factor corrections that gives better power factor.

The first section consists of a DC converter

The DC converter converts the incoming power supply from AC to DC using four diodes connected like a bridge. Inductors and capacitors are connected before the converter to reduce the electrical noise being introduced into the power supply due to the switching of the transistors.

In the simplified diagram below, the single phase power supply is used. If 3-phase supply is used, six diodes will be needed to convert the AC power to DC power

The second section being PFC or power factor correction

Being an active power converter means that the power factor correction for this design is able to correct the power factor of the equipment to more than 98% compared to the other solution based on LC (included and capacitor filter).

It also helps to reduce the harmonic current emission to a low level which is acceptable to the standards being imposed by the Electromagnetic Compatibility technical committee. The only setback with this method is the higher cost needed for its implementation.

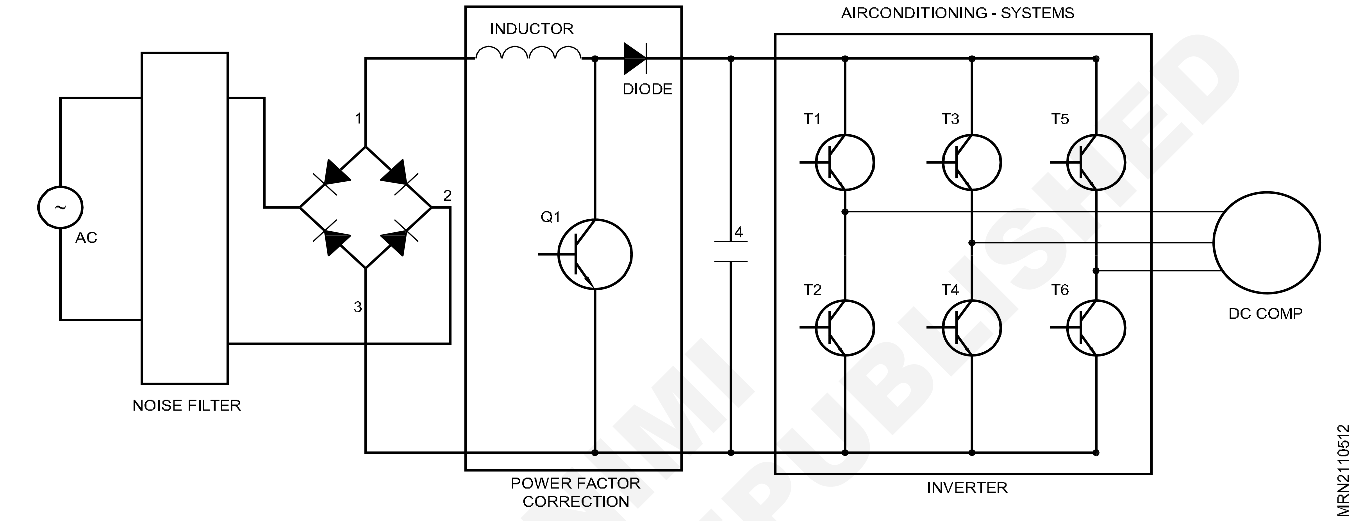
The third section is the INVERTER consisting of IGBT transistors

This section generates 3 phase voltage supply to the DC compressor motor. In the initial design, the designers used six discrete IGBT transistors which are controlled by the microcomputer.

The software is written in such a way that proper signals are being used to power ON or OFF each transistors at a correct timing depending on the feedback such as the position of the rotors in relation to the stator motor and the voltage levels detected.

The brush less DC motor of the compressor will receive close to a 3 phase sinusoidal voltage that turns the motor ON. The speed of the motor can be controlled from low to high by varying the power supplied to the motor through the switching of the transistors. In this way, capacity controlled HVAC can be achieved. When cooling or heating is needed immediately, the motor will turn at the highest speed. When the temperature of the room has stabilized, the motor will turn at a lower speed.

