

REFRIGERATION AND AIR CONDITIONING TECHNICIAN

NSQF LEVEL - 4

2nd Year

TRADE THEORY

SECTOR : CAPITAL GOODS & 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**

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

Sector : Capital Goods and Manufacturing
Duration : 2 Year
Trade : R&ACT - 2nd year Trade Theory - NSQF Level - 4 (Revised 2022)

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FOREWORD

The Government of India has set an ambitious target of imparting skills to 30 crores people, one out of every four Indians, 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 Media Development Committee members of various stakeholders viz. Industries, Entrepreneurs, Academicians and representatives from ITIs.

The National Instructional Media Institute (NIMI), Chennai, has now come up with instructional material to suit the revised curriculum for **R&ACT 2nd Year Trade Theory in CG & M Sector under Yearly Pattern**. The NSQF Level - 4 (Revised 2022) Trade Practical will help the trainees to get an international equivalency standard where their skill proficiency and competency will be duly recognized across the globe and this will also increase the scope of recognition of prior learning. NSQF Level - 4 (Revised 2022) trainees will also get the opportunities to promote life long learning and skill development. I have no doubt that with NSQF Level - 4 (Revised 2022) the trainers and trainees of ITIs, and all stakeholders will derive maximum benefits from these Instructional Media Packages IMPs and that NIMI's effort will go a long way in improving the quality of Vocational training in the country.

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

Jai Hind

ATUL KUMAR TIWARI, I.A.S

Secretary

Ministry of Skill Development & Entrepreneurship,
Government of India.

October 2023
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 2nd Year NSQF Level - 4 (Revised 2022)** under **Capital Goods & Manufacturing** Sector for ITIs.

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

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

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

INTRODUCTION

TRADE PRACTICAL

The trade practical manual is 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 Ten modules

Module 1	Commercial Compressor
Module 2	Water Cooled Condenser with Cooling Tower
Module 3	Expansion Valve
Module 4	Evaporator & Chillers
Module 5	Cooler & Freezer
Module 6	Applications of Commercial Refrigeration
Module 7	HVAC Systems
Module 8	Central Industrial Air Conditioning
Module 9	Mobile Air Conditioning
Module 10	Evaporator & Chillers

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

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

TRADE THEORY

The manual of trade theory consists of theoretical information for the Course of the **R&ACT 2nd Year NSQF Level - 4 (Revised 2022) in CG & M**. 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 perceptual capabilities for performing the skills.

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

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

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

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QR CODE

Module 1



Ex.No. 2.1.99&100



Ex.No. 2.1.104



Ex.No. 2.2.115&116



Ex.No. 2.2.117



Ex.No. 2.1.118

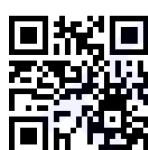


Ex.No. 2.1.120

Module 2



Ex.No. 2.3.121



Ex.No. 2.4.123-127



Ex.No. 2.5.129



Ex.No. 2.5.133-137



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Module 3

Module 4

Module 5

Module 6

Module 7

Module 8



Ex.No. 2.6.143&144



Ex.No. 2.6.149-153



Ex.No. 2.7.157



Ex.No. 2.7.160&161



Ex.No. 2.8.163

Module 8

Module 9



Ex.No. 2.8.171&172



Ex.No. 2.8.173&174



Ex.No. 2.8.184



Ex.No. 2.9.185-188

LEARNING / ASSESSABLE OUTCOME

On completion of this book you shall be able to

S.No	Learning Outcome	Ref. Ex.No.
1	Carry out servicing, dismantling, checking different parts of different types of commercial compressor, re-placing worn out parts, Check lubrication system. Assemble & check performance. NOS- ELE/N3140	2.1.99 - 2.1.114
2	Perform servicing of different types of water-cooled condenser. NOS- ELE/N3140	2.2.115 - 2.2.118
3	Perform servicing and performance test of Cooling tower NOS- ELE/N3141	2.2.119
4	Conduct Servicing, backwash & re-generate Water treatment plant of circulating water. NOS CSC/N9415	2.2.120
5	Perform Fitting of expansion valve, adjustment of refrigerant flow according to heat load. NOS- ELE/N3140	2.3.121 - 2.3.122
6	Perform servicing of evaporator & chillers. NOS- ELE/N3140	2.4.123 - 2.4.128
7	Carry out servicing and retrofit of Water cooler and dispenser. NOS CSC/N9416	2.5.129 - 2.5.132
8	Service, retrofit of visible cooler and bottle cooler and test performance. NOS CSC/N9417	2.5.133 - 2.5.137
9	Conduct servicing of deep freezer and test performance. NOS CSC/N9418	2.5.138 - 2.5.141
10	Install, service, repair, gas charging and testing performance of Ice Cube machine. NOS CSC/N9419	2.6.142
11	Repair, servicing & retrofit of ice candy plant. NOS CSC/N9420	2.6.143 - 2.6.144
12	Perform servicing of Ice plant and evaporative condenser. NOS CSC/N9421	2.6.145 - 2.6.146
13	Perform Servicing and preventive maintenance of walk in cooler & cold storage. NOS CSC/N9422	2.6.147 - 2.6.153
14	Study psychrometric chart and measure psychrometric properties using psychrometric, anemometer i.e. DBT, WBT, RH, air flow etc. NOS- ELE/N3140	2.7.154 - 2.7.156
15	Perform servicing of motor and blowers used in different air conditioning system. NOS- ELE/N3141	2.7.157
16	Construct, install, pack thermal and acoustic insulation of different air ducts. NOS- ELE/N3141	2.7.158 - 2.7.160
17	Perform servicing and maintenance of different types of air filters. NOS- ELE/N3141	2.7.161
18	Perform servicing, installation, fault diagnosis and remedial measures on Package AC with Air cooled condenser. NOS CSC/N9423	2.8.162 - 2.8.163
19	Carry out Servicing, installation, fault diagnosis and remedial measures in Package A.C. with water cooled condenser. NOS- ELE/N3140	2.8.164 - 2.8.166
20	Identify the various components of central AC test electrical components and make wiring. Servicing of A.H.U, damper, check air flow, De-scaling of condenser and CT servicing. NOS- ELE/N3141	2.8.167 - 2.8.170
21	Pump down the system, top up oil and gas and check temperature and pressure. NOS- ELE/N3140	2.8.171 - 2.8.172
22	Identify components of DX system. Test components, make wiring of DX system. Test leak and evacuate, gas charge the system and check the performance. Maintenance, trouble shoot and operate the plant. NOS- ELE/N3140	2.8.173 - 2.8.174

23	Identify the different parts of VRF/VRV system, check and service VRF/VRV system. NOS- ELE/N3141	2.8.175 - 2.8.177
24	Identify different parts of indirect or chillers system. Check components and make wiring, leak test, evacuate and gas charge/ top up. Servicing the plant and trouble shoot. NOS- ELE/N3141	2.8.178 - 2.8.179
25	Identify chilled water pipe line. Servicing of dampers, FCU and water control valves. NOS- ELE/N3141	2.8.180 - 2.8.181
26	Troubles shoot both Central A.C. plant DX and indirect system. Check different control system, installation of other major components, servicing of all parts including cooling tower and water treatment plant. NOS- ELE/N3141	2.8.182 - 2.8.184
27	Perform servicing of car AC. Fault diagnosis & remedial measures. NOS- ELE/N3141	2.9.185 - 2.9.188
28	Perform Servicing, fault diagnosis, repair and maintenance of mobile A.C. leak test, evacuation, gas charging, check magnetic clutch and make wiring. Test performance after start. NOS- ELE/N3141	2.9.189 - 2.9.190
29	Perform preventive maintenance of different plants. Maintain log book based on daily operation. NOS- ELE/N3141	2.10.191 - 2.10.192

SYLLABUS

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)		
Professional Skill 95 Hrs.; Professional Knowledge 20 Hrs.	Carry out Servicing, dismantling, checking different parts of different types of commercial compressor, re- placing worn out parts, Check lubrication system. Assemble & check performance. NOS- ELE/N3140	99.Familiarization with commercial type reciprocating compressor and centrifugal compressor. (04 hrs.)	COMMERCIAL COMPRESSOR (Fixed & Variable) Function, types, Construction & working, applications of compressors used in commercial refrigeration. Volumetric efficiency, Capacity control. (05 hrs.)		
		100.Dismantling and checking of compressor & accessories. (10 hrs.)			
		101.Check and service valve plate and piston assembly. (05 hrs.)			
				102.Lapping valve plate, and refit. (05 hrs.)	Compressor lubricant oil, types, properties, types of lubrication methods such as splash, forced feed. Study the Construction and working principle of different commercial compressor, open type, (Reciprocating, centrifugal (05 hrs.)
			103.Check belt tension		
			104.Check and test lubricating system. (05hrs.)		
			105.Servicing of filter and oil pump. (08 hrs.)		
				106.Cutting gasket. (04 hrs.)	Screw compressor. Star and Delta connection and their comparison. Production of rotating magnetic field by three phase AC supply. Working principle of three phase induction motor. Terms such as torque, slip, rotor frequency and
	107.Assemble compressor and Test overall efficiency. (07 hrs.)				
	108.Star & Delta connection on a three- phase motor and show line voltage, line current, phase voltage and phase current insulation test,and continuity. (10 hrs.)				

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
		<p>109. Identify the terminals of a Squirrel cage induction motor. (06 hrs.)</p> <p>110. Start the motor through DOL starter and measure starting current, running current and show changing of DOR. (06 hrs.)</p> <p>111. Start the motor through Star Delta or Auto transformer starter and measure starting current, running current and show changing of DOR. (06 hrs.)</p> <p>112. Familiarise with Slip-ring induction motor and identify it's terminals. (04 hrs.)</p> <p>113. Start the Slip-ring induction motor through Rotor resistance starter and measure starting current, running current and show changing of DOR. (03 hrs.)</p> <p>114. Rectify fault through insulation test, continuity, open circuit and short circuit test. (8 Hrs)</p>	<p>their relation. Construction of squirrel cage induction motor. Importance of phase sequence. Construction of slip ring induction motor Comparison between SCIM and SRIM. Three phase motor starters such as DOL starter, Star – Delta starter, Auto transformer starter and Rotor resistance starter. Common faults, causes and remedies in three phase AC motors. (10 hrs.)</p>
Professional Skill 50 Hrs.; Professional Knowledge 15Hrs.	Perform Servicing of different types of water-cooled condenser. NOS-ELE/N3140	<p>115 Servicing of water-cooled condenser and receiver. (13 hrs.)</p> <p>116 Testing its performance by inlet and outlet pressure and temperature. (13 hrs.)</p> <p>117. De-scaling by diluted HCl to increase efficiency. (12 hrs.)</p>	<p>WATERCOOLED CONDENSER</p> <p>Study the water-cooled Condenser, its type and capacity, construction and working, de scaling, application. (08 hrs.)</p>
		<p>118. Pump down the gas for necessary servicing and repairing. (12 hrs.)</p>	<p>Evaporative condenser, function, construction and application. Liquid receiver, function. Drier, types and application. (07 hrs.)</p>
Professional Skill 15 Hrs.; Professional Knowledge 06 Hrs.	Perform servicing of and performance test of Cooling tower. NOS-ELE/N3141	<p>119. Servicing of natural draft, forced draft and induced draft cooling tower. (15 hrs.)</p>	<p>COOLING TOWER</p> <p>Cooling tower, types, Construction, capacity advantage & disadvantages of different types of cooling tower. Efficiency, approach and Cooling tower range. (06 hrs.)</p>
Professional Skill 10 Hrs.; Professional Knowledge 06 Hrs.	Conduct servicing, & regenerate water treatment plant of circulating water. NOS CSC/N9415	<p>120. Dismantle and Assemble water circulating pump. (10 hrs.)</p>	<p>WATERTREATMENT</p> <p>Causes for water contamination and water treatment. (6 Hrs)</p>
Professional Skill 20 Hrs.; Professional Knowledge 11 Hrs.	Perform fitting of expansion valve, Adjustment of refrigerant flow according to heat load. NOS- ELE/N3140	<p>121. Familiarize with thermostatic and Electronic expansion valve.(10 hrs.)</p>	<p>EXPANSION VALVE</p> <p>Types and function, construction, working principle, & their advantage& disadvantages. Thermostatic Expansion Valves</p>

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
			(TXV), Automatic Expansion Valves (AXV), Float valves, fixed and modulating orifice controls & electronic Expansion Valves, LMC (level master control).(07 hrs.)
		122. Identify automatic expansion valve.(10 hrs.)	Selection of Expansion valves and capillaries for various Refrigeration and Air-conditioning applications. (04 hrs.)
Professional Skill 60 Hrs.; Professional Knowledge 13 Hrs.	Perform servicing of evaporator & chillers. NOS- ELE/N3140	123. Identify extended surface forced air-cooled evaporators.(05 hrs.) 124. Service air cooled evaporator by blower.(15 hrs.) 125. Service water cooled or brine cooled chiller.(15 hrs.) 126. Check de-frosting system and anti-freeze thermostat.(10 hrs.) 127. Oil removing from coil.(05 hrs.)	EVAPORATOR Function, types, Plate & Tube forced air DX evaporators. Types of Defrost system. Water/ Brine chillers. Types of brine used as secondary refrigerant. Accumulator, its function. (06 hrs.)
		128. Servicing of liquid suction heat exchanger used in central plant. (10 hrs.)	Liquid-suction-liquid Heat-exchanger, their function, construction, application & advantages. Study of Accumulator and Oil separator. (07 hrs.)
Professional Skill 40 Hrs.; Professional Knowledge 05 Hrs.	Carry out Servicing and retrofit of Water cooler and dispenser. NOS CSC/N9416	129. Identify parts, control, electric circuit, accessories of storage type water cooler and Bubble type water dispenser.(03 hrs.) 130. Trouble shoot of commonly faced problems like condenser fan motor failure, corrosion etc. (10 hrs.) 131. Install gauge manifold, Leak test and refrigerant charging after evacuation. (15 hrs.) 132. Installation, servicing and maintenance of water cooler and dispensers. (12 hrs.)	WATER COOLER & WATER DISPENSER Study the refrigeration cycle of storage type water cooler and dispenser types. Construction & working, Capacity & applications. Study the electrical and mechanical components of storage type water cooler. (05 hrs.)
Professional Skill 45 Hrs.; Professional Knowledge 05 Hrs.	Service, retrofit of visible cooler and bottle cooler and test performance. NOS CSC/N9417	133. Checking and servicing of visible cooler and bottle cooler and its parts.(10 hrs.) 134. Preventive maintenance and trouble shooting (05 hrs.) 135. Evacuation, flushing with dry nitrogen, Retrofit the machine with HFC 134a, R- 600a, R-290.(10 hrs.) 136. Check wiring circuit, test components & replace.(10 hrs.) 137. Install and Test performance of the machine. (10 hrs.)	VISIBLE COOLER AND BOTTLE COOLER Visible cooler & bottle coolers. Description, construction & working, with HFC-134a and hydrocarbons, safety especially for flammable refrigerants, maintenance, testing of mechanical and electrical components including sealed electrical components fitted in appliances using flammable refrigerants. (05 hrs.)

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
Professional Skill 35 Hrs.; Professional Knowledge 05 Hrs.	Conduct servicing of deep freezer and test performance. NOS CSC/N9418	138 Checking and servicing of horizontal and vertical deep freezer / display cabinet and their different parts. (10 hrs.) 139 Preventive maintenance and trouble shooting. (05 hrs.) 140 Check wiring circuit, test and replace defective components. (10 hrs.) 141 Install and test performance. (10 hrs.)	DEEP FREEZER / DISPLAY CABINET Description, Construction, working, specifications, function, care and maintenance, faults and remedies. (05 hrs.)
Professional Skill 15 Hrs.; Professional Knowledge 05 Hrs.	Install, service, repair, gas charging and testing performance of Ice Cube machine. NOS CSC/N9419	142. Checking and servicing of ice cube machine and its different components. (15hrs.)	ICE CUBE MACHINE- Description, Construction, working, reverse cycle functioning & Circuit diagram, installation method. SOFTY MACHINE - Description, Construction and function. (05 hrs.)
Professional Skill 20 Hrs.; Professional Knowledge 05 Hrs.	Repair, servicing & retrofit of ice candy plant. NOS CSC/N9420	143. Identify different parts, controls and accessories used in ice-candy plant. (10 hrs.) 144. Prepare brine solution, function of agitator and temperature maintained in brine. (10 hrs.)	ICE CANDY PLANT- Function, construction, working principle, Circuit diagram, capacity & types of compressor used. Brine composition to maintain required temperature. Operation, maintenance, retrofit. (05 hrs.)
Professional Skill 25 Hrs.; Professional Knowledge 06 Hrs.	Perform servicing of Ice plant and evaporative condenser. NOS CSC/N9421	145. Identify parts, accessories and controls of ice plant. (10 hrs.) 146. Check, service and operate ice plant (15 hrs.)	ICE PLANT- Details about components of Ice plant their functioning, (06 hrs.)
Professional Skill 55 Hrs.; Professional Knowledge 12 Hrs.	Perform Servicing and preventive maintenance of walk in cooler & cold storage. NOS CSC/N9422	147. Identify parts, accessories, controls and operation of walk in cooler and reach in cabinet. (10 hrs.) 148. Preventive maintenance, trouble shooting and servicing of components. (10 hrs.) 149 Identify parts, controls and accessories of Cold storage plant. (05 hrs.) 150 Service and operation of cold storage plant. (10 hrs.) 151 Check the refrigeration system of the cold storage plant. (05 hrs.) 152 Measure pressure and temperature. (05 hrs.) 153 Evacuation by two stage rotary vacuum pumps and gas charging. (10 hrs.)	WALK IN COOLER & REACH IN CABINET Details about components, their functioning, working principle, Circuit diagram, capacity & types. Care and maintenance. (03 hrs.) COLD STORAGE Study of cold storage plant, parts, Construction, applications, controls & electrical diagram used in cold storage plant. Food preservation spoiling agents- controlling of spoiling agents, preservation by refrigeration system, maintaining temperature in different places. Types of cold storage and its details. (05 hrs.)