Fig 2



PWM Inverter (Pulse Width Modulation)

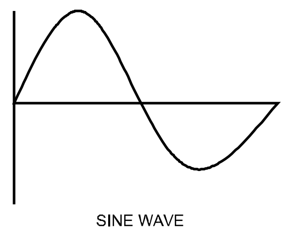
To design an Inverter, many power circuit topologies and voltage control methods are used. The most important aspect of the Inverter technology is the output waveform. To filter the waveform (Square wave, quasi sine wave or sine wave) capacitors and inductors are used Pulse Width Modulation or PWM technology is used in inverters to give a steady output voltage of 230 or 110 V AC irrespective of the load. The inverters based on the PWM technology are more superior to the conventional inverters. The use of MOSFET's in the output stage and the PWM technology makes these inverters ideal for all types of loads. In addition to the pulse width modulation, the PWM inverters have additional circuits for protection and voltage control.

The quality of the output wave form (230/110 volt AC) from inverter determines its efficiency. The quality of the inverter output waveform is expressed using **Fourier analysis data** to calculate the Total Harmonic Distortion (THD). THD is the square root of the sum of the square of the harmonic of the harmonic voltage divided by the fundamental voltage.

THD = V 22+ V 32+ V 42 ……….. V n2 / V 1

Based on the output waveforms, there are three types of Inverters. These are Sine wave, Modified sine wave or Quasi sine wave and Square wave inverters.

Fig 3



Sine wave

Alternating current has continuously varying voltage, which swing from positive to negative. This has an advantage in power transmission over long distance. Power from the Grid is carefully regulated to get a pure sine wave and also the sine wave radiate the least amount of radio power during long distance transmission. But it is expensive to generate sine wave in an inverter. Its quality is excellent and almost all electrical and electronic appliances work well in sine wave inverter.

The sine wave is the AC waveform we get from the domestic lines and from the generator. The major advantage of sine wave inverter is that all of the house hold appliances are designed to operate in sine wave AC. Another advantage is that the sine wave is a form of soft temporal rise voltage and it lacks harmonic oscillations which can cause unwanted counter forces on engines, interference on radio equipments and surge current on condensers.

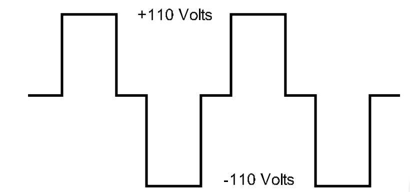
Modified sine wave or Quasi sine wave

Modified sine wave is designed to simulate a sine wave since the generation of sine wave is expensive. This waveform consists of a Flat Plateau of positive voltage, dropping abruptly to zero for a short period, then dropping again to a flat plateau of negative voltage. It then go back to zero again and returning to positive. This short pause at zero volts gives more power to 50 Hz fundamental frequency of AC than the simple square wave.

Modified sine wave

Inverters providing modified sine wave can adequately power most house hold appliances. It is more economical but may present certain problems with appliances like microwave ovens, laser printers, digital clocks and some music systems. 99% of appliances run happily in modified sine wave. Instruments using SCR (Silicon Controlled Rectifier) in the power supply section behave badly with modified sine wave. The SCR will consider the sharp corners of the sine wave as trashes and shut off the instrument. Many of the laser printers behave like this and fail to work in inverters and UPS providing modified sine wave power. Most variable speed fans buzz when used in modified sine wave inverters.

Fig 4

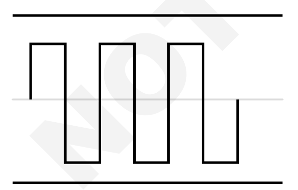


MODIFIED SINE WAVES

Square wave

This is the simplest form of output wave available in the cheapest form of inverters. They can run simple appliances without problems but not much else. Square wave voltage can be easily generated using a simple oscillator. With the help of a transformer, the generated square wave voltage can be transformed into a value of 230 volt AC or higher.