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
			capacity and specification. Use of vibration eliminator and shock absorber, Study the lay out . Cold storage plant operation, its common trouble & remedies. Deep freezing, freezing tunnel, blast freezer its function and working, its application.(04 hrs.)
Professional Skill 50 Hrs.; Professional Knowledge 11 Hrs.	Study psychrometric chart and measure psychrometric properties using psychrometric, anemometer i.e. DBT, WBT, RH, air flow etc. NOS- ELE/N3140	154 Find out DBT, WBT, RH & other properties by using psychrometric chart. (15 hrs.) 155 Use psychrometer for finding DBT and WBT.. (15 hrs.)	HVAC (Plant) – Introduction to HVAC, Fundamentals of Central Air Conditioning / HVAC plant, requirements of comfort A.C, study of psychrometric terms, DBT, WBT, RH, enthalpy, dew point, and specific humidity. (05 hrs.)
		156 Use Anemometers for measuring air flow. (20 hrs.)	Types of Central air conditioning (Direct and indirect system) Construction, working, components, faults, care and maintenance. (06hrs.)
Professional Skill 20 Hrs.; Professional Knowledge (07 hrs)	Perform servicing of motor and blowers used in different air conditioning system. NOS- ELE/N3141	157 Service of fans and blowers used in air-conditioning system. (20 hrs.)	Description of blowers & fans, function and types, static and velocity pressure measurements. (07 hrs.)
Professional Skill 30 Hrs.; Professional Knowledge 05 Hrs.	Construct, install, pack thermal and acoustic insulation of different air ducts. NOS- ELE/ N3141 Perform servicing and maintenance of different types of air filters. NOS- ELE/N3141	158. Construct Ducts as per duct layout drawing. (10 hrs.) 159. Insulate Ducts. (05hrs.) 160. Service and maintain different filters. (10 hrs.) 161. Placing of filters. (05 hrs.)	DUCT Function, types, materials, duct designing, duct insulation, properties of insulating AIR FILTERS Function of air filters, types, construction, maintenance, effect of choked Air filter, (05 hrs.)
Professional Skill 35 Hrs.; Professional Knowledge 6 Hrs.	Perform servicing, installation, fault diagnosis and remedial measures on Package AC with Air cooled condenser. NOS CSC/ N9423	162. Identify various components of Package AC (Air Cooled Condenser). (15 hrs.) 163. Check electrical circuit of Package AC (Air Cooled Condensers). (20 hrs.)	PACKAGE AC (with Air Cooled Condenser) Study the Package AC (with Air Cooled Condensers), its construction and working principle, types, trouble shooting. (6hrs.)
Professional Skill 25 Hrs.; Professional Knowledge 15 Hrs.	Carry out servicing, installation, fault diagnosis and remedial measures in Package A.C. with water cooled condenser. NOS- ELE/ N3140	164. Identify various components of package AC, (Water cooled condenser). (06hrs.) 165. Identify various components of split package AC. (07 hrs.) 166. Electrical circuit of split package AC. (12 hrs.)	PACKAGE A.C WITH WATER COOLED CONDENSER Study Package AC, construction and working principle, Duct system, AHU. Care and maintenance. (15 hrs.)

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
Professional Skill 30 Hrs.; Professional Knowledge 07 Hrs.	Identify various components of central AC, test electrical components and make wiring. Servicing of A.H.U, damper, check air flow, De-scaling of condenser and CT servicing. NOS- ELE/ N3141	167. Identify various components of central AC plant.(Direct) (04 hrs.) 168. Electrical circuit of central AC plant. (10 hrs.) 169. Servicing AHU including fire dampers. (06hrs.) 170. Checking airflow, damper, temperature and pressure. (10 hrs.)	CENTRAL/ INDUSTRIAL AIRCONDITIONING. Construction and working principle, types, maintenance of Industrial Air-conditioning plant. Humidification and dehumidification methods. Description of AHU and FCU (07 hrs.)
Professional Skill 10 Hrs.; Professional Knowledge 07 Hrs.	Pump down the system, top up oil and gas and check temperature and pressure. NOS- ELE/ N3140	171. Pump down gas from central AC plant. (05 hrs.) 172. Check temperature and pressure control. (05 hrs.)	Temperature and pressure controls used in AC plant, its construction, working, safety devices, piping lines. (07 hrs.)
Professional Skill 20 Hrs.; Professional Knowledge 05 Hrs.	Identify components of DX system. Test components, make wiring of dx system. Test leak and evacuate, gas charge the system and check the performance. Maintenance, trouble shoot and operate the plant. NOS- ELE/N3140	173. Identify various components of direct expansion type central AC plants. (10 hrs.) 174. Electrical circuit of direct expansion type central AC plants. (10 hrs.)	DIRECT EXPANSION SYSTEM Study Direct expansion system. Operation & Preventive Maintenance Schedule of central AC plant. Maintain log book for daily operation. (05 hrs.)
Professional Skill 20 Hrs.; Professional Knowledge 6 Hrs.	Identify the different part of VRF/VRV system, check and service VRF/VRV system. NOS- ELE/N3141	175. Identify VRF / VRV system. (05 hrs.) 176. Check and service VRF / VRV system. (10 hrs.) 177. Identify error code. (05 hrs.)	VRF / VRV system – description and function of different parts. Details of piping have and controls system, Common reason for error code, types of ODU and IDU. (6hrs.)
Professional Skill 15 Hrs.; Professional Knowledge 07 Hrs.	Identify different part of indirect or chiller system. Check components and make wiring, leak test, evacuate and gas charge/ top up. Servicing the plant and trouble shoot. NOS- ELE/N3141	178. Service various components of indirect expansion type central AC plants. (05 hrs.) 179. Check electrical circuit of indirect expansion type central AC plants. (10 hrs.)	INDIRECT/CHILLER SYSTEM Study central station AHU and FCU, Air washers used in chilled water system, understanding lay out, modulating valves for temperature control. Expansion valves & other related control – description and function. (07 hrs.)
Professional Skill 20 Hrs.; Professional Knowledge 05 Hrs.	Identify chilled water pipe line. Servicing of dampers, FCU and water control valves. NOS- ELE/N3141	180. Insulate chilled water piping's. (08 hrs.) 181. Servicing of FCU and water control valves. (12 hrs.)	Study of Humidification & De-humidification. Humidifiers & De-humidifier's. Humidity control. Use of hygrometer. (05 hrs.)
Professional Skill 20 Hrs.; Professional Knowledge 10 Hrs.	Troubles shoot of both central A.C. plant Dx and indirect system. Check different control system installation of other	182. Check Vibration eliminator and water proofing insulation. (5 hrs.) 183. Check different controls used in central AC system. (10 hrs.)	Construction and study of commercial A.C plant, package chillers, screw chillers, reciprocating chillers. (5 hrs.)

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
	major components, servicing of all parts including cooling tower and water treatment plant. NOS- ELE/N3141	184. Trouble shooting of central AC. (5hrs.)	Controls used in AC system, Electromechanical, pneumatic and electronic. Detail study of heat load calculation for commercial and industrial buildings. (5 hrs.)
Professional Skill 35 Hrs.; Professional Knowledge 10 Hrs.	Perform servicing of car AC. Fault diagnosis & remedial measures. NOS- ELE/N3141	185. Identify various mechanical and electrical components used in car AC. (03 hrs.) 186. Testing of system components & fault finding (08 hrs.) 187. Install gauge manifold to check suction and discharge pressure in charging time and running time. (04 hrs.) 188. Leak testing using dry nitrogen, evacuation and gas charging (HFC-134a, HFO- 1234yf and blends of HFCs and HFOs). (04 hrs.)	CAR AIR CONDITIONING Study various components and cycle of Car AC, electrical circuits, Study of good service practice, trouble shooting, Magnetic clutch operation, free movement of flywheel (nonfunctioning of clutch), care and maintenance. (05 hrs..)
	Perform Servicing, fault diagnosis, repair and maintenance of mobile A.C. leak test, evacuation, gas charging, check magnetic clutch and make wiring. Test performance after start. NOS- ELE/N3141	189. Installation and trouble shooting (08 hrs.) 190. Testing magnetic clutch, compressor overhauling, condenser cleaning and add refrigerant Regular maintenance (08 hrs.)	MOBILE AC (Bus, train) Construction and working of bus AC. Construction & working of train AC and its operation. Trouble shooting in train A.C. (5 hrs.)
Professional Skill 25 Hrs.; Professional Knowledge 05 Hrs.	Perform preventive maintenance of different plants. Maintain log book based on daily operation. NOS- ELE/ N3141	191 Study/execute repair of different commercial units at site. (13 hrs.) 192 Study/execute preventive maintenance of different commercial units at site. (12 hrs.)	Planning for Preventive maintenance and scheduling of maintenance activities in large AC and Refrigeration plant. (05 hrs.)

Commercial reciprocating and centrifugal compressors

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

- explain the types of commercial compressors
- explain the classification of commercial reciprocating compressor
- describe the construction and working of commercial reciprocating compressor
- describe the construction and working of centrifugal compressor.

Types of commercial compressors

The compressor referred as the 'HEART' of mechanical refrigeration system. The compressor sucks low pressure low temperature vapour refrigerant from the evaporator and compress it to high pressure and high temperature refrigerant and delivers it to the condenser. Compressor creates the flow of high pressure high temperature refrigerant through the discharge line to the condenser and also compressor creates the flow of refrigerant through the entire refrigeration system.

There are five basic type of compressors used in the refrigeration and air conditioning industry.

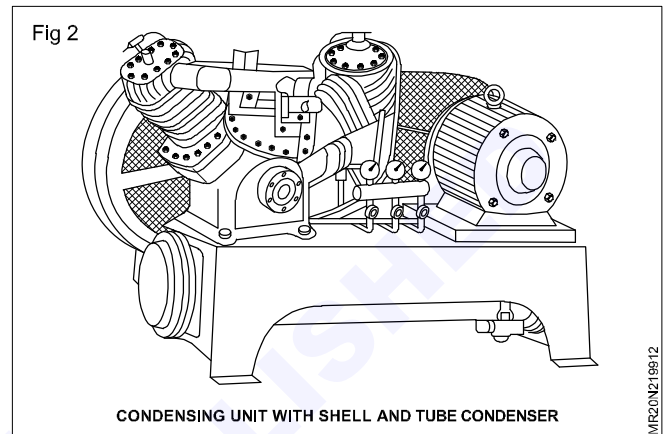
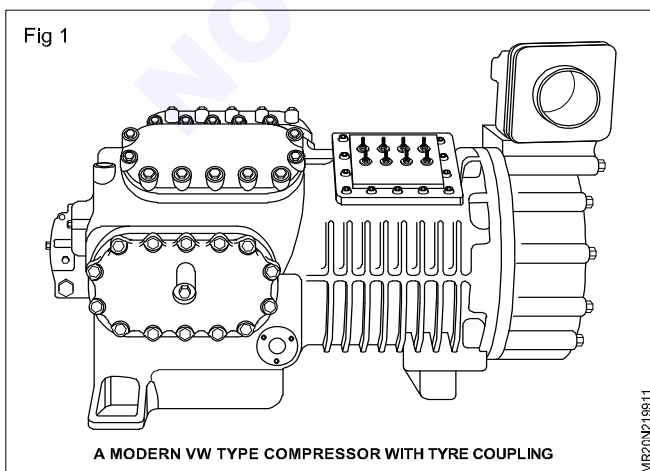
- Reciprocating compressor
- Screw, scroll type compressor
- Scroll compressor
- Screw compressor
- Centrifugal compressor

The type of compressor used for a given application depends upon the capacity of the unit and temperature required, cost, serviceability, and noise. Air conditioning plant employs either reciprocating, screw, scroll type or a centrifugal compressor.

Compressor motor drive system: (Fig 1 & 2)

To operate the compressor, we need electric energy by means of an electric motor. Here the electrical energy is converted into mechanical energy. Electric motor may remain connected with the compressor as follows.

1 Direct Drive: Compressor shaft connected by tyre coupling with motor shaft.



2 Indirect Drive : Compressor flywheel which is attached with the extended outward portion of crankshaft remains connected by belts with motor pulley.

Classification of commercial reciprocating compressor. The reciprocating compressors are classified in a number of ways.

By cylinder arrangement

- | | |
|------------|---------------------------|
| 1 Vertical | 2 Horizontal |
| 3 Inclined | 4 'V' 'W' and radial type |

By number of cylinders

- | | |
|-------------------|-------------------|
| 1 Single cylinder | 2 Double cylinder |
| 3 Multi cylinder | |

By construction

- 1 Sealed or Hermetically sealed
- 2 Semi sealed or semi Hermetic
- 3 Open type

By method of compression

- 1 Single stage
- 2 Multi stage

Construction and working of reciprocating compressor

Commercial reciprocating compressor consist of service valves, compressor pulley, muffler oil separator, compressor valve plates, oil filter, capacity control valves, compressor shaft, cylinder and piston assembly, shaft seal, direct coupling or 'V' belt, foundation bolt of compressor, chassis mounted bolts, handle cover etc.

The original energy source for reciprocating compressor is usually an electric motor its rotary motion needs to get changed to reciprocating motion. This change is usually made by a crank or eccentric shaft and a connecting rod. The connecting rod connects the crank to the piston. The complete mechanism is housed in a leak proof container called a crank case. when the piston moved downward in the cylinder [i.e. when the piston moves from TDC (Top Dead Centre) to BDC (Bottom Dead Centre)] it sucks the low pressure-low temperature refrigerant vapour from the suction chamber through suction valve, as when the piston moves downward there creates a low pressure inside the cylinder and thus the suction valve moves downward to open and the low pressure-low temperature refrigerant vapour gets into the whole cylinder space. After that when piston start to move upward [i.e. when the piston moves from BDC (Bottom Dead Centre) to TDC (Top Dead Centre)] it compresses the sucked refrigerant into a much smaller space. After compressing, due to pressure difference inside the cylinder and outside the cylinder i.e. high pressure below the discharge valve and low pressure outside the discharge valve the compressed vapour pushes the discharge valve to open up and hence the compressed vapour is being pushed through the discharge valve, discharge chamber and discharge line into the condenser. Thus compressor makes the flow of refrigerant throughout the system by providing it the required pressure and temperature according to the need.

- Due to abnormal sound when the compressor is in operation.
- Improper pressure variation, due to short cycle of refrigerant vapour, between suction and discharge valves.
- Compressor pumping capacity is very poor.

The procedures of dismantling open type reciprocating commercial compressors - Refer exercise Trade Practical.

Crankcase heater used in the compressor oil sump, is to minimise the quantity of refrigerant being absorbed in the lubrication oil.

The low temperature, refrigerant vapour enters into the crankcase and mixes with the oil and exchange heat with the hot lubricating oil thus reducing the temperature of the lubricant oil resulting in the change of viscosity of the oil.

To retain that viscosity, the crankcase heater the crankcase oil temperature and improve the oil lubricating function.

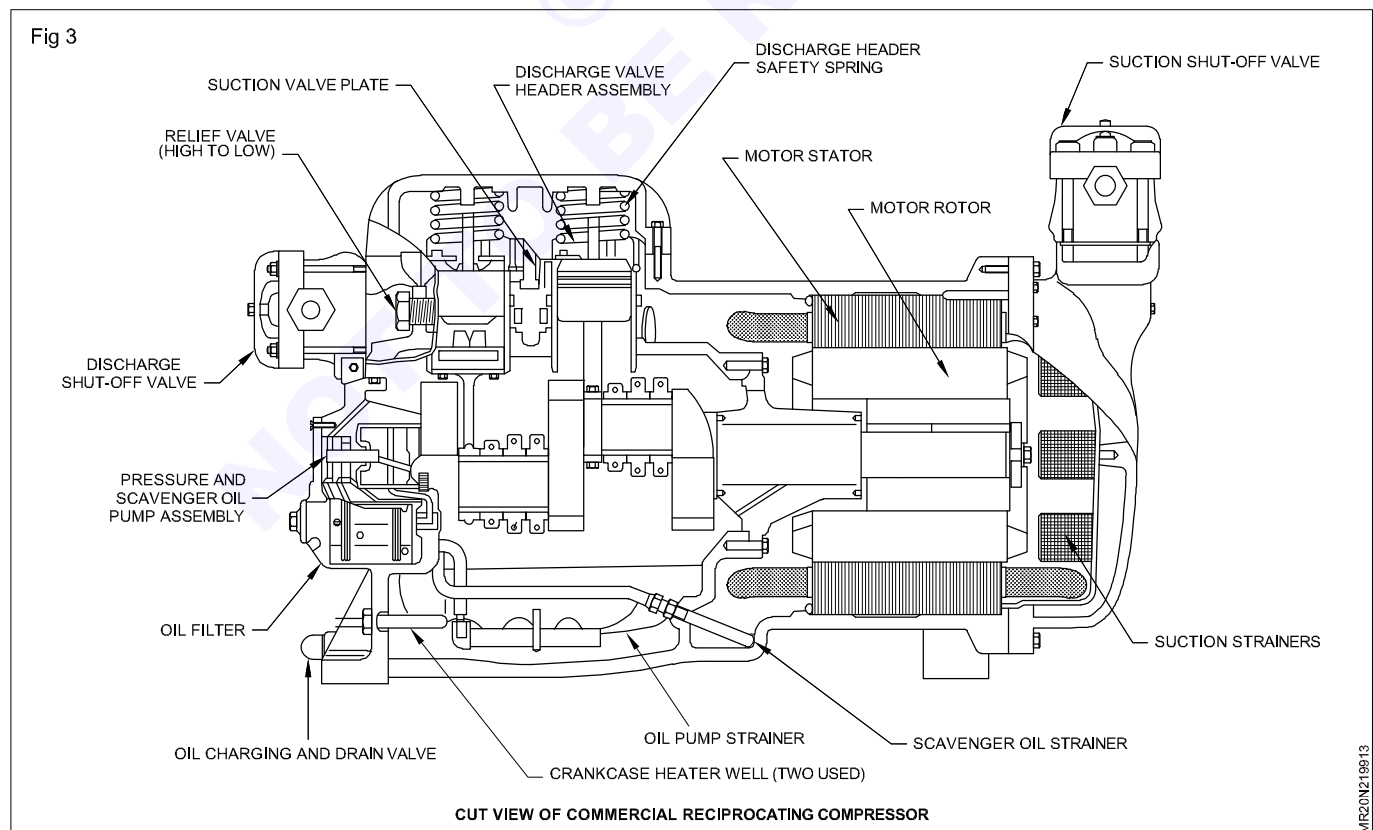
During the operation of the compressor / idle time of the compressor the heater will be controlled by thermostat, sensing the oil temperature, keep it within the range.

Fly wheel is generally made of cast iron. It is connected to the one end of the crank shaft for driving the compressor by the 'V' belt, is connected with the other end, the pulley of the prime motor, which enable it to revolve.

Safety procedures to be followed

- As per schedule maintenance the compressor overhauling.

- When slipping the belt between the belt and pulley groove by screw driver, care should be taken of the fingers.



- Care should be taken while removing the head and the valve assembly. Try not to damage the gaskets.
- Care handling should be followed, when removing and shifting the compressor, since it is very heavy.
- Should be cautious about the spring tension, while dismantling the oil-seal and valve assembly.
- Use suitable recommended tools.
- Attend the faults with your Instructor's direct attention and instruction.

There are various parts of commercial reciprocating compressor. Before isolation of the compressor and drive system from the chassis identify the parts from out side.

Service valves, compressor pulley, muffler oil separator, compressor heads, suction & discharge line, oil filter, capacity control valve, compressor shaft opened at the point shaft seal (oil seal) end cover, coupling or 'v'-belt foundation bolts of compressor & chassis mounted bolts, handle cover etc.

Basically all compressors design or shapes are not same, but main functionary parts are almost same

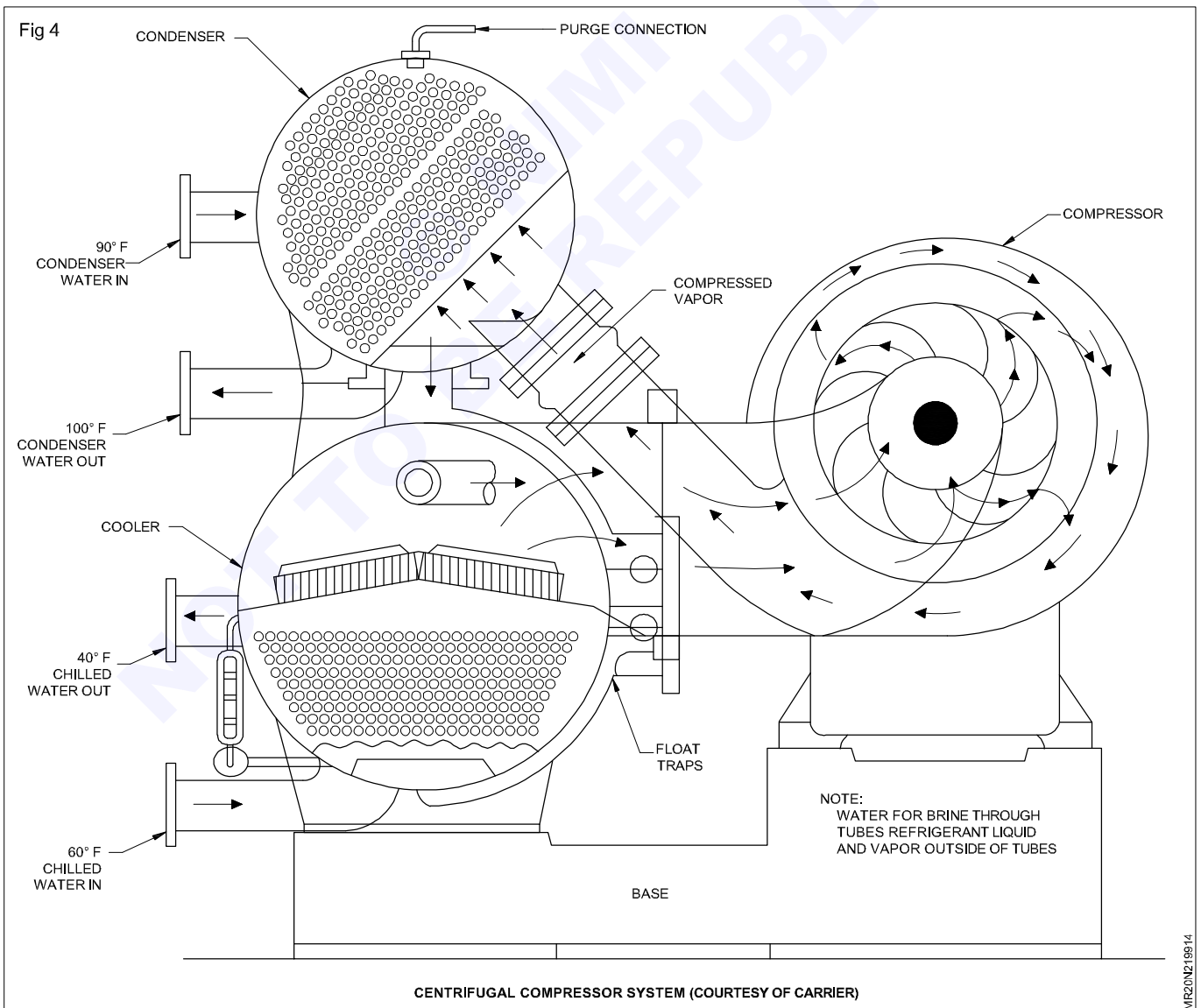
Ammonia commercial compressor cylinder may be different design but must have the water cooling jackets but other commercial compressors basically return gas cooling types.

The air compressor design & shape also to some extent different.

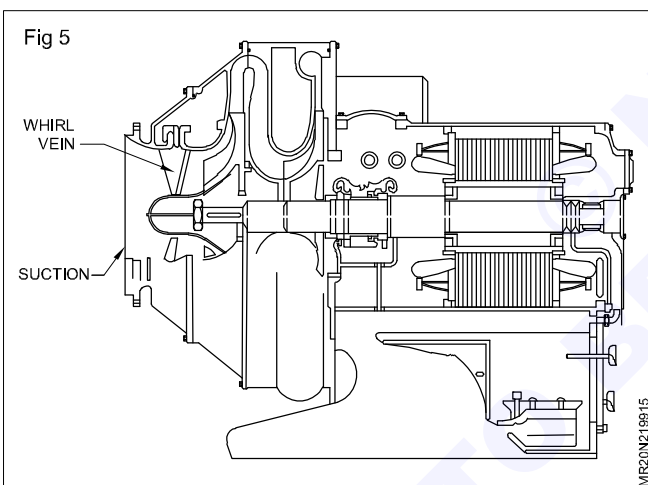
Construction and working of centrifugal compressor (Fig 4 & 5)

Compressor: The compressor is a single-stage centrifugal type powered by an open-drive electric motor. The rotor assembly consists of a heat-treated alloy steel drive shaft and impeller with a cast aluminium, fully shrouded impeller. The impeller is designed for balanced thrust and is dynamically balanced and over speed tested. The inserted type journal and thrust bearings are fabricated of aluminium alloy.

Refrigerant flow is takes place at different part of the compressor. Part one is the refrigerant inlet and part two is the impeller. There is the refrigerant passages and four is the vane less diffuser and five is the volute casing and six is the refrigerant discharge. Low pressure refrigerant vapour enters the compressor through the eye of the



impeller. Eye of the impeller is nothing but the inlet of the impeller. Through the eye the low pressure low temperature refrigerant enters the flow passages formed by the impeller blades which rotate at very high speed. That means the impeller will be rotating at very high speed. As the refrigerant flows through the passages towards the tip of the impeller its angular momentum and static pressure increases. From the tip of the impeller the refrigerant flows into a stationary diffuser. In the diffuser the refrigerant is decelerated and as a result the velocity pressure drop is converted into static pressure rise. Thus increasing the static pressure. Further the vapour from the diffuser enters the volute casing where further conversion of velocity into static pressure takes place due to the divergent shape of the volute. So as the refrigerant flows through volute casing its velocity reduces gradually and velocity is converted into static pressure. So finally the refrigerant comes out of the compressor at high pressure. Finally the pressurized refrigerant leaves the compressor from the volute casing. So this is the working principle of a centrifugal compressor. So and a result as the refrigerant flows through the impeller flow passages, it continuously gets compressed and its static pressure rises. Hence the maximum achievable pressure rise which is nothing but which is related to your maximum achievable temperature lift of single stage centrifugal compressor is limited. So multi-staging is required.



The blades of the compressor are either forward curved or backward curved or radial that means in practical you can have either forward curved blades or radial curved blades or backward curved blades in the older machines mainly backward curved blade were used. But now-a-days the modern trend is to use radial curved blade the stationary diffuser can be vanned or vaneless. So this is the vaneless diffuser you can also have vane diffuser that means inside the diffuser you can have vanes and these working principle of centrifugal compressor carry out thermodynamic analyses of steady flow compressors and establish relationship between impeller speed diameter and power input and pressure rise, centrifugal compressors also known as turbo compressors belong to the rot-dynamic type. In these compressors the required pressure rise takes place due to the continuous conversion of angular momentum imparted to the refrigerant vapour by a high-

speed impeller into static pressure. Unlike reciprocating compressors centrifugal compressors are steady-flow devices. Hence they are subjected to less vibration and noise. The construction features of a centrifugal compressor, the refrigerant inlet is also known as eye of the impeller. So refrigerant enters through this and then takes a ninety degrees turn and enters into the blade passages of the impeller, So the refrigerants flows through the passages provided by these impeller blades and these impeller blades rotates at very high speed. As a result of which momentum will be imparted to the refrigerant when it comes in contact with the impeller blades. So from the impeller it enters into a region called diffuser. In the diffuser conversion of velocity pressure into static pressure takes place as a result of which its velocity reduces and the refrigerant pressure increases. And from the diffuser it enters into a volute casing the volute casing has a divergent shape which also causes to raise the pressure of refrigerant then the high pressure refrigerant discharges through volute exit.

Single helical gears with crowned teeth are designed so that more than one tooth is in contact at all times. Gears are integrally assembled in the compressor rotor support and are film lubricated. Each gear is individually mounted in its own journal and thrust bearings. The open-drive compressor shaft seal is a double bellows cartridge style with ceramic internal and atmospheric seal faces. The seal is oil-flooded at all times and is pressure-lubricated during operation. For the oil pump different supply is required to drive the oil pump motor.

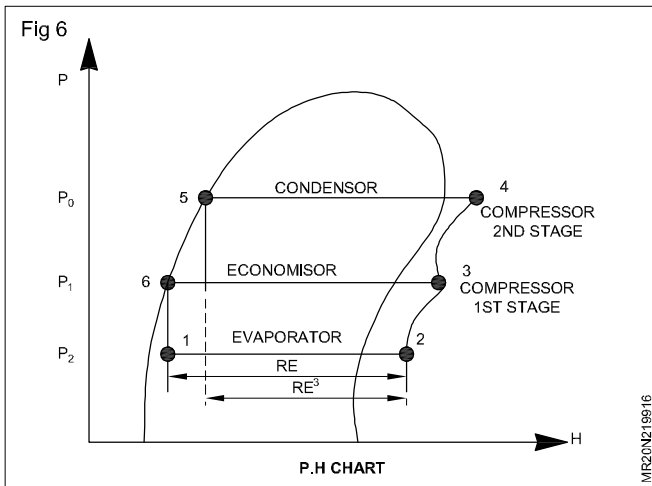
Compressor motor : The compressor motor is an open-drip-proof, squirrel cage, induction type constructed to work design specification, 50 hertz motors operate at 2975 rpm. The open motor is provided with a D-flange, cast iron adapter mounted to the compressor and supported by a motor support. Motor drive shaft is directly connected to the compressor shaft with a flexible disc coupling. This coupling has all metal construction with no wearing parts to assure long life, and no lubrication requirements to provide low maintenance. For units utilising remote electro-mechanical starters, a terminal box is provided for field connected conduit. Motor terminals are brought through the motor casing into the terminal box. Jumpers are furnished for three-lead type of starting. Motor terminal lugs are not furnished. Overload/over current transformers are furnished with units increasing area.

Servicing of centrifugal compressor

Cooling cycle (Fig 6 & 7)

The refrigeration cycle of the CVGF chillers can be described using the pressure enthalpy diagram shown in fig key state points are indicated and will be referred to in the following discussion. A schematic of the system showing refrigerant flow is given in figure.

Evaporator : A liquid vapour refrigerant mixture enters the evaporator at state point 1 liquid refrigerant is vaporized to state point 2 as it absorbs heat from the system cooling load. The vaporized refrigerant flows into the compressor first state.



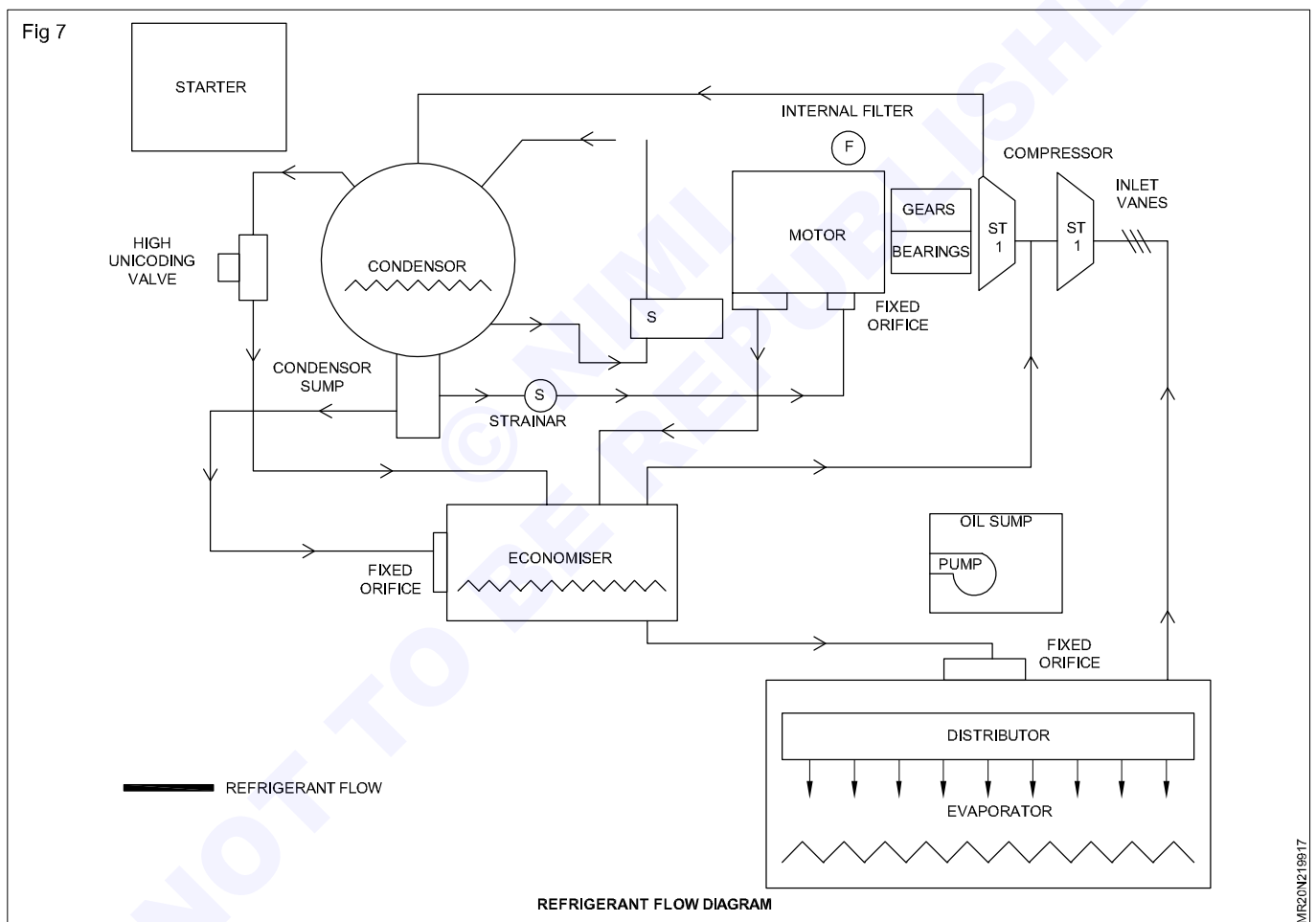
Compressor first state : Refrigerant vapour is drawn from the evaporator into the first stage compressor. The first

stage impeller accelerates the vapour increasing its temperature and pressure to state point.

Compressor second stage : Refrigerant vapour leaving the first stage compressor is mixed with cooler refrigerant vapour from the economizer. This mixing lowers the enthalpy of the vapour entering the second stage. The second stage impeller accelerates the vapour, further increasing its temperature and pressure to state point 4.

Condenser : Refrigerant vapour enters the condensers where the system cooling load and heat of compression are rejected to the condenser water circuit. This heat rejection cools and condenses the refrigerant vapour to a liquid at state point 5.

Economizer and refrigerant orifice system- Liquid refrigerant leaving the condenser at state point 5 flows through the first orifice and enters the economizer to flash a small amount of liquid refrigerant.



Effect from RE to RE The economizer provides around 4 percent energy savings compared to chillers with no economizer. To complete the operating cycle, liquid refrigerant leaving the economizer at state point 8 flows through a second orifice.

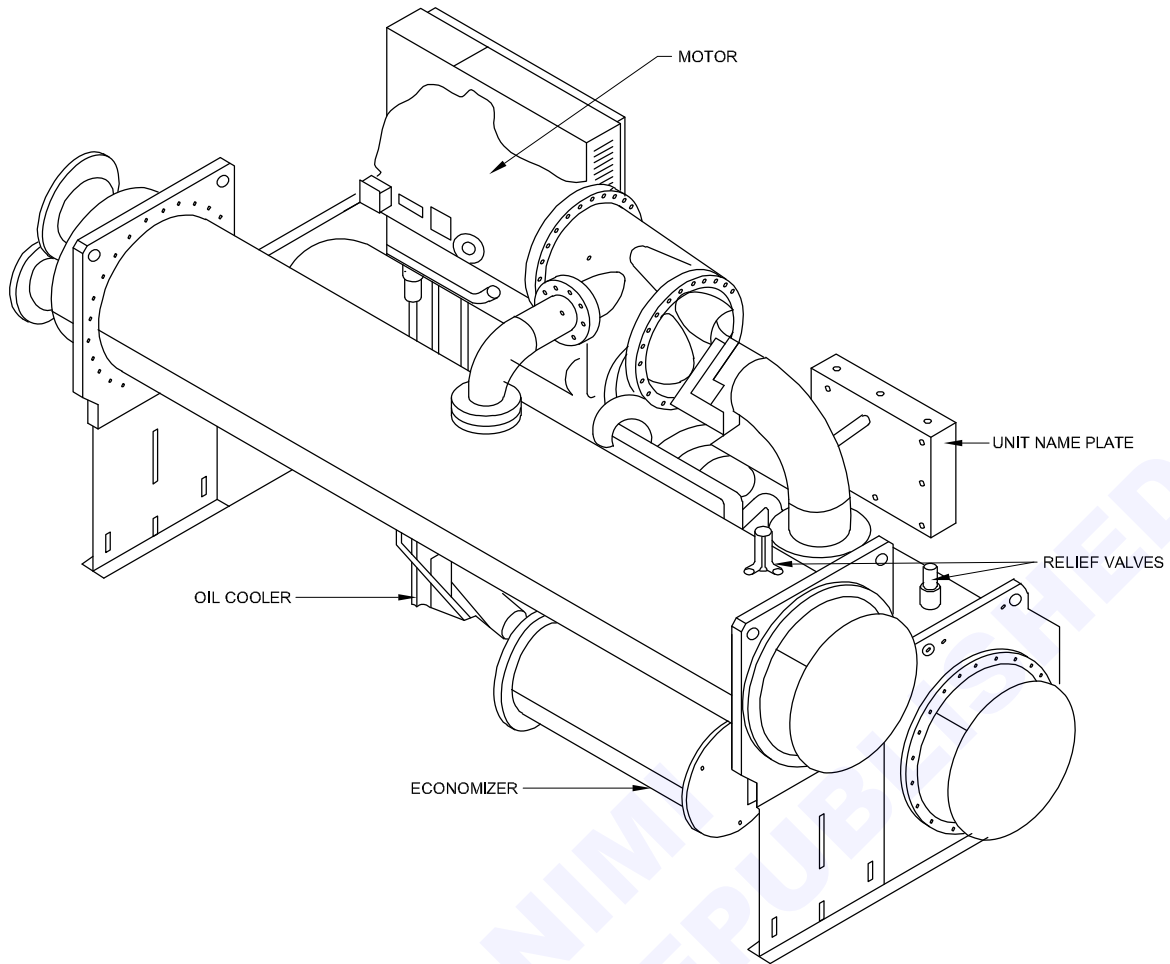
Here refrigerant pressure and temperature are reduced to evaporator conditions at state point 1. An innovative design feature of the CVGF chiller is maximizing the evaporator heat transfer performance while minimizing

refrigerant charge requirements. This is accomplished by the tranepatented falling film evaporator design the amount of refrigerant charge required in CVGF is less than that in comparably sized chillers of flooded evaporator design.