Fig 5

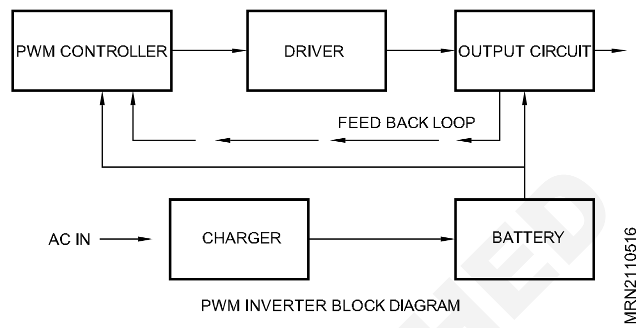


SQUARE WAVE

Advantage of Pulse Width Modulation

In a standard inverter without the PWM technology, the output voltage changes according to the power consumption of the load. The PWM technology corrects the output voltage> according to the value of the load by changing the width of the switching frequency in the oscillator section. As a result of this, the AC voltage from the inverter changes depending on the width of the switching pulse. To achieve this effect, the PWM inverter has a PWM controller IC which takes a part of output through a feedback loop. The PWM controller in the inverter will makes corrections in the pulse width of the switching pulse on the feedback voltage. This will cancel the changes in the output voltage and the inverter will give a steady output voltage irrespective of the load characteristics.

Fig 6



PWM INVERTER BLOCK DIAGRAM

How it works?

To design an inverter, many power circuit topologies and voltage control methods are used. The most important aspect of the inverter technology is the output waveform. To filter the waveform (Square wave, quasi sine waves or sine wave) capacitors and inductors are used. Low pass filters, are used to reduce the harmonic components. Resonant filter can be used if the inverter has a fixed output frequency. If the inverter has adjustable output frequency, the filter must be turned to a level above the maximum fundamental frequency. Feedback rectifiers are used to bleed the peak inductive load current when the switch turns off.

As per the Fourier analysis, a square wave contains odd harmonic like third, fifth, seventh etc, only if it is anti- symmetrical> about 180-degree point. If the waveform has steps of certain width and heights, the additional harmonics will be cancelled. If a Zero voltage step is introduced between the positive and negative parts of the square wave, the harmonics that are divisible by three can be eliminated. The width of the pulse should be of the period for each positive and negative steps and 1/6 of the period for each of the Zero voltage steps. This leaves on the fifth, seventh, eleventh, thirteenth harmonics etc.

The Pulse Width Modulation technology is meant for changing the characteristics of the square wave. The switching pulses are modulating, and regulating before supplied to the load. When the inverter requires no voltage control, fixed pulse width can be used.

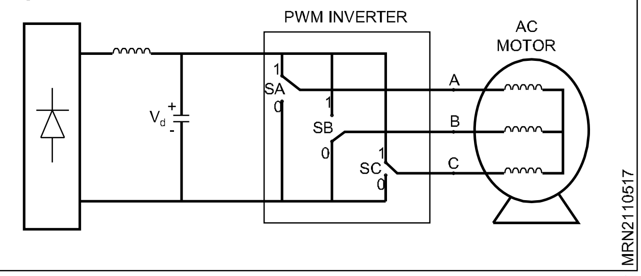
Multiple Pulse Width Modulation (MPWM) Technology

In multiple pulse width technology, waveform that contain a number of narrow pulses are used. The frequency of these narrow pulses is called switching or carrier frequency. The MPWM technology is used in inverters driving variable frequency motor control systems. This allows wide range of output voltages and frequency adjustments. More over the MPWM technology overall improves the quality of the waveform.

PWM inverter characteristics

In order to increase the efficiency of the PWM inverter, the electronic circuit is highly sophisticated with battery charge sensor, AC mains sensor, soft facility, output control etc. The PWM controller circuit uses PWM IC KA 3225 or LM 494. These ICs have internal circuits for the entire operation of the pulse width modulation. The Oscillator circuit to generate the switching frequency is also incorporated in the IC. Output driver section uses transistors or driver IC to drive the output according to the switching frequency. Output section uses an array of switching MOSFETs to drive the primary of the stepping transformer. Output voltage is available in the secondary of the stepping transformer.

Fig 7



What is a VFD?

A Variable Frequency Drive (VFD) is a type of motor controller that drives an electric motor by varying the frequency and voltage supplied to the electric motor. Other names for a VFD are **variable speed drive, adjustable frequency drive, AC drive, Microdrive, and inverter.**

Frequency (or hertz) is directly related to the motor's speed (RPMs). In other words, the faster the frequency, the faster RPMs go. If an application does not require an electric motor to run at full speed, the VFD can be used to ramp down the frequency and voltage to meet the requirements of the electric motor's load. As the application's motor speed requirements change, the VFD can simply turn up or down the motor speed to meet the speed requirement.