Compression description

The CVGF compressor consists of three distinct sections the two-stage centrifugal compressor, the motor, and the gear box with integral oil sump. See (Fig 8 & 9)

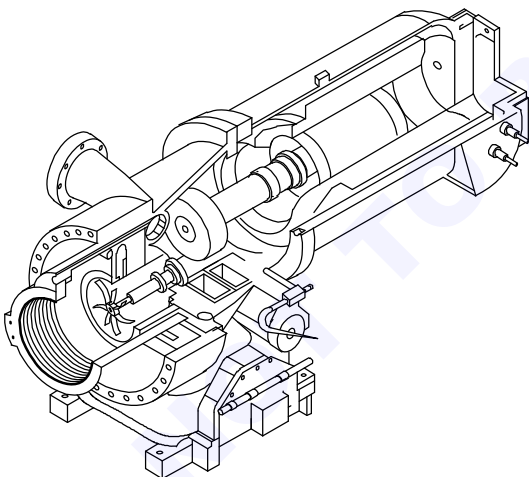
Fig 8



COMPONENT LOCATION FOR TYPICAL CVGF UNIT (BACK VIEW)

MIR20N219918

Fig 9



COMPRESSOR CROSS-SECTION VIEW

MIR20N219919

Compressor

The centrifugal compressor is two-stage with high strength aluminium alloy fully shrouded impellers. The impellers are tested at 25 percent over design operating speed. The rotating assembly is dynamically balanced for vibration of less than 5.1 mm/sec(0.2 is peak velocities) at nominal operating speeds. The control system affords 20 To 100 percent capacity modulation by electrically actuated guide vanes upstream of each impeller.

Drive train

The drive train consists of helical bull and pinion gears. Gear tooth surfaces are case hardened and precision ground. The one-piece impeller shaft is supported by hydrodynamic thrust and radial bearings.

Motor

The motor is hermetic, liquid refrigerant cooled, two-pole, low-slip squirrel cage induction motor. A radial hydrodynamic bearing and duplex angular contact ball bearings support the rotor assembly. Winding embedded sensors provide positive thermal protection.

Control overview

Controls operator interface

Information is tailored to operators, service technicians and owners. When operating a chillier, there is specific information you need on a day to-day basis such as set points, limits, diagnostic information and reports. When servicing a chillier, you need different information and a lot more of it such historic and active diagnostics, configuration settings and customisable control algorithms, as well as operation settings. By providing two different tools, one for daily operation and one for periodic service, appropriate information is readily accessible.

For the operator, day to day operational information is presented at the panel. Up to seven lines of data (English or SI units) are simultaneously displayed on the touch sensitive screen. Logically organized groups of information such as chillers modes of operation, active diagnostics, settings and reports put information conveniently at your fingertips. See operator interface section for details.

Chillier

For the service technician or advanced operator all chillier status, machine configuration settings, customisable limits, and up to 60 active or historic diagnostics are displayed through the Tech view TM.

Interface. Using Tech view" a technician can interact with an individual device or a group of devices for advanced troubleshooting. LED lights and their respective Tech View TM indicators visually confirm the viability of each device. Any PC that meets the system requirements may download the service interface software and Tracer CH530 updates.

Oil temperature control

The oil heater is used to maintain the oil temperature within +/-2.5°F (4.5°C) of the oil temperature control set point. The oil heater is commanded off when the oil pump is commanded on.

Oil Differential pressure check

The oil differential pressure check validates the oil differential pressure before the oil pump is turned on. This check is necessary in case the differential pressure switch is not operational. Without this check, the differential oil pressure feedback is gone. This check is made after post-lube is complete to verify that the differential pressure has dropped to indicate no oil flow. Here are the details

- CH530 verifies that the pressure switch is reading no differential pressure with the oil pump off before proceeding with pre lube.
- CH530 displays a mode waiting for low oil differential press.
- The check is made if oil pump is off and before it is turned on.
- CH530 allows five minutes for the differential oil pressure switch to open

This check is performed on power up or reset also. If a MPL occurred or power up was within the post-lube time, oil pump is running so do not do the check.

Protective diagnostics and their description

Differential oil pressure overdue is a latching diagnostic that can come up while the unit is in pre lube. The differential pressure switch status is used instead of the low differential oil pressure cut out set point.

Low differential pressure cut out is a latching diagnostic that can come up while the unit is running. Oil pressure is indicative of oil flow and active oil pump operation. Significant fall in oil pressure is indicative of failure of the oil pump, oil leakage, or other blockage in the oil circuit.

Once oil flow has been established, if the differential pressure switch indicates there is not oil pressure for 2 seconds, this diagnostic will be issued.

Unexpected differential oil pressure is a latching diagnostic that can come up while the unit is idle and is implemented to recognize and ensure that the pressure switch is operational and that it is open for a period of five minutes.

Screw compressor

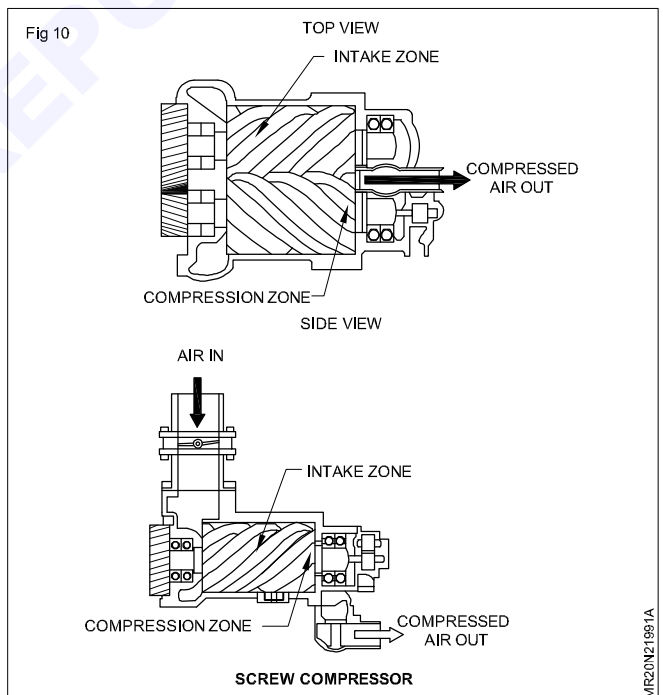
A helical rotary screw compressor consist of two mating helically grooved rotors, the male rotor is called "LOBES" & Female rotor is called "grooves". The grooved rotor rotates in a stationary housing providing suction & discharge ports this H.R.S compressor is also known as "LYSMOLM" type compressor

Working

In let is at top at one end & the discharge out let is at the bottom at other end. As the rotor rotates the male lobe pulls out the female rotor & suction gas is drawn in to the grooves where it is squeezed between the lobe & groove thus compression takes place.

Screw compressor (Fig 10)

Screw compressor is a positive displacement compressor. There are two types of screw compressor-a) Twin screw (Double helical) b) Single screw (Mono screw)

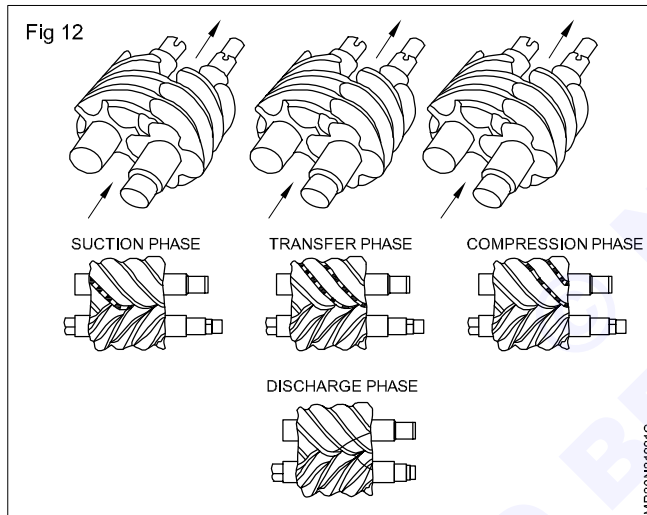
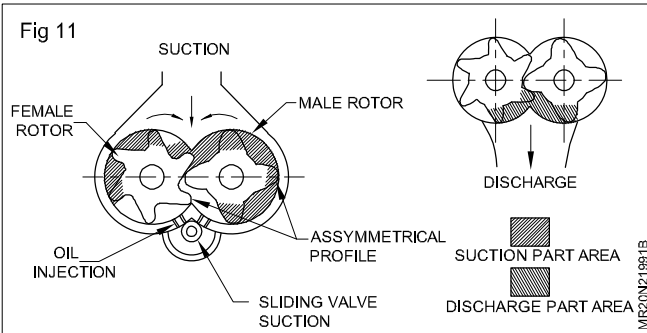


Screw compressors are mainly used in large industrial systems running at high speeds through the use of step up gears. It is available from 12 TR and above. Refrigerants like R - 22, R - 717, R - 134a and R - 404a can be used with this compressor.

Twin screw compressor (Fig 11 & 12)

It consists of two meshing helically grooved rotors with very close tolerance, within a housing. Suction and discharge are at either end of the shaft. The rotor

connected to the drive is known as male, the other rotors being the female. The female rotor is driven by the male rotor. A flowing oil film between the rotors provides lubrication, cooling and also prevent metal to metal contact. The two rotors provide lubrication, cooling and also prevent metal to metal contact. The two rotors usually have different lobe combinations, such as 4 and 6, 5 and 6 or 5 and 7 (In the male and female respectively) In general the upstanding metal shapes on both rotors tend to be called the lobes. However, it is convenient to call the male shapes "lobes" and the opening on the female are identified as "flutes"



The male rotor rotates female rotor $\frac{2}{3}$ rd at its rated speed. If the male rotor has four lobes so in each revolution the gas discharge is 4 times if R.P.M is 3600 thus gas discharge is 14400 times per min.

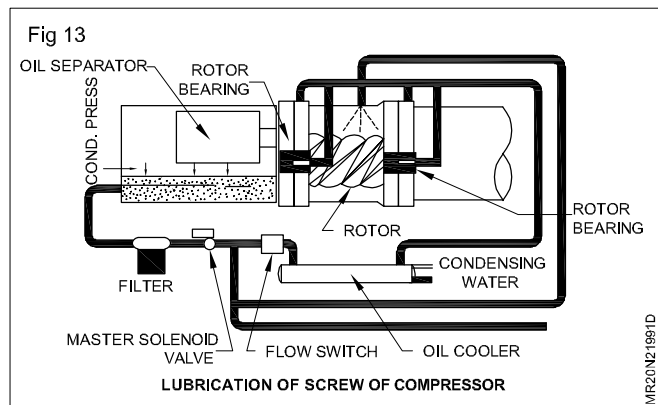
In operation, when the male rotor rotates in clockwise while the female rotor rotates anticlockwise. As it rotates, at the suction port end of the rotors, because of the small unmeshed portion between the male and female rotors a voids formed into which the suction gas enters through the suction port in the housing gas. As the rotor rotates, say by a quarter turn, the gas pocket moves away from the suction port with the entrapped gas still at suction pressure, confined within the pocket by the housing. As the rotor rotates, the meshing of the rotor lobes progressively reduces the volume of the inter lobes space, the meshing of the rotor lobes progressively reduces the volume of the inter lobes space, there by compressed gas passes out through the discharge port in the housing. With further rotation, the volume of the pocket is reduced practically zero, squeezing out all the compressed gas.

Thu, the clearance volume effect becomes negligibly low. With the continuous rotation of the rotors, successive mating lobes align with the suction port and the refrigerant vapour is continuously sucked and compressed by the constant reduction in volume. So unlike in reciprocating compressor, the suction – compression process in the screw compressor is practically continuous and the gas flow is only in one direction. This makes it possible for an additional suction point on the rotor through a port in the rotor housing. This additional suction port can be used either to connect another evaporator working at a higher temperature (pressure) than the main evaporator or to connect an economizer to obtain substantial sub-cooling of the high pressure liquid refrigerant to achieve a much better cycle efficiency.

Again with continuous unidirectional flow of gas and continuous compression, there is no need for the suction and discharge valve and so there is no pressure drop due to these valves. This improves the system capacity.

Lubrication of screw of compressor (Fig 13)

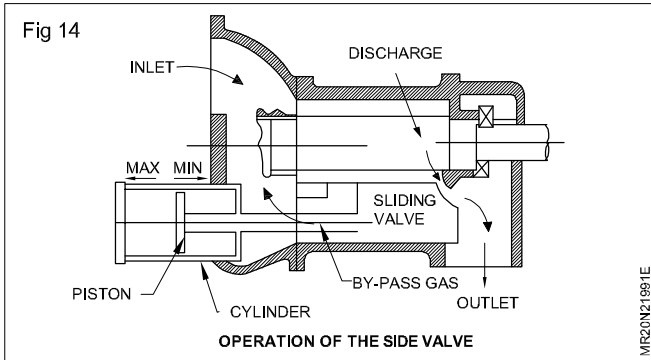
Oil lubricates, seals clearances, Cools compressed refrigerant vapour and lubricates slide valve operation for capacity control. The oil system thus, critical for proper operation of the compressor. Lubricating oil is sprayed over the rotors for lubricating as well as to cool the rotors. The oil also helps to keep down the discharge gas super heat and the noise level. The oil film between the rotors prevents leakage of gas under compression to the preceding lobe pockets and the sprayed oil leaves the housing along with the discharge gas to the oil separator. The oil from the oil separator flows into an oil sump, in which an electric heater heats the oil to drive the gas away from it, and also vaporizes any refrigerant liquid particles present. The oil is then cooled in an oil cooler before it is again sprayed over the rotors.



Capacity control (Fig 14)

Compressor capacity is controlled by an axially moving sliding valve located in the housing above or below the rotors at their line of meshing. When the valve is at the discharge end of the housing, the discharge gas can flow through the discharge port on the housing as well as through the port in the sliding valve, thus allowing maximum flow of gas. So for full compressor capacity, the valve slides to the discharge end and is closed, allowing the

compressor to pump maximum volume of gas. At the partial load, the valve is moved back towards the open position and this allows some gas from the pocket to flow back to the suction. This retards the start of the compression process gas release and by-pass to suction occurs before compression begins, there is no loss due to re-expansion and hence, Power requirement per ton is reduced. By the modulating movement of the slide valve, 10% to 100% capacity modulation of the compressor is achieved.

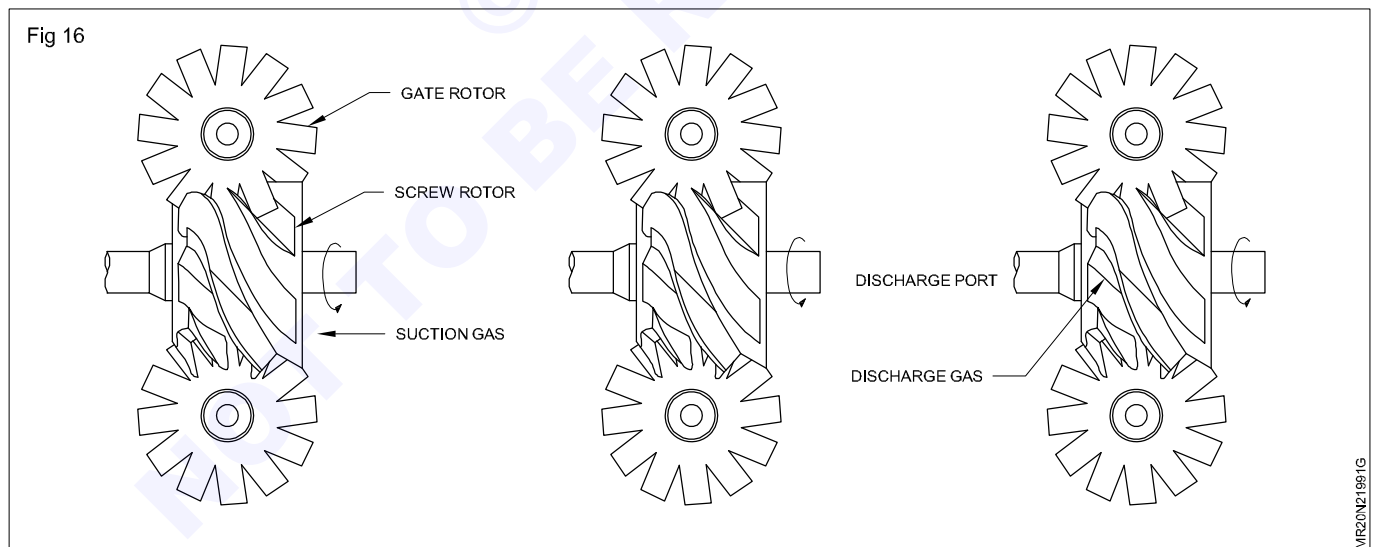
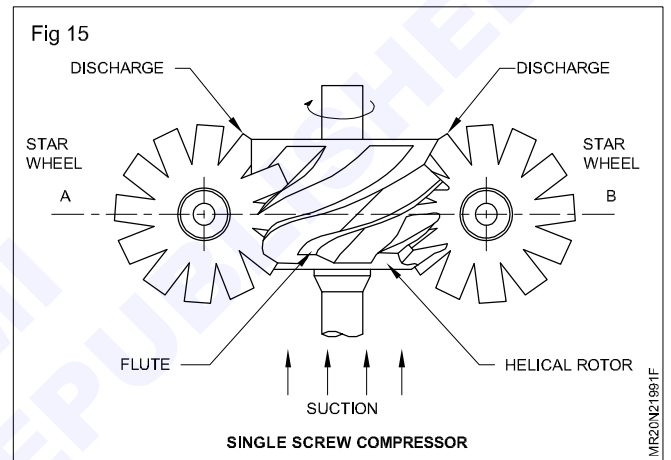


Single screw compressor (Fig 15 & 16)

As the name implies, the single screw consists of one main rotor working with a pair of gate rotors or star wheels. This compressor utilizes one screw rotor with two star wheels meshing with it. The star wheels are located on separate shafts mounted at right angles to the main rotor axis. The main rotor typically has six helical flutes and a globoid route profile. The gate rotors or star wheel each have 11 teeth and are located on opposite sides of the main rotors.

In operation, as the main screw rotates space form

between the screw, flute and star wheels and casing. The lobes separate at suction port. This increases in volume causes the reduction in pressure. The flutes filled continuously with suction vapour until the suction end of this flute is meshed with the one of the star wheels. The reduced pressure draws the gas through suction connection of the compressor. As the main rotor continuous to rotate, it engages a tooth from the gate rotor from the opposite direction. The trapped gas is within the flute, the casing, the wall and the tooth of the generator. As soon as the discharge end of this flute opens to the discharge port and the leading edge of the groove coincides with the edge of the discharge port compress on stops. The hot gas is discharged through the discharge port. The gas is continuously pushed out the flute the volume within the flute and the tooth of the gate rotor is zero.



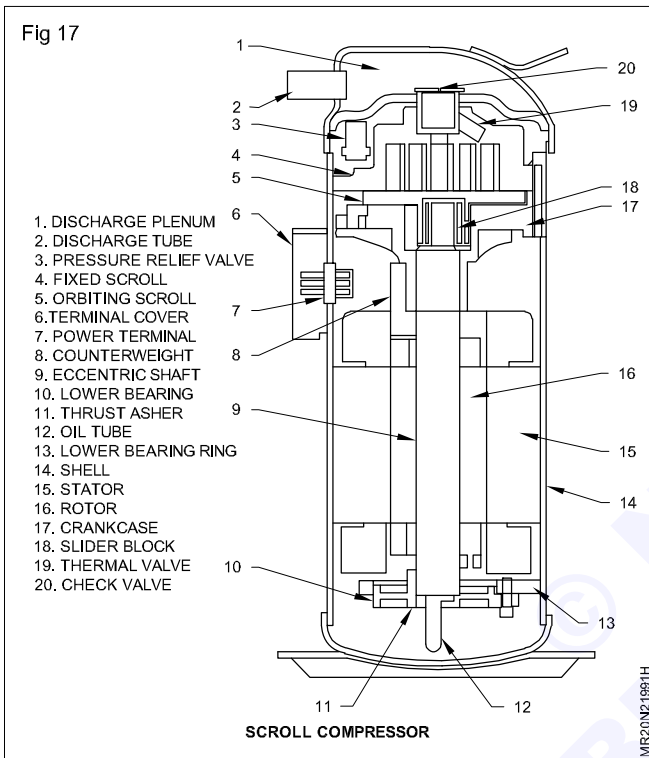
Advantages of screw compressor

- Construction is simple
- Less wear and tear
- Low maintenance cost
- More reliable
- Discharge temperature is low
- Gas discharging is non pulsating
- High compression ratio
- Less sensitive to liquid slugging
- Available in large capacities per single unit

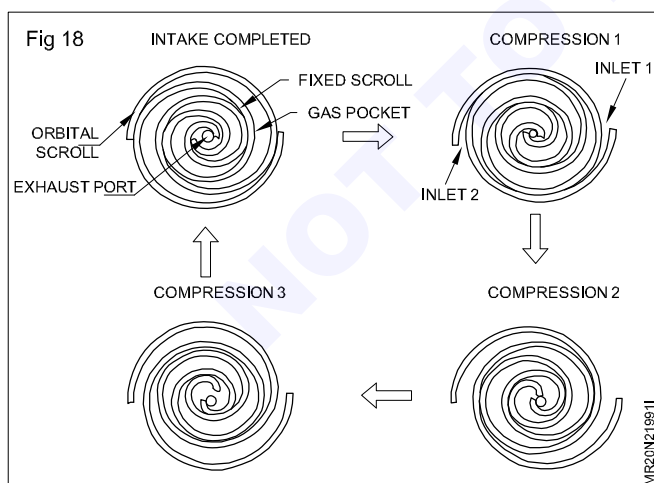
Scroll compressor

The scroll compressor consists of two scroll members. A scroll is a disc with a spiral shaped member, one end of

which is cast integral with the disc or base plate the other being open end. This is a positive displacement compressor. These compressors are used in applications like residential/ commercial air conditioners, liquid chillers refrigeration, automotive, heat pump, etc. It is better in energy efficiency than reciprocating and screw compressor. EER of 12BTU/Watt is claimed by many manufacturers of the two scrolls, one is inverted and inserted into the other and so the free end of each of the scroll vanes contacts the base plates of matching scroll. In this assembly of two matching scrolls, one scroll is held stationary, while the other rotates in an orbital path hence the scroll compressor is also known as an orbital motion machine. (Fig 17)



Working (Fig 18)



As compressor shaft rotates, at a particular instant of the rotation, at diametrically opposite sides on the circumference of the fixed and orbiting scroll assembly,

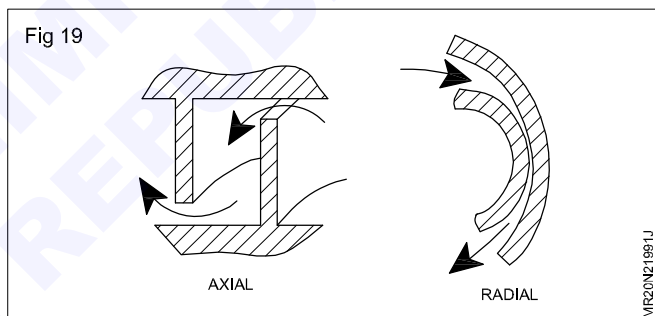
two closed ends of the spiral scroll vanes open up, through which low pressure suction gas from the evaporator enters the pockets with the continued rotation of scroll, the peripheral open passage closes and get sealed, trapping the gas at suction pressure in this pockets, the volume of the pockets progressively reduces, compressing the gas. As the pockets reach the center of the scroll full compression is achieved and the compressed gas discharges into the delivery line.

Obviously several pockets of gas get compressed simultaneously. Since a new pocket of compressed gas reaches the discharge point very shortly after the preceding one, the discharge process is nearly continuous. Thus a quiet, smooth non pulsating compression cycle is achieved after three complete orbits.

A check valve at the delivery line prevents backing of high pressure gas from high side to low side, and the compressor from running back wards, when compressor stops.

The capacity of scroll compressor available presently is around 5 to 20TR and are generally hermetically sealed type. For larger capacity requirements multiple parallel connected scroll compressors are employed.

Inter scroll leakages (Fig 19)



There are two inter scroll gas leakage points, which need sealing as they affect the compressor performance. The leakage points are :

- 1 Through the inevitable clearance necessary between the three end tips of the scroll vanes and the base plates. This is called axial leakage.

The axial leakage is sealed by providing a floating seal between the surfaces, which ensures good sealing with minimum of frictional losses.

Another design, keeps the scroll vane tips and the base plates in continuous contact with an oil film.

- 2 Between pockets. Across the line of contact of two vane walls, this is called radial leakage.

The radial leakage is tackled by an oil film seal, thus avoiding mechanical metal to metal contact and friction.

Capacity control

Capacity control is done by the following methods.

1 Variable speed

The compressor speed is varied through the use of an inverter, by which a frequency of the electric supply to the compressor motor is varied. Frequency variation 15-50 cycles is generally obtained, the compressor capacity is directly proportional to its speed.

2 Variable displacement

The compressor capacity is controlled by varying the effective displacement of the compressor. On the fixed scroll number of porting holes are provided, which are opened or closed through the control mechanism. by opening the porting hole, the compression chamber gets connected to the suction side thereby some hot gas flows back to the suction side, thus reducing the compressor capacity.

Bearings

Instead of ball bearings journal bearings are used for main shaft. A thrust bearing is provided below the rotating scroll in the internal frame.

Advantages of scroll compressors

- 1 Large suction and discharge ports reduce pressure losses during suction and discharge
- 2 Physical separation of suction and compression reduce heat transfer to suction gas, leading to high volumetric efficiency
- 3 Volumetric efficiency is also high due to very low re-expansion losses and continuous flow over a wide range of operating conditions
- 4 High compression efficiency, low noise and vibration compared to reciprocation compressors
- 5 Compact with minimum number of moving parts
- 6 Compression being smooth and practically continuous there is no reciprocating pulsations.
- 7 Unlike the reciprocating compressor can tolerate some liquid flood back.

Construction and function of compressor valves, cylinder and piston assembly

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

- explain suction and discharge valves
- explain the types of valves and valve locations
- explain valve lapping
- explain the construction of piston on the connecting rod and the cylinder.

Suction and discharge valves of refrigeration compressors

The design of the compressor suction and discharge valves is the most important consideration in compressor design. To minimize back leakage of the vapour through the valves, the valves should be designed to close quickly and tightly. In order to open easily and close quickly, the valves should be constructed of light weight material and be designed for a low lift, they should be strong and durable and they should operate quietly and automatically. These valves should be designed and must be placed in such a way that these do not increase the clearance volume of the compressor.

Valves used in refrigeration compressors can be grouped in to three basic types the poppet, the ring plate the flexing or reed valves.

All three types, operate automatically by opening and closing in response to pressure differentials caused by changes in the pressure. To facilitate rapid closing of the valve, most discharge valves and some suction valves are spring-loaded.

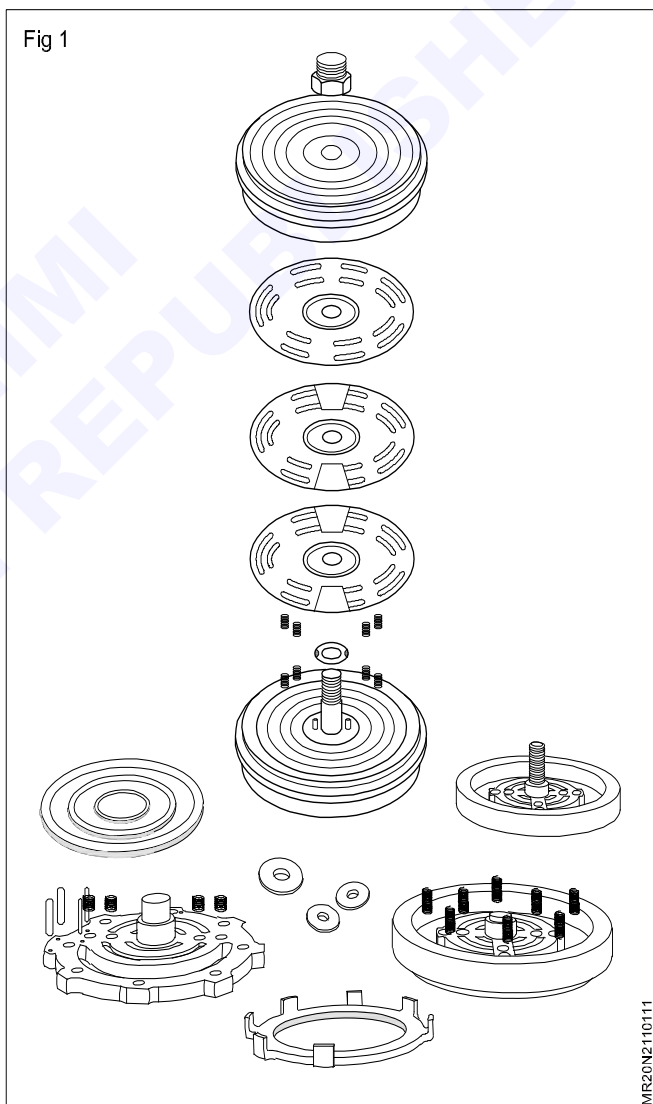
Poppet valves (Fig 1)

The poppet valve is similar to the automotive valve, except that the valve stem is much shorter. The valve is enclosed in a cage that serves both as a valve seat and valve stem guide and also as a retainer for valve spring. Except some minor difference, the construction of suction and discharge poppet valves are same, the principle difference is that the suction poppet valve is bevelled on the stem side of the valve face, whereas the discharge poppet valve is bevelled on the opposite side. The poppet valve is essentially a slow speed valve and in present time is limited use to a few types of slow speed compressors. The principal advantage of the poppet valve is that it can be mounted flush and therefore does not increased the clearance volume of the compressor.

Ring plate valves (Fig 1)

The ring plate valve consist of a valve seat, one or more ring plates, one or more valve springs, and a retainer. The ring plates are held firmly against the valve seat by the valve springs, which also help to provide sudden closing of the valves. The function of the retainer is to hold the valve springs in place and to limit the valve lift. The ring plate

valve is suitable in both slow speed and high speed compressors, and it may be used as either suction or discharge valve. When both suction and discharge valves are located in the compressor head, they are usually contained in the same ring plate assembly.



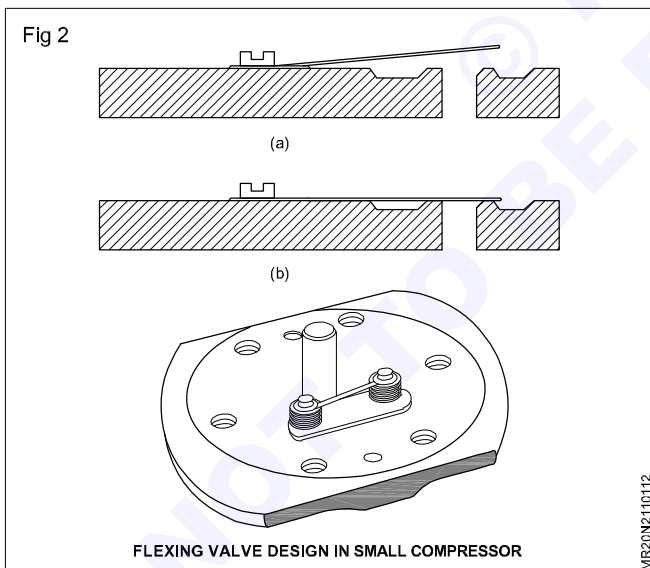
One modification of the ring plate valve is the disc valve (Fig 2) which is simply a thin disc held in place on the valve seat by a retainer.

Flexing valves (Fig 2)

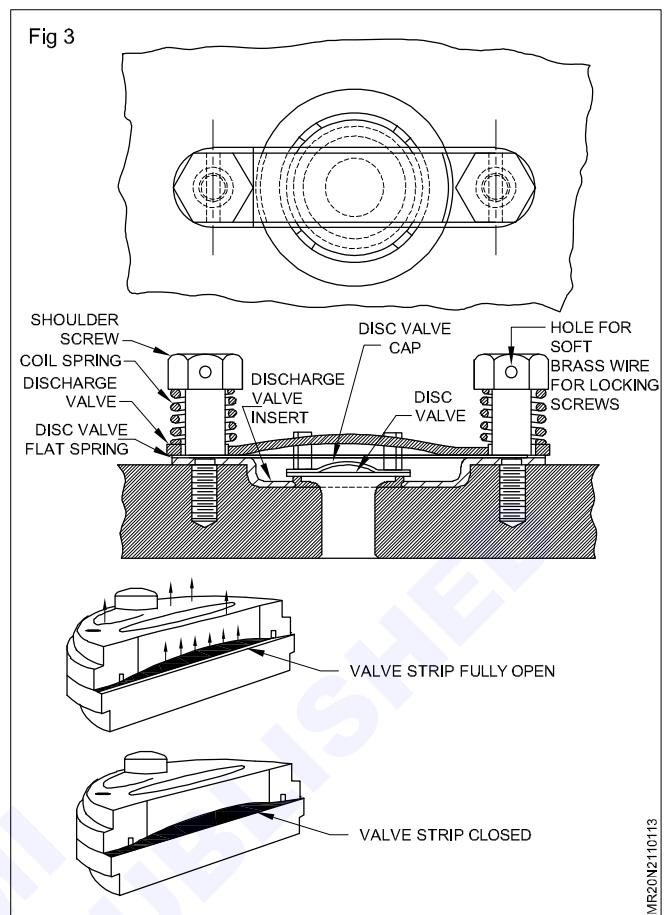
Flexing valves vary in individual design to a much greater extent than do either the poppet or ring plate types. One popular type of flexing valve suitable for use in medium and large compressors is the feather valve (Fig) which consists of valve seat, a series of ribbon steel strips and a valve guard or retainer. The flexible metal strips fit over slots in the valve seat and are held in place by the valve guard. The operation of the feather valve is explained in the figure. The principal advantages of the feather valve is that the reeds are light weight and easily opened and are so designed that they provide a large restricted area, all of which tend to reduce the wiredrawing effect to a minimum. One disadvantage of the flexing valve is the clearance volume is necessarily increased in all compressors employing either ring plates or flexing valves of any design.

A flexing valve design widely used in small compressors is the flapper valve or have some of its variations. A flapper valve is a thin steel reed, which is usually fastened securely at one end while the opposite unfastened rests on the valve seat over the valve port. The free end of the reed flexes or flaps to cover and uncover the valve port.

A flapper valve design frequently employed in discharge valves called a beam valve is shown in Fig. The valve reed is held in place over the valve port by a spring loaded beam which is arched in the centre to permit the reed to flex upward at this point. The ends of the reed are slotted and as held down by only the tension of the coil spring in order to allow the ends of the reed to move as the reed flexes up and down at the center.



Another type of flexing valve in common use in the diaphragm valve. The diaphragm valve consists of a flexible metal disc which is held down on the valve seat by a screw or bolt through the centre of the disc. The disc flexes up and down to uncover and cover the valve port. The diaphragm valve used as a suction valve mounted in the crown of a piston is illustrated in Figure.



Valve location (Fig 3): As previously described, the discharge valves are usually located in the cylinder head, where as the suction valves may be located either in the head, in which case the suction vapour enters the cylinder through cylinder head, or in the crown of the piston, in which case the suction vapour enters through the side of the cylinder. As a general rule, with large compressor, the suction valves are located in the piston and the suction vapour enters through the cylinder wall. In small and medium compressors the suction valves are located in the cylinder head. When both valves are placed in the cylinder head, the head must be portioned to permit the separation of the suction and discharge vapours.

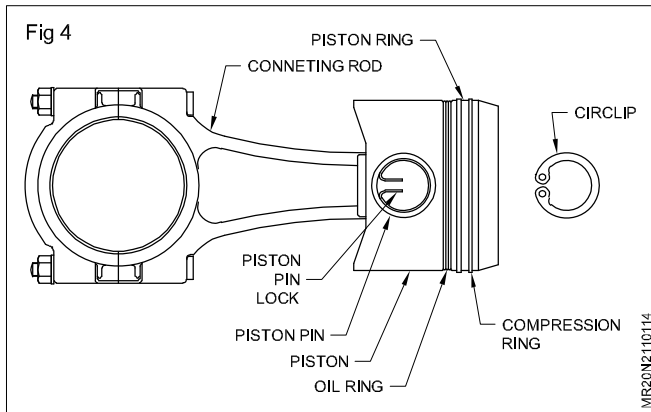
In large compressors, the valves and seats are removable for replacement. In small compressors the suction and discharge valves are usually incorporated into a valve plate assembly, which is removed and replaced as a unit.

Valve lapping: It is a process of finishing the surface of valve plates very fine and accurate, so that there will be no small scratches in there finished surface.