How does a variable frequency drive work?

The first stage of a variable frequency AC drive, or VFD, is the converter. The converter is comprised of six diodes, which are similar to check valves used in plumbing systems. They allow current to flow in only one direction; the direction shown by the arrow in the diode symbol. For example, whenever A-phase voltage (voltage is similar to pressure in plumbing systems) is more positive than B or C phase voltage, then that diode will open and allow current to flow. When B-phase becomes more positive than A-phase, then the B-phase diode will open and the A-phase diode will close. The same is true for the 3 diodes on the negative side of the bus. Thus, we get six currents "pulses" as each diode opens and closes. This is called a "six-pulse VFD:, which is the standard configuration for current variable frequency drives.

Let us assume that the drive is operating on a 480V power system. The 480V rating is "rms" or root-mean-squared. The peaks on a 480V system are 676V. as you can see, the VFD de bus has a dc voltage with an AC ripple. The voltage runs between approximately 580V and 680V.

Fig 8

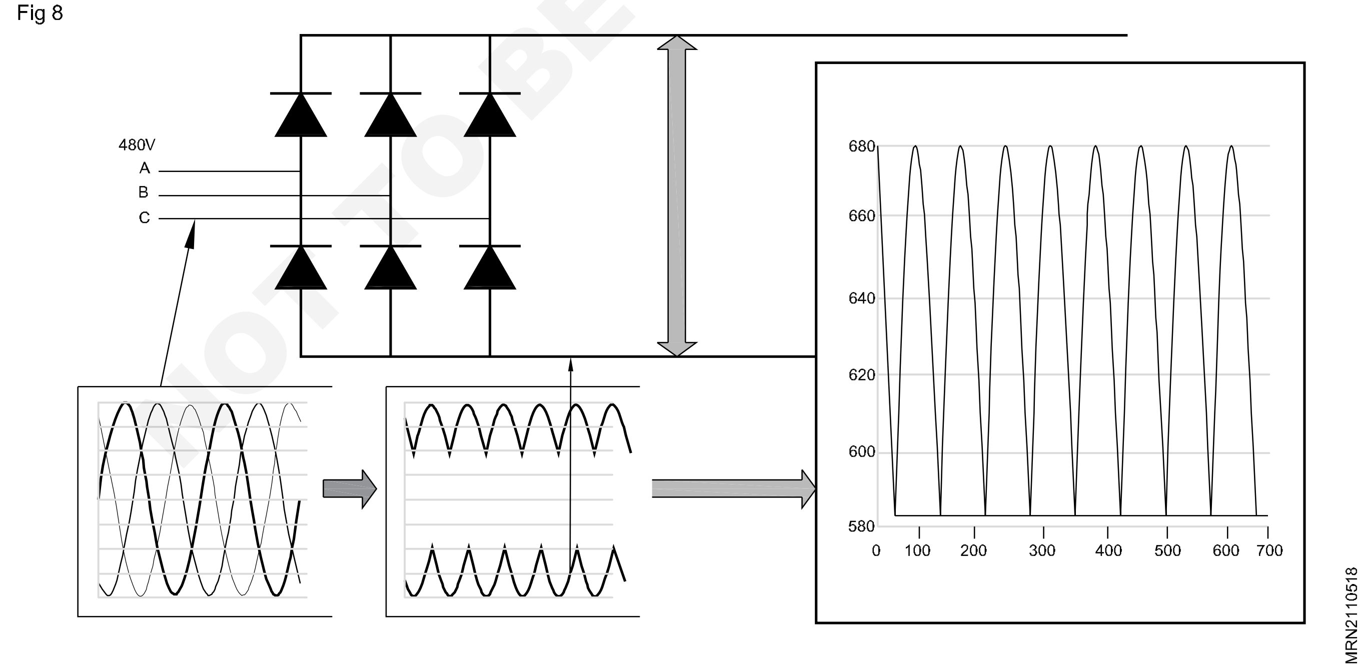
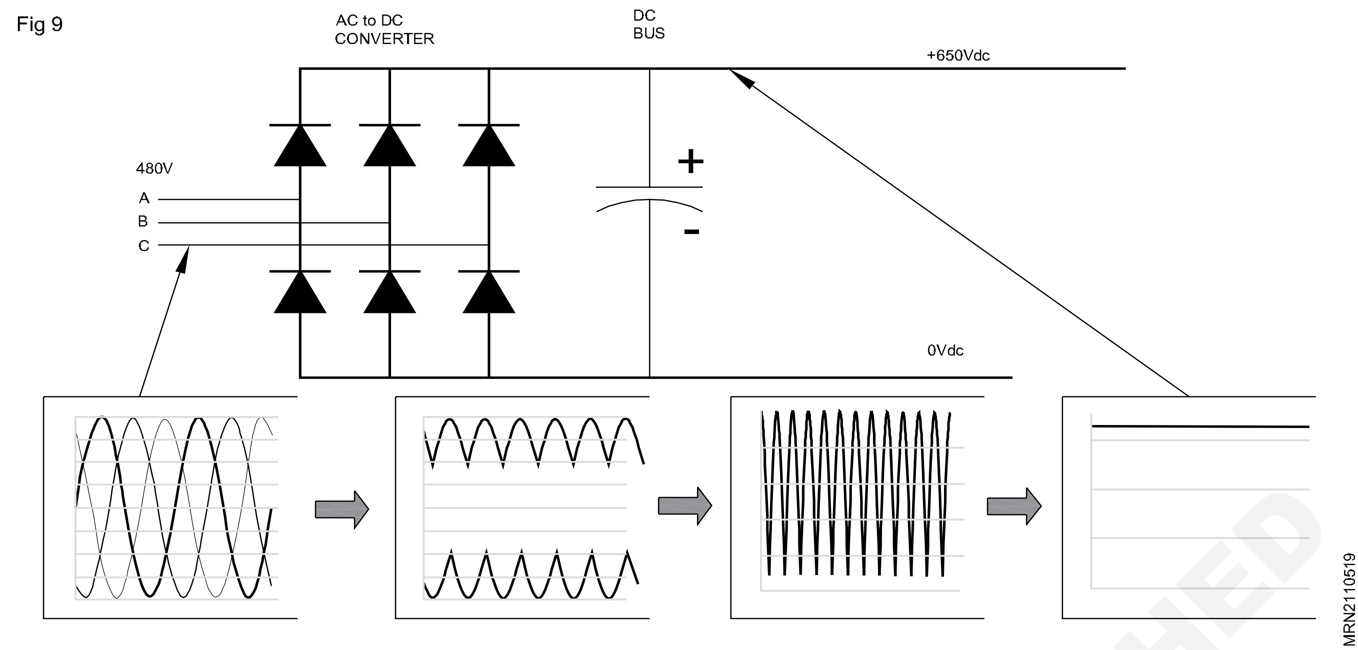


Fig 9



We can get rid of the AC ripple on the DC bus by adding a capacitor. A capacitor operates in a similar fashion to a reservoir or accumulator in a plumbing system. This capacitor absorbs the ac ripple and delivers a smooth dc voltage. The AC ripple on the DC bus is typically less than 3 volts. Thus, the voltage on the DC bus becomes “approximately” 650VDC. The actual voltage will depend on the voltage level of the AC line feeding the drive, the level of voltage unbalance on the power system, the motor load, the impedance of the power system, and any reactors or harmonic filters on the drive.

The diode bridge converter that converts AC to DC is sometimes just to as a converter. The converter that converts the dc back to ac is also a converter, but to distinguish it from the diode converter, it is usually referred to as an “inverter”. It has become common in the industry to refer to any DC to AC converter as an inverter.

Note that in a real VFD, the switches shown would actually by transistors

When we close one of the top switches in the inverter, that phase of the motor is connected to the positive dc bus and the voltage on that phase becomes positive. When we close one of the bottom switches in the converter, that phase is connected to the negative dc bus and becomes negative. Thus, we can make any phase on the motor become positive or negative at will and can thus generate any frequency that we want. So, we can make any phase be positive, negative, or zero.

The blue sine –wave is shown comparison purposes only. The drive does not generate this sine wave.

Notice that the output from the VFD is a ‘rectangular’ wave form. VFD’s do not produce a sinusoidal output. This rectangular waveform would not be a good choice for a general purpose distribution system, but is perfectly adequate for a motor.

Fig 10

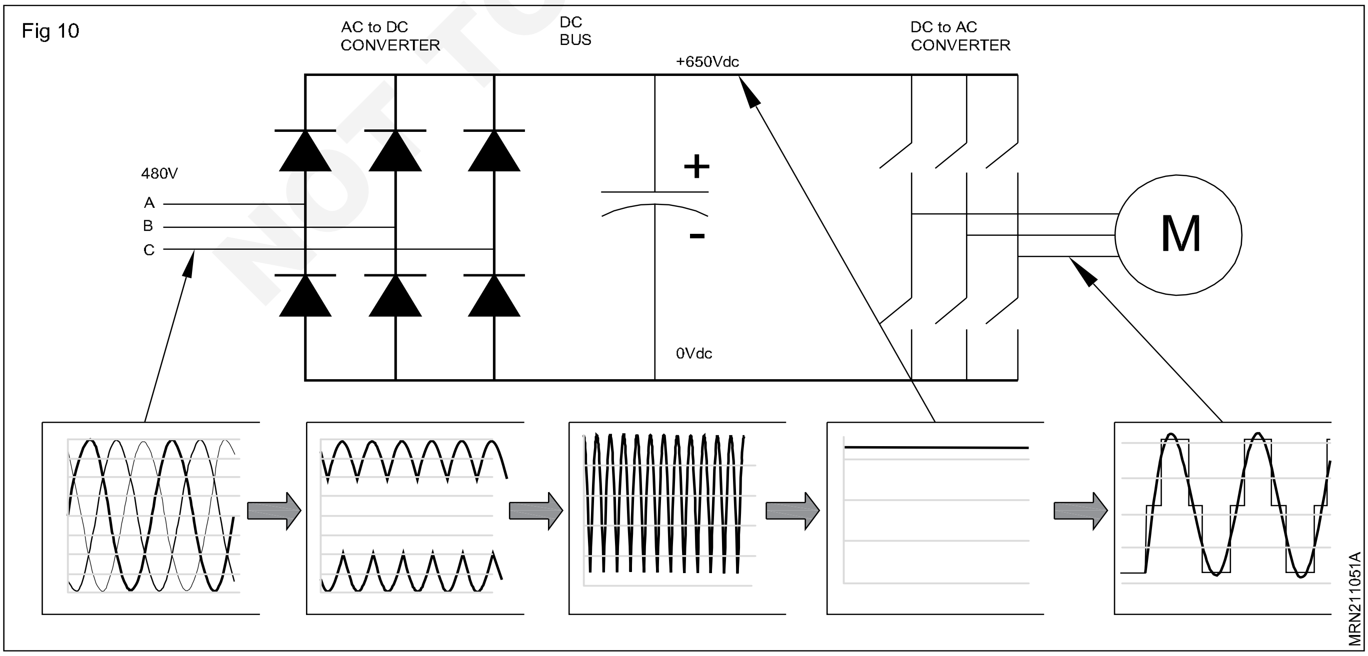
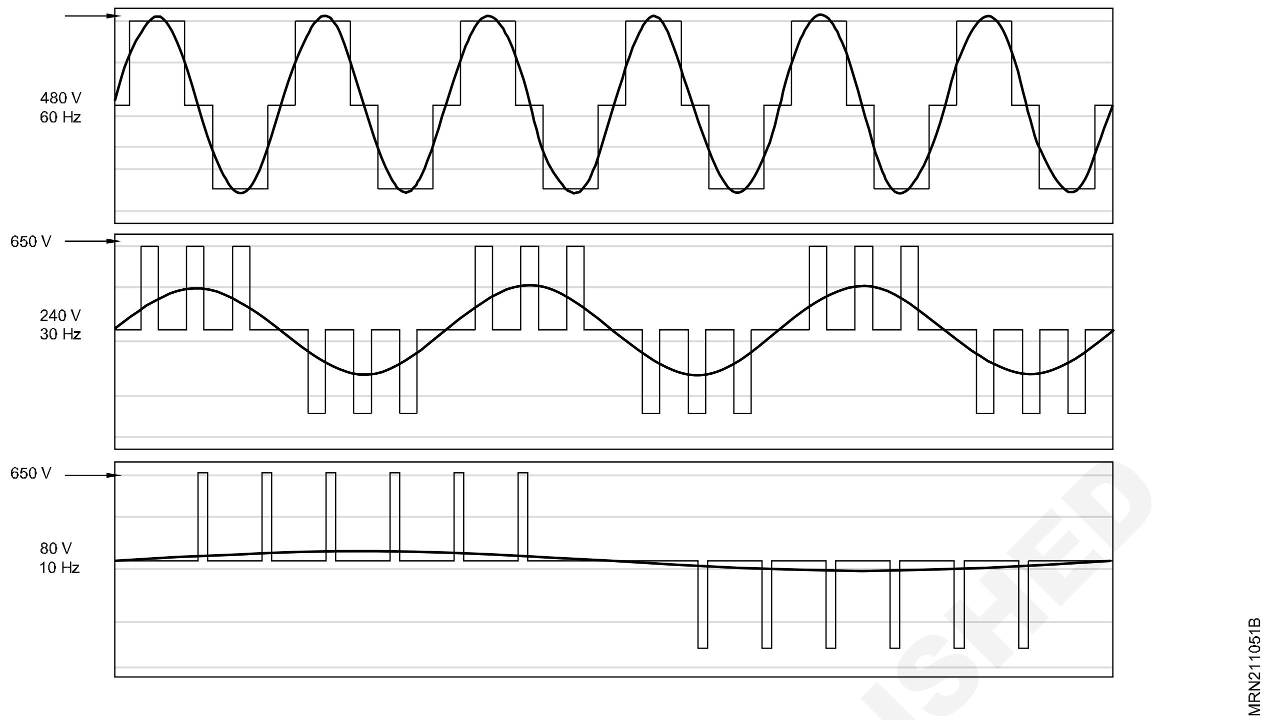