Cylinder piston assembly (Figs 4, 5 & 6)

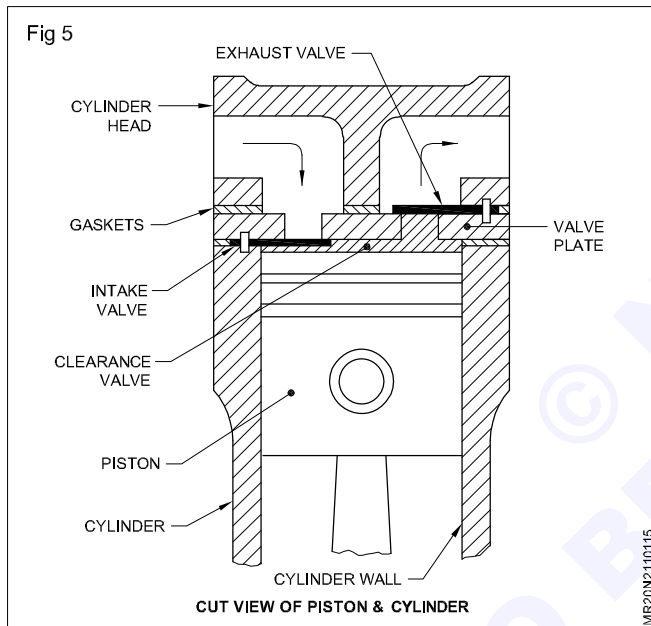
Construction of the piston with the connecting rod is shown in (Fig 4)

Piston is made of best grade cast iron or Aluminium casting and mechanically polished. These have drilled holes to fit the piston pin. The circle or piston pin lock in arresting the piston pin not to get out.



The function of the piston is only to compress the refrigerant in an enclosed cylinder. In commercial reciprocating compressors pistons have grooves for piston rings and oil scraper rings.

Generally two or more piston rings are used on a piston, it will set in the grooves of the piston to minimise the clearance between the grooves of the cylinder and piston. (Fig 5)



Piston rings and oil scraper rings to maintain the proper lubrication, and a good seal between the cylinder wall, to prevent the leakage of the compressed gas in the crank case.

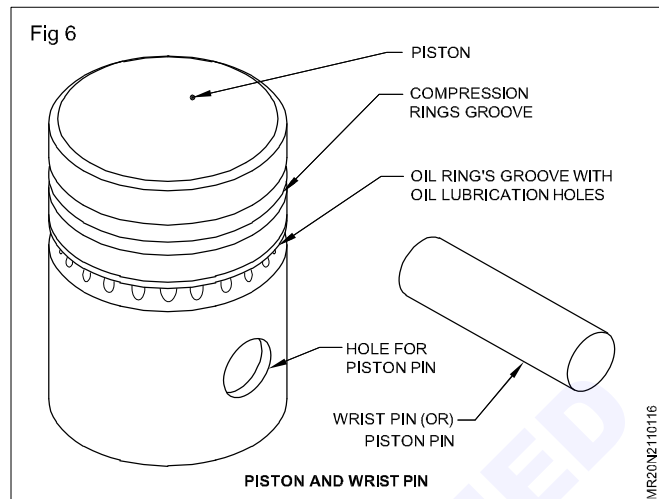
The clearance between the cylinder or bore wall and the piston wall is kept 0.003" for each inch of diameter of the piston. The piston rings completes at 45° angle with a gap of 0.001" for each inch diameter of piston for exerting a pressure against cylinder wall.

There are two types of piston rings

- Compression ring
- Oil ring

Connecting rod is usually made of high grade cast iron or forged steel. It forms the link between the piston and the shaft. Its small end bearing is connected to the piston by means of a highly polished carbon steel gudgeon pin or wrist pin or piston pin. Fig 6. The big end bearing is

connected to the crankshaft. To provide piston pin lubrication connecting rods have an oil passage or holes for supplying oil.



The connecting rod has a big end bearing, split off into two parts (halves) which clamps around the crank shaft journal tightened by bolt and nut and locking pin. For dismantling of the piston refer the Exercise the assembling process will be the reverse procedures of the same.

Due to wear and tear of the rings the compressor gas will escape through the clearance of the piston to crankcase. It will affect the compressors efficiency. The damaged rings and pistons should be replaced.

Normally the scoring or scratches of the piston on cylinder bores can be re-polished by lapping the rubbing paste. For the major faults the cylinder can be sent for reboring and machined to match the piston dia and lapped to suit the designed clearance. After fixing the connecting rod with piston assembly, flush with lubrication oil and check flow, apply oil on assembled parts.

Service valve description types, functions (Fig 7)

The piston rings will have sharp edges and it will be located in the 1st, 2nd or even more number of grooves in the piston depending on the size.

The oil scrapper rings will have slots in the centre and the width will be larger, also the grooves in the piston will have holes.

The cylinder will be of the same single casting along with the crankcase of the compressor. The inside of the cylinder bore will be bored and honed for smooth surface.

Service valve used in compressor named as compressor service valve. Generally, service valve used in compressor suction discharge & liquid line in condenser for the purpose of deliver the vapour and liquid. In small compressor no service valve is require in general. The line connects directly with compressor.

The commercial large compressor must have the service valve to serve the different line and different port. It helps in servicing such as, checking pressure delivering the vapour to evaporator, condenser and also charging purpose.

So function of service valve to serve the vapour or liquid through suction discharge & liquid line.

Types of construction (Fig 7)

Basically service valve made of brass or cast iron. Generally, the compressor service valve are three-way service shutoff valve.

Cylinder or receive service valve used in liquid line or receiver.

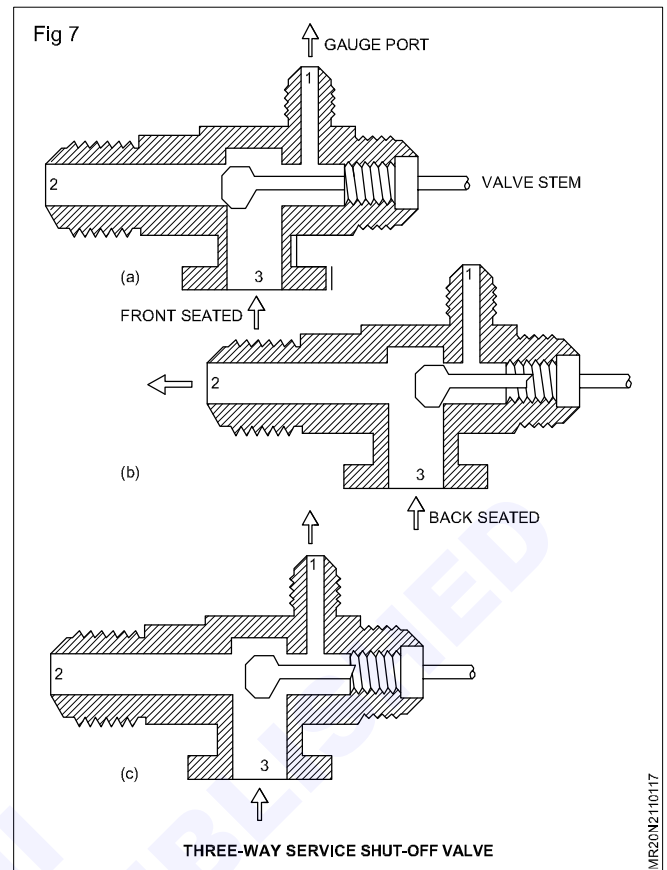
Inside body valve stem is moving with gland packing & gland packing nut for prevent the gas leak during operation.

If the valve is turned all the way in figure the connection between the compressor (3) and the condenser or evaporator (2) is cut off but gauge port (1) is in communication with the compressor (3) If the valve is turned all the way out the compressor port (3) is in communication with the condenser/evaporator (2). But the gauge port (1) is cut off from the system. This helps in fixing gauges, charging lines etc. without loss of refrigerant.

Basically three portions of valve stem i.e. full in full out & intermediate or crack position.

In full in position main port (suction /discharge) is closed gauge port is opened. In full out position main port is opened & gauge port is closed. In intermediate or crack position both ports are opened.

Receiver service valve or liquid line valve only one out let to deliver the liquid.



Lubrication methods in commercial compressors

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

- explain what is lubrication and properties of lubricating
- explain the lubricating oil circulation methods in reciprocating compressor and centrifugal compressor.
- describe the specification of lubricating oils
- describe the construction and use of oil separator.

Lubrication is simply the use of a material to improve the smoothness and reduce the friction between moving surface the materials which is used in this Purpose are called lubricant. Lubricants are usually liquids or semi-liquids, but may be solids or gases or any combination of solids, liquids and gases.

Some of the important properties of the oil that must be considered when selecting the compressor lubricating oil are :

- Acidity
- Flock point
- Pour point
- Cloud point
- Dielectric strength
- Chemical stability
- Viscosity

In evaluating this oil properties with relation to an individual compressor, all the following factors should be taken into account.

- The type and design of the compressor
- The nature of the refrigerant to be used
- The evaporator temperature and pressure
- The compressor discharge temperature

Acidity : Nearly all lubricating oils have certain amount of organic acidity. The degree of acidity is determined by the weight (milligram) of potassium hydroxide required to neutralize the acidity in one gram of oil and this is known as the neutralizing number. Acidity cause damage to the refrigeration system and so should be kept very low- the neutralization number of oil for refrigeration duty should not exceed 0.05.

Flock point : Refrigeration oil may contain certain amount of paraffin. The wax in the oil will precipitate as the oil temperature is lowered. The flock point of an oil is the temperature at which the oil begins to precipitate from a mixture of 90% refrigerant and 10% oil by volume. Low Flock point oil should be used for refrigeration duty, as otherwise, wax from the oil can precipitate at low temperature points and block orifice in throttling device. Synthetic oil do not contain wax.

Pour point : The temperature at which oil ceases to flow is its Pour point'. This is important particularity for low temperature applications. With a high pour point, the oil becomes sluggish in movement and tends to cling to the cold evaporator surface affecting oil return and evaporator capacity. A low pour point oil will have a low flock point too.

Cloud point : Temperature at which a cloud or haze of wax crystals appears at the bottom of lubricating oil. Cloud point is a indicator of the tendency of the oil to plug filters or small orifices at cold operating temperatures. It is very similar to wax appearance point.

Dielectric Strength : The dielectric strength of oil is a measure of the resistance that the oil offers to the flow of electric current. It is expressed in terms of the voltage required to cause an electric current to arc across a gap 1/10 in wide between two poles immersed in the oil. Since any moisture, dissolved metals, or other impurities contained in the oil will lower its di-electric strength, a high di-electric strength is an indication that the oil is relatively free of contaminants. This is especially important in oils used with hermetic motor-compressor units.

Chemical stability : The oil should be chemically stable at the extremes of temperatures encountered in the refrigeration system and against chemical reaction by refrigerant in the presence of all the materials such as. Metals , motor insulation, moisture, contaminants in the system , etc.

Viscosity : Viscosity may be defined as a measure of fluid friction or as a measure of the resistance that a low viscous fluids will flow more readily than thicker, more viscous fluids. To provide adequate lubrication for the compressor, the viscosity of the lubricating oil must maintained within certain limits. If the viscosity is too low, the oil will not form a protective film between the rubbing surfaces and keep them separated. However, if the oil viscosity is too high, the oil will not have sufficient fluidity to penetrate between the rubbing surfaces.

Table 1 - Oil specifications

Property	
Viscosity in say bolt	
Universal seconds at 100°	150 to 320
Pour point	-10° F or lower
Moisture	Not over .01%
	passes 25 to 30KV test
Acidity, ASTM	Not over .01mg KOH/g
Wax separation	Depends on evaporator temperature
Flash point	320 to 400°F
Slight oxidation number	10 or less
Saponifiable matter	None
Sulphur	15% or less

Oil separator : Oil separator is a device used to separate oil from refrigerant gas, returning the oil to the compressor and allow the oil free refrigerant to flow through the system. (Fig 2) Oil separators are installed in the compressor compress or discharge line.

Small amounts of oil circulating through the system will not affect the system performance. Too much refrigeration oil circulating in the system will have adverse effects on the components in the system. Circulating oil reduces the ability of the system to effectively remove the heat. Condensers, evaporators and other heat exchangers loose efficiency when coated internally with an oil film. Refrigeration oil not returning to the compressor causes improper lubrication and eventual compressor failure. At low temperature application refrigeration oil thickness becomes difficult to move, causing oil to be trapped in the system.

The advantages of the oil separator on the discharge line of a compressor in a refrigeration system are confirmed by many years. The oil separator intercepts the oil mixed with compressed gas and returns it.

A viscosity of 120 say bolt seconds at 100°F means it takes 120 seconds for a sample of oil at 100°F to flow through the orifice.

Oil is needed to lubricate all moving parts in the compressor to remove the friction so the oil has to circulate to all part, it is circulated by splash feed or forced feed system.

Splash Feed : It is commonly used in small compressor the oil is splashed to the parts by the crankshaft webs, or even by the crankshaft counter weights dipping in the oil. In this method of lubrication, the lubricating oil is filled into the crankcase of the compressor, so that the crank or the eccentric remain dipped into the oil. A sight glass fixed in the compressor crankcase is used to judge the level of the oil. With each revolution of the crank shaft, connecting rod and crank dip into the oil causing the oil to be splashed up to the cylinder walls, bearings and other rubbing surfaces. A modified type of splash lubrication, sometimes called flooded lubrication employs singer rings, discs or similar devices to raise the oil to a level above the crank shaft or main bearings. This method is particularly suitable for small, high speed compressors.

Force Feed : It is used in all big compressors. It has lubrication oil pump driven by a gear pump connecting the crank shaft. The oil for lubrication are transferred to the moving parts are under pressure through oil tubes and or rifle drilled passages in the crank shafts and connecting rods to the various rubbing surfaces.

Lubrication oil pumps : In force feed the oil is circulated under pressure by an oil pump located in the crank case of the compressor, usually at the end of the crank shaft. Oil strainers are always placed at the suction inlet of the oil pump to prevent the entrance of foreign material into the pump or bearings. An oil pressure failure safety switch should be employed in conjunction with all forced feed lubrication systems.

In some large compressors, cylinders are lubricated by mechanical forced feed lubricators which are located external to the compressor crank shaft. In such cases, the cylinder lubrication system is entirely separate from the internal pressure lubricating system.

The lubrication oil pump is the positive displacement pump. It means any quantity (as per design of the manufacturer) it makes. It has to deliver the whole same quantity. (Fig 1) due to any blockage in lubrication oil delivery flow line, when the pumps get overloaded and the pressure increases, therefore valve can be adjusted manually to the extent and safeguard the oil pump to the crankcase of the compressor thus assuring the efficient lubrication of its moving parts. Further more the oil separate maintains a high coefficient of condenser and evaporator performance by almost completely removing oil deposits from their exchange surfaces & limit accumulates of oil at sensitive system components. When a very high temperature at the end of the compression stage leads to the formation of oil vapour, a separator with a capacity should be used. Moreover, the oil separator, damping the valves pulsations, reduces system noise with an open or semi-hermetic compressor.

Function : Refrigerants gas leaving the compressor through the discharge line contains refrigeration oil in a vapour mist. As this mixture enters the oil separator, the velocity is reduced to allow oil separation to begin. The refrigerant gas and oil mixture enters the oil separator and passes through an inlet screen, causing the fine particles to combine. Larger oil particles are formed and drop to the bottom of the oil separator. The refrigerator gas then passes through an outlet screen to remove residual oil particles. The oil gathers in the bottom of the oil separator until a float operated needle valve opens to allow the return of oil to the compressor. Oil returns quickly to the compressor, because of the higher pressure in the oil separator than in the compressor crankcase. When the oil level has lowered, the needle valve closes to prevent refrigerant gas from returning back to the compressor. The refrigerant gas leaves through the outlet of the oil separator and goes to the condenser. (Fig 3)

Lubrication methods in centrifugal compressor

- Pressure type lubrication is possible for centrifugal compressor.
- There are two types of oil pump used for centrifugal compressor lubrication
 - i shaft driven oil pump
 - ii motor driven oil pump
- Shaft drives (or) submerged oil pump is operated by using compressor motor shaft and there is no separate motor for operating the pump
- Submerged pump is welded inside of the compressor housing
- Motor driven oil pump is located separate (or) externally mounted pump sucks the oil from oil reservoir and supply the pressurised oil to required moving parts of compressor.

Working

The structure of the gear pump is very simple and gear pumps work on a popular pumping principle.

Gear pumps are available in a single (or) double pump configurations with spur, helical & herring bone gear.

Gear pump uses two identical gears rotating against each other, one gear is driven by a motor and it turns and drives the other gear.

Each gear is supported by a short and suitable bearing.

When the gear comes out of mesh they create expanding volume on the inside of the pump, oil flows into the cavity and is trapped by the gear teeth as they rotate.

Oil travels around the interior in the casing in the pockets between teeth & the casing.

Finally the meshing of the gear forms liquid through the outlet port under pressure.

Helical and herring bone gears are smoother flow than spur gear.

Advantages

- High speed
- High pressure
- Quiet operation
- No overhauling bearing loads

Disadvantages

- Fixed end clearance
- Four bushing in liquid area.

Motor : Direct driven motor is used for gear pump for constant speed rotation

Oil cooler : Oil coolers are employed to maintain oil temperature during normal condition

Oil heater : Oil heaters are usually installed in the oil reservoir to prevent excessive refrigerant dilution of the oil during the period of shutdown.

The chiller lubrication system consists of the oil pump, oil filter, oil cooler and all interconnecting oil piping and passages. The main points within the compressor which must be supplied with forced lubrication.

Compressor drive shaft (low speed) shaft seal front and rear journal bearings - one on each side of driving gear. low speed thrust bearing (forward and reverse) Compressor driven shaft (high speed) forward and reverse high speed thrust bearing two journal bearings speed increasing gears meshing surfaces of drive and pinion gear teeth. To provide the required amount of oil under the necessary pressure to properly lubricate these parts.

Motor driven submersible oil pump is located in a remote oil sump. Upon pressing of the compressor start switch on the panel, the oil pump is immediately energized. After a 50 second pre-lube period, the compressor runs for 150 seconds during compressor shutdown. The submerged oil pump takes suction from the surrounding oil and discharges it to the oil cooler where heat is rejected. The oil flows from the oil cooler to the oil filter. The oil leaves the filter and flows to the emergency oil reservoir where it is distributed to the compressor bearings. The oil lubricates

the compressor rotating components and is returned to the oil sump. There is an emergency oil reservoir located at the highest point in the lubrication system internally in the compressor. It provides an oil supply to the various bearings

Oil pump : For normal operation, the oil pump should operate at all times during chiller operation. On shutdown of the system for any reason, the oil pump operates and continues to run for 150 seconds. The system cannot restart during that time interval.