Fig 11



If we want to reduce the motor frequency to 30 Hz, then we simply switch the inverter output transistors more slowly. But, if we reduce the frequency to 30Hz, then we must also reduce the voltage to 240V in order to maintain the V/Hz ratio (see the VFD motor theory presentation for more on this). How are we going to reduce the voltage if the only voltage we have is 650 VDC?

This is called pule width modulation or PWM. Imagine that we could control the pressure in a water line by turning the valve on and off at a high rate of speed. While this would not be practical for plumbing systems, it works very well for VFD's. notice that during the first half cycle, the voltage is ON half the time and OFF half the time. Thus, the average voltage is half of 480V or 240V by pulsing the output, we can achieve any average voltage on the output of the VFD.

Advantages of VFD

Reduce energy consumption and energy costs

If you have an application that does not need to be run at full speed, then you can cut down energy costs by controlling the motor with a variable frequency drive, which is one of the benefits of variable frequency drives. VFDs allow you to match the speed of the motor-driven equipment of the load requirement. There is no other method of AC electric motor control that allows you to accomplish this.

Electric motor systems are responsible for more than 65% of the power consumption in industry today. Optimising motor control systems by installing or upgrading to VFDs can reduce energy consumption in your facility by as much as 70%. Additionally, the utilization of VFDs improves product quality, and reduces production costs. Combining energy efficiency tax incentives, and utility rebates, returns on investment for VFD installations can be as little as 6 months.

Extend equipment life and reduce maintenance

Equipment will last longer and will have less down time due to maintenance when it's controlled by VFDs ensuring optimal motor application speed. Because of the VFDs optimal control of the motor's frequency and voltage, the VFD will offer better protection for motor from issues such as electro thermal overloads, phase protection, under voltage, over voltage, etc,. when you start a load with a VFD you will not subject the motor or driven load to the "instant shock" of across the line starting, but can start smoothly, thereby eliminating belt, gear and bearing wear. It also is an excellent way to reduce and/or eliminate water hammer since we can have smooth acceleration and deceleration cycles.