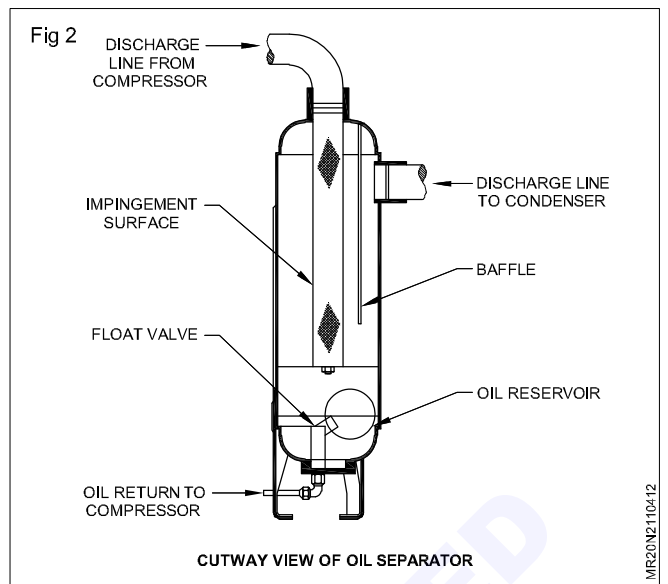
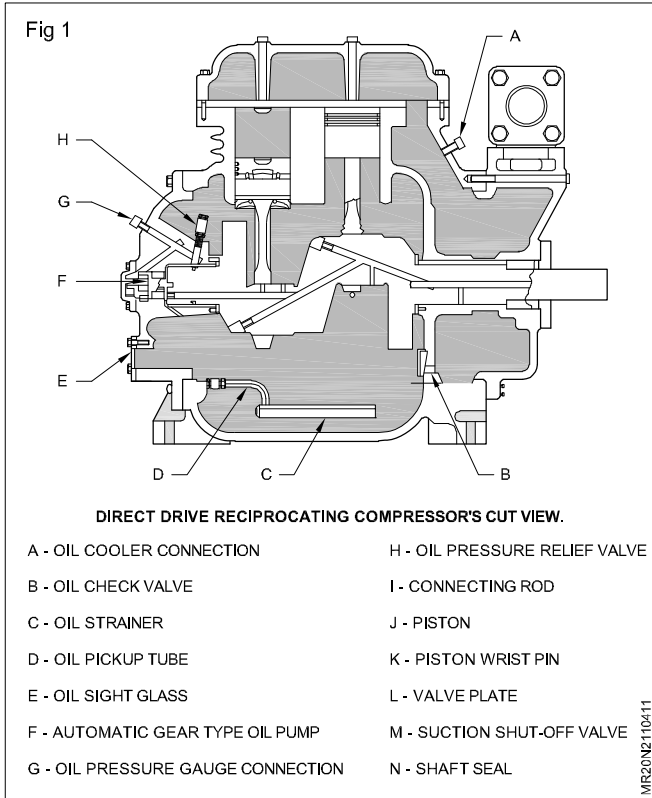
Oil heater : During long idle periods, the oil in the compressor oil reservoir tends to absorb as much refrigerant as it can hold, depending upon the temperature of the oil and the pressure in the reservoir. As the oil temperature is lowered, the amount of refrigerant absorbed will be increased. If the quantity of refrigerant in the oil becomes excessive, violent oil foaming will result as the pressure within the system is lowered on starting. This foaming is caused by refrigerant boiling out of the oil as the pressure is lowered. If this foam reaches the oil pump suction the bearing oil pressure will fluctuate with possible temporary loss of lubrication, causing the oil pressure safety cut out to actuate and stop the system.

The lubrication oil pump is the positive displacement pump. It means any quantity (as per the design of the manufacturer) it intakes. It has to deliver the whole same quantity. (Fig 1)

Due to any blockage in lubrication oil delivery flow line, when the pumps get overloaded and the pressure increases, the relief valve can be adjusted manually to the extent and safeguard the oil pump. (Fig 2)

Servicing lubrication oil pump (Fig 4)

Remove the lubrication oil pump from compressor body. Keep it on the work bench in the tray. Punch mark the matching parts to the body in a sequential manner. Remove external main drive gear and remove end cover bolts, then tap it with mallet and open the end cover. Remove the dowel pins fixed in the body tilt the pump and remove the drive and drive gears. Then check all the parts and clean it. Check for scoring burrs, rectify. Check the drive and drive gears for wear even the clearance between gears, shaft and bearing. Ensure the same bearing can be used or replace it. Now start assembling the lubrication oil pump. When assembling check the clearance between gear face and end cover. Check backlash between drive and driven gear. Connect it to the compressor body, match the oil pump's drive gear to the crankshaft gear. Now you can run the compressor and check the oil pressure is attaining the normal. If not adjust the relief valve according to the designing operational pressure. The lubrication oil pump is directly driven by the crankshaft with gear connection. While servicing the gear, backlash has to be checked. That is, the gear should not engage tight close, neither very loose. If we found the oil pressure gauge needle or pointer is hunting or moving to low high often, it is the indication. The suction line of oil line strainer is choked. It needs a service we can assume. After removing the strainer clean with petrol manually remove



the tiny metal pieces of the worn out bearing or may other foreign materials. While flush out the strainer. Hold the strainer firmly and stretch the hand to the maximum with the other hand hold and dry nitrogen hose (throttled the N2 pressure to required level) flush it and maintain the distance of your body, not to get hurt of any metal pieces

in rapid force, use goggles to protect eyes. Compressors serving commercial refrigeration are lubricated by the following methods.

Refer table for knowing the selection of oil for different temperatures. (Table 1)

Only oil recommended by manufacturers of the equipment should be used. When the manufacturers recommendation cannot be found, the viscosity of oil is indicated below.

Refrigerant oil should be selected according to compressor temperature, evaporator temperature and kind of refrigerant used

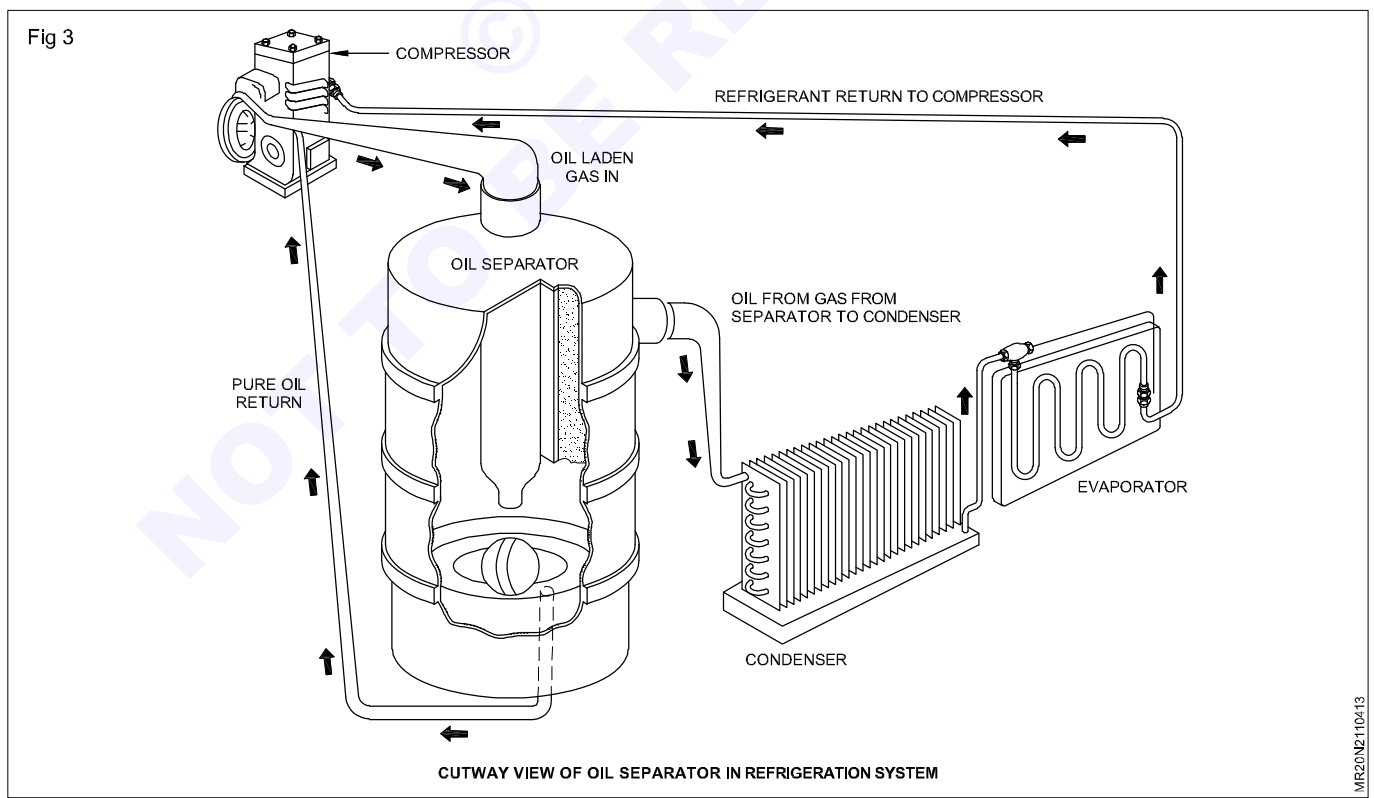
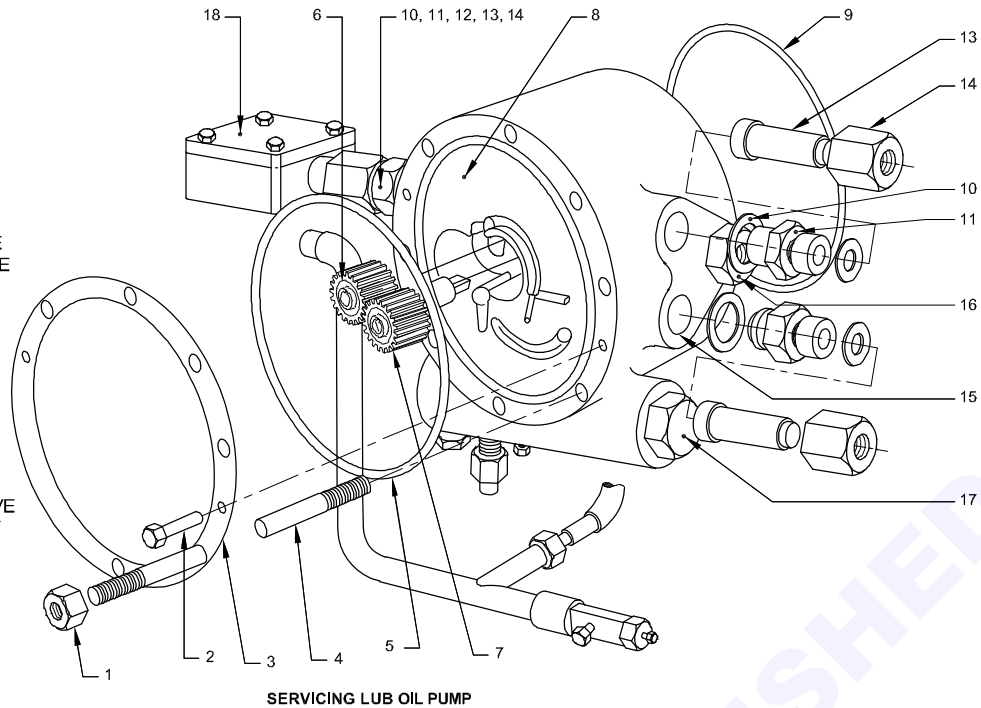


Fig 4

1. NUT
2. BOLT
3. END COVER
4. STUD
5. O-RING
6. DRIVEN GEAR COMPLETE
7. DRIVING GEAR COMPLETE
8. PUMP HOUSING WITH BUSHES
9. O-RING
10. PACKING
11. NIPPLE
12. PACKING
13. PIPE PIECE
14. UNION NUT
15. DIFFERENTIAL PRESSURE REGULATOR
16. PRESSURE RELIEF VALVE
17. HYDRAULIC TIME DELAY
18. OIL STRAINER



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Table 1

Service condition	Refrigerant	Viscosity
Compressor Temperature		
Normal	All	150 150/additives
High	Halogen	150/additives
	Ammonia	300 300/additives
Evaporator Temperature		
Above 0°F Halogen	Halogen	150 150/ additives
	Ammonia	300
0°F to 40°F	Halogen	150 150/ additives
	Ammonia	150 150/ additives
below 40°F	Halogen	150,150/ additives
	Ammonia	150,150 additives
Automotive compressors	Halogen	500

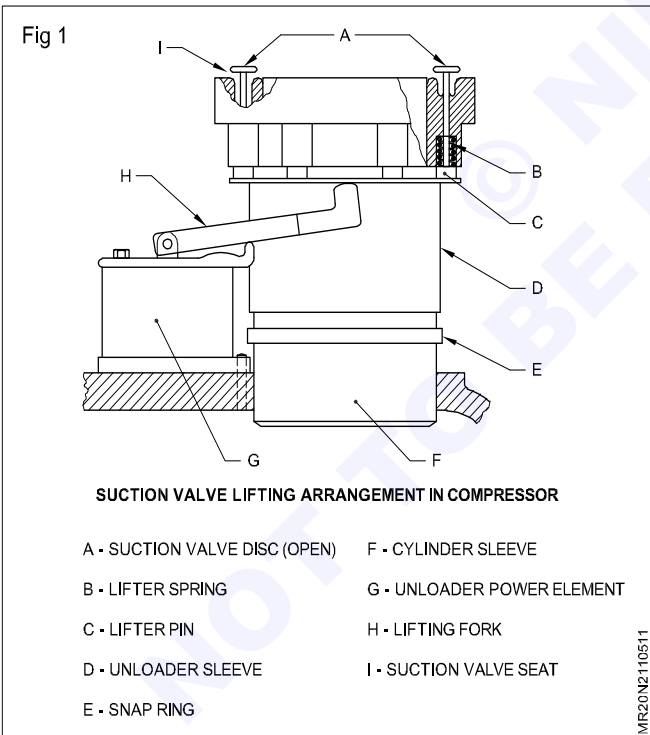
Reciprocating Compressor - Capacity Control

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

- describe the lifting arrangements of suction valve
- explain two speed motor control
- explain the hot gas bypass method
- explain the cylinder bypass method
- explain the whirl vein control method for centrifugal compressor.

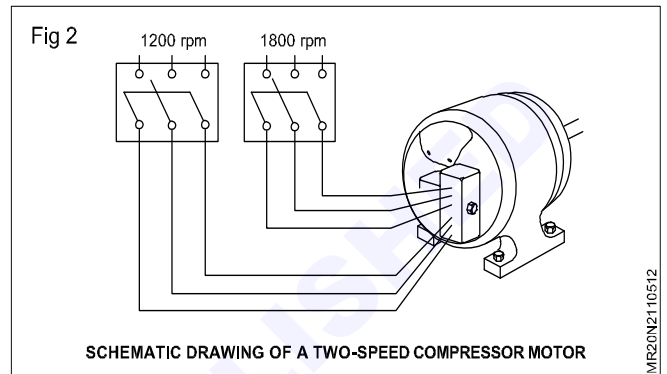
Suction valve lifting arrangements in compressor

The outlet temperature of the medium cooled is sensed by a thermostat and the signal is transmitted to the control panel, which cuts off the oil supply to the unloader power element (Refer Fig 1) thus operating the lifting fork. Which lifts the suction valve off the seat, so suction is not created in the cylinder. This could be for a single cylinder operation, or number of cylinder operation without effecting the unbalanced load on the crankshaft. To achieve this the unloading should be distributed evenly depending on the number of cylinders. Also it should not be operated unload for a long period, this could cause heating of the cylinder heads. If the unloading continues for hours, then the compressor is to be switched off.



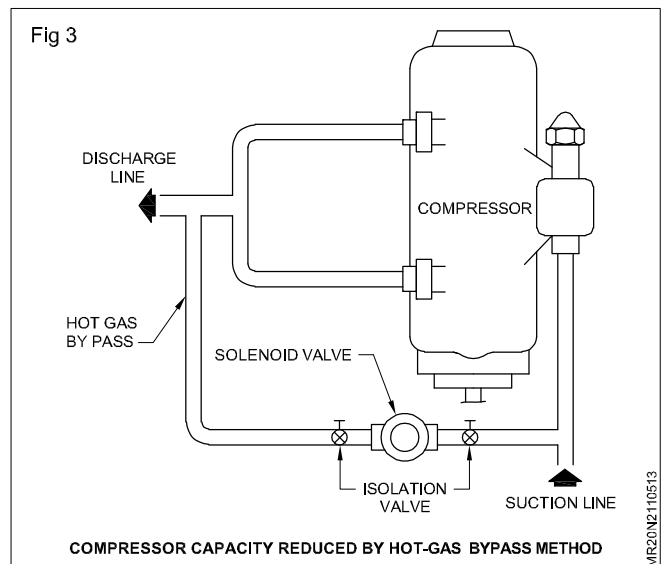
Two speed motor-control capacity control

The outlet temperature of the medium cooled is sensed by a thermostat and the signal is transmitted to the control panel where the windings in the motor is selected to change over the speed of the motor. (Fig 2)



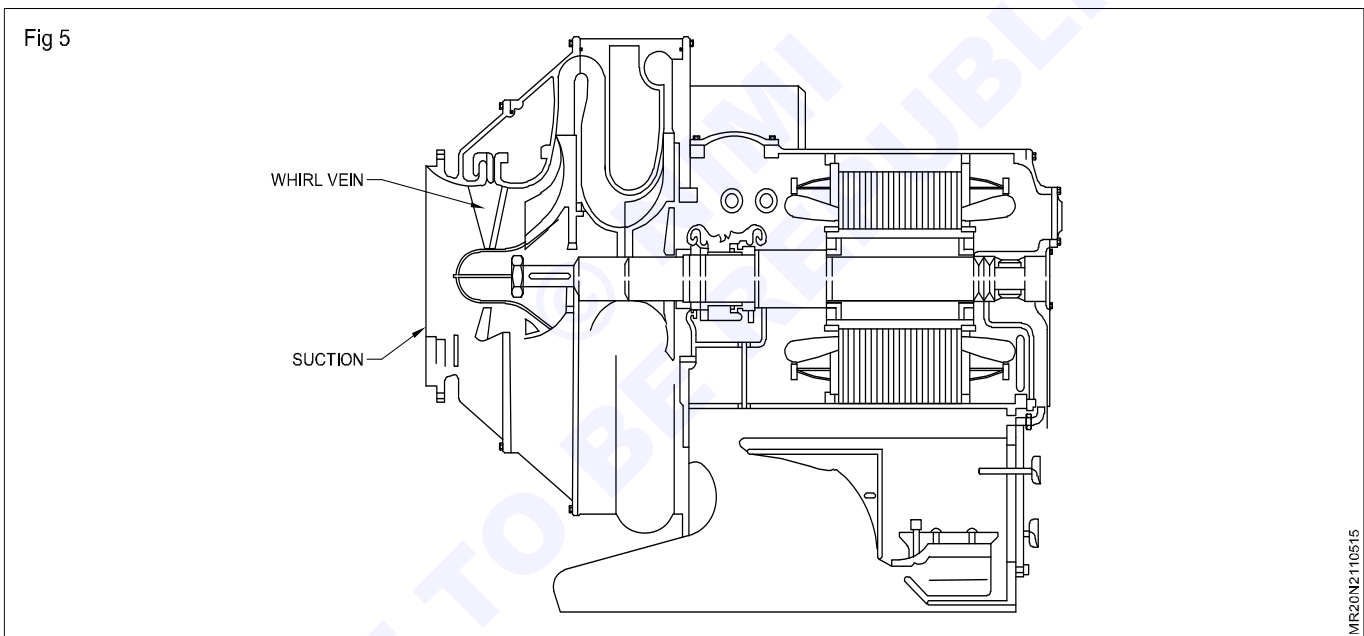
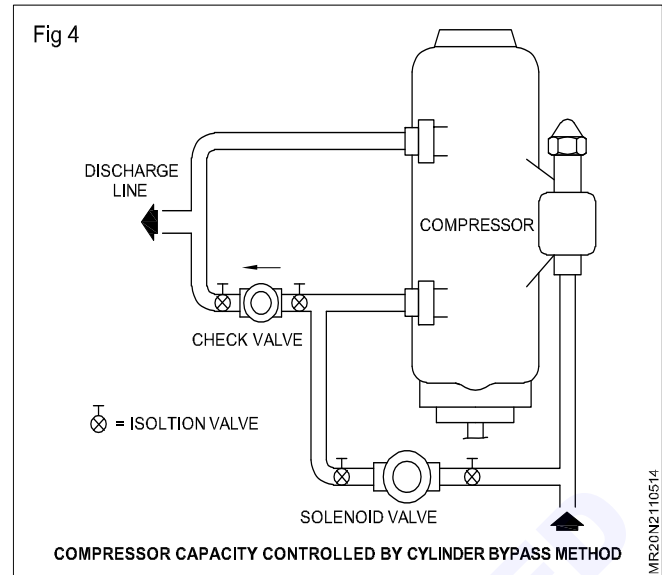
Hot gas bypass method - Capacity control

This has a solenoid valve in the line which connects suction and discharge (interconnection line) when the temperature of the medium is low it is sensed by the temperature sensor and the signal is sent to the control panel which is transmitted to the solenoid. The solenoid valve is opened allowing some of the discharge gas back to the suction. Thus unloading the compressor. The compressor should not be operated unloaded for long periods as the cylinder head will get heated up. If the duration of unload is for hours then the compressor to be switched off. (Fig 3)



Cylinder bypass method-capacity control: The medium cooled when temperature drop is low the low temperature is sensed by the sensor and it is transmitted to the control hand which receives the signal and gives to the solenoid valve then the solenoid valve opens allowing the gas to bypass from discharge to suction. Thus unloading the compressor (reducing the capacity). The check valve does not allow the gas from the next cylinder head to enter the unloaded cylinder head. (Fig 4)

Whirl vein capacity for centrifugal compressor: The vein control consists of number of veins assembled together and connected to a rack and pinion. The rack and pinion is located outside of the suction whereas the vein control is fitted in the suction of the compressor. The temperature of the medium cooled is sensed by the sensor and the signal is given to the capacity control module. This module receives the signal and the solenoid state relays give the feed back to the solenoid valves which engages and allow the lubrication oil to move rack. Thus the pinion moves and the vein control operates inside the suction cone, when the vein closes the suction gas quantity reduces. This is indicated by the current reading on the panel thus the load has reduced. (Fig 5)



Dismantling and assembling of scroll type compressor

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

- explain scroll type compressor

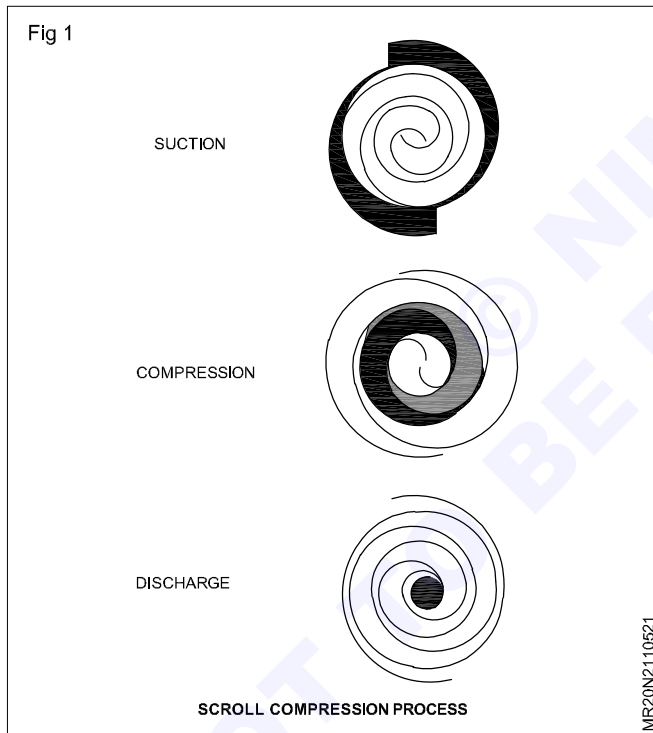
Scroll compressor are orbital motion, positive displacement machines that compress with two inter fitting, spiral shaped scroll members. (one is fixed and another is movable)

Key components

- | | |
|--------------------|----------------------|
| 1 Discharge plenum | 3 Fixed scroll |
| 2 Thermal valve | 4 Orbiting scroll |
| | 5 Crankcase |
| | 6 Counter weight |
| | 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

Scroll compressor components (Fig 1)



A cut away view of the scroll compressor with key components labeled in shown in Fig 2. 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.

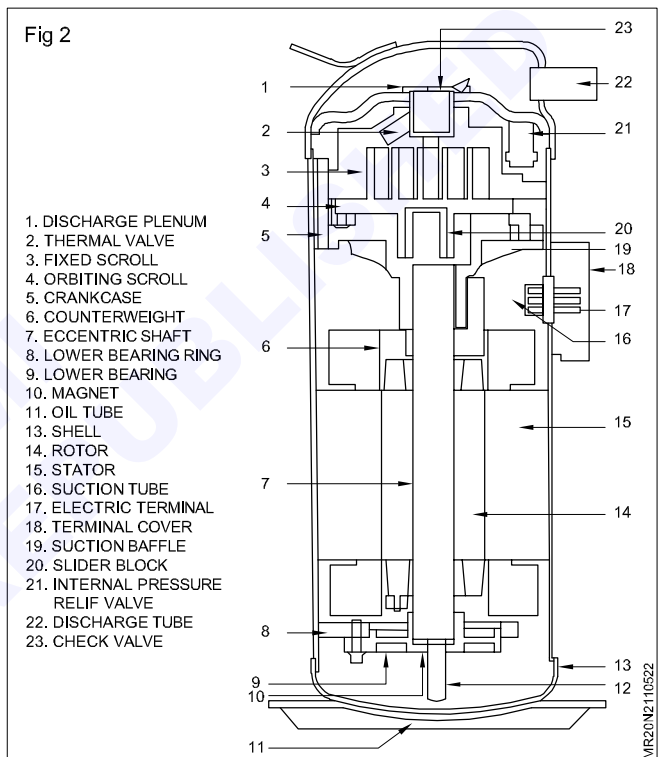
Scroll compression process

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. One 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 simultaneously opened to the discharge port.

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



Star connection: In each 3 phase alternator six terminals come out from 3 coils placed at 120° apart from each other. If any three ends starting or finishing ends are connected at one point we get supply from other three points the connections are called star. That junction points is called star point or neutral [point see Fig 3]

In star Line voltage = $\sqrt{3}$ phase voltage

Line current = phase current

Power in both cases in same ie; $3 V_L I_L \cos\theta$

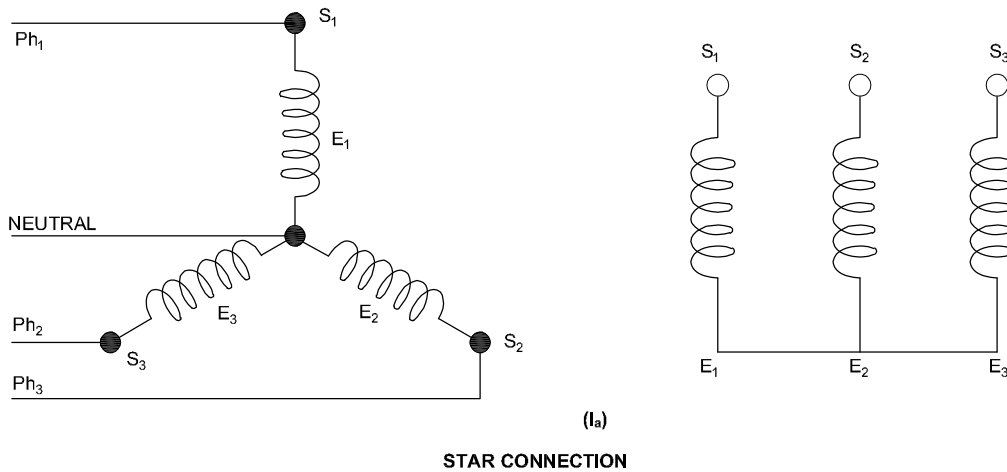
Delta connection

If the six ends are connected that end of first coil (assumed) is connected to start of the second coil and end of second coil is connected to start of the third coil and end of third coil is connected with start of first coil, the connections are called delta connected the supply is taken from the use connected points as shown as (Fig 4)

In delta Line voltage = phase voltage

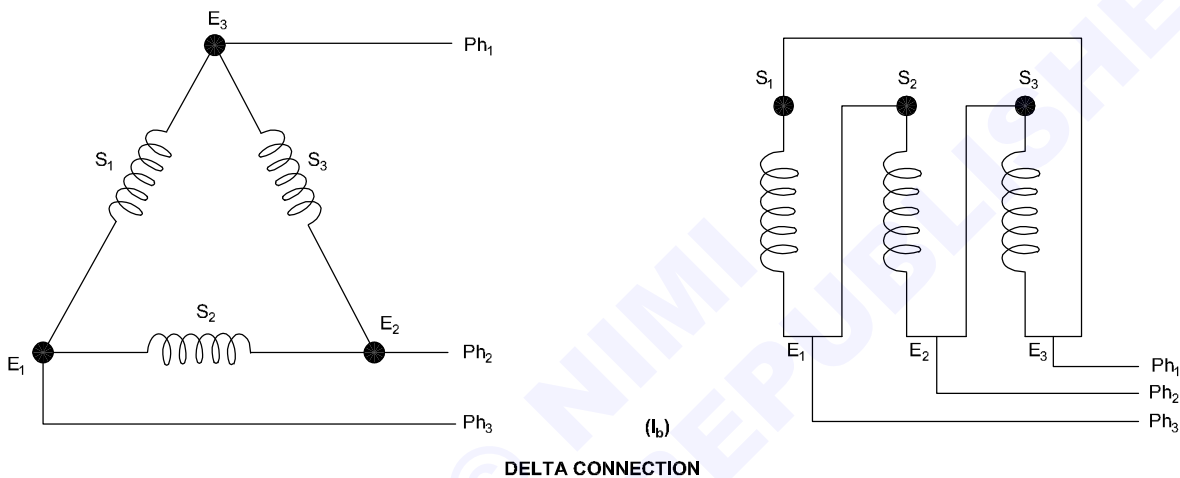
Line current = $\sqrt{3}$ phase current

Fig 3



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Fig 4



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STAR Connection (Y)	DELTA Connection (A)
In STAR Connection , the starting or finishing ends (similar ends) of three coils are connected together to form the neutral point in the shape of letter “Y”. A common wire is taken out from the neutral point which is known as the Neutral Wire.	In DELTA Connection , the opposite ends of three coils are connected together which forms the shape of Greek alphabet “Δ”. In other words, the end of each coil is connected with the starting point of another coil, and the common joints form the three phase wires.
There is a Neutral or Star Point .	No Neutral Point in Delta Connection.
There are Four conductors in the star connection (3 Phase Wires + 1 Neutral Wire).	There are Three conductors in the delta connection (3 Phase Wires e.g. All are phases).
Three phase four wire system is derived from Star Connections (3-Phase, 4 Wires System). 3 Phase 3 Wire System is also possible in the Star Connection as Neutral is optional if not needed.	Three phase three wire system is derived from Delta Connections (3-Phase, 3 Wires System). i.e. 3 Phase, 4 Wires system is not possible in Delta Connection due to the absence of the Neutral wire.
Line Current is Equal to the Phase Current. i.e. · Line Current = Phase Current · $I_L = I_{PH}$	Line Current is “3 times of Phase Current. i.e. · Line Current = “3 × Phase Current · $I_L = “3 \times I_{PH}$
Line Voltage is “3 times of Phase Voltage. i.e. · Line Voltage = “3 × Phase Voltage · $V_L = “3 \times V_{PH}$	Line Voltage is Equal to the Phase Voltage. i.e. · Line Voltage = Phase Voltage · $V_L = V_{PH}$

In Star Connection, the total Power supplied by three Phases could be found by: $P = \sqrt{3} \times V_L \times I_L \times \cos\phi$... Or $P = 3 \times V_{PH} \times I_{PH} \times \cos\phi$ $P = \sqrt{3} \times V \times I$	In Delta Connection, the total Power of three phases could be found by: $P = \sqrt{3} \times V_L \times I_L \times \cos\phi$... Or $P = 3 \times V_{PH} \times I_{PH} \times \cos\phi$ $P = 3 \times V \times I$
The speeds of Star connected motors are slower as they receive $1/\sqrt{3}$ voltage.	The speeds of Delta connected motors are high because each phase gets the total of line voltage.
In Star Connection, Smooth starting and operation with nominal power and normal operation without overheating can be achieved.	In Delta Connection, motor receives the highest power output.
In Star Connection, the phase voltage is low as $1/\sqrt{3}$ of the line voltage. Therefore, it needs a low number of turns, hence saving in copper.	In a Delta connection, The phase voltage is equal to the line voltage, hence it needs more turns which increase the total cost.
Low insulation required as phase voltage is low as compared to Delta.	More insulation is required as Phase voltage = Line Voltage.
Star connection is preferred for long distance transmission and distribution as it requires low insulation and has a Neutral which helps to balance the circuit.	Delta connection is preferred for shorter distance transmission and distribution as it requires more insulation and has the problems of unbalanced currents.
Two different voltage levels can be achieved by using star connection i.e. single phase and three phase supply. (3 Phases and Phase + N).	Only a single magnitude of voltage can be achieved by using the delta connection e.g. three phase supply across three phase conductors.
Star connection is preferably used in the domestic and residential applications for single phase supply (Line or Phase + Neutral = 230V AC - IEC) and three phase supply (Three Phases = 400V AC - IEC). But the case is different and complex in US - NEC).	Delta connection is generally used in the industrial and commercial applications for three phase supply (Three Phases = 400V AC - IEC). This role is not applicable in the US - NEC as they offer different levels of voltages based on the system requirement).
Star connection is commonly used for appliances which need less amount of starting current e.g. small load applications.	Delta connection is generally used for high starting torque applications e.g. large electric motors in the industries etc.
Star Connection is a common and general system which is used for both single phase and three phase power transmission & distribution.	Delta Connection is a typical system commonly used in the distribution Networks & systems and Industries.

Description, construction functions of 3 ϕ motors & starters

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

- description, construction, function and application of 3 ϕ motor and starters.

Introduction

The most common type of AC motor being used throughout the work today is the "Induction Motor". Applications of three-phase induction motors of size varying from half a kilowatt to thousands of kilowatts are numerous. They are found everywhere from a small workshop to a large manufacturing industry.

The advantages of three-phase AC induction motor are listed below:

- Simple design
- Reliable operation
- Easy operation and simple maintenance
- Simple control gear for starting and speed control
- High efficiency
- Rugged construction
- Low initial cost

Induction motor is originated in the year 1891 with crude construction. Then an improved construction with distributed stator windings and a cage rotor was built.

The slip ring rotor was developed after a decade or so. Since then a lot of improvement has taken place on the design of these two types of induction motors. Lot of research work has been carried out to improve its power factor and to achieve suitable methods of speed control.

PRINCIPLE OF 3 PHASE INDUCTION MOTOR

Induction motor works on the same principle as a DC motor, that is the current carrying conductors kept in a magnetic field will tend to create a force.

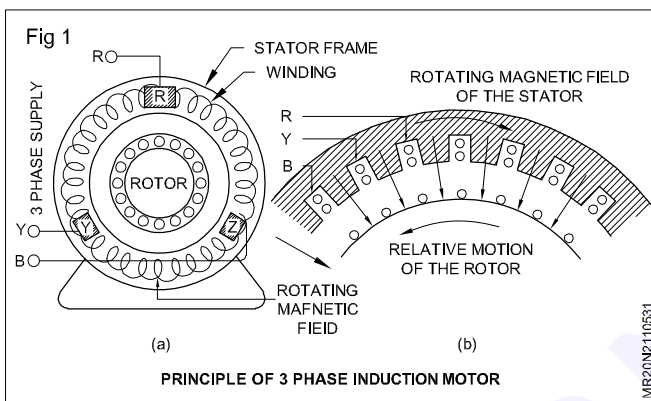
However, the induction motor differs from the DC motor in the fact that the rotor of the induction motor is not electricity connected to the stator, but induces a voltage/

current in the rotor by the transformer action, as stator magnetic field sweeps across the rotor.

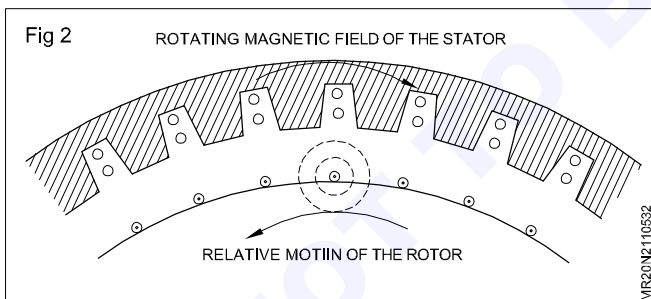
The induction motor, derives its name from the fact that the current in the rotor is not drawn directly from the supply, but is induced by the relative motion of the rotor conductors and the magnetic field produced by the stator currents.

The stator of the three-phase induction motor is simulant to that of a 3-phase alternator, a revolving field type. If a three phase supply is connected to the three phase winding in the stator that produces a rotating magnetic field in the stator core. The rotor of the induction motor may have either shorted rotor conductors in the form of a squirrel cage or in the form of a three phase winding to facilitate the circulation of current through a closed circuit.

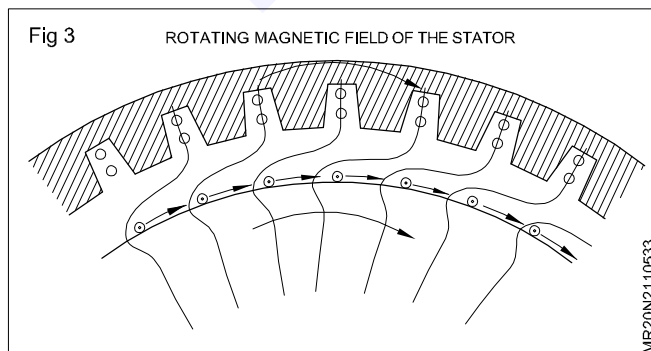
Let us assume that the stator field of the induction motor is rotating in a clockwise direction as shown in Fig 1. This makes for the relative motion of the rotor in an anti-clockwise direction as shown in Fig 1.



Applying Fleming's right hand rule, the direction of emf induced in the rotor will be towards the observer as shown in Fig 2. As the rotor conductors have a closed electric path, due to their shorting a current will flow through them as in a short circuited secondary of a transformer.



The magnetic field produced by the rotor current will be in counter-clock wise direction as shown in Fig 3.



Accordingly, to Maxwells Corkscrew Rule, the interaction between the stator magnetic field and the rotor magnetic field results in a force to move the rotor in the same direction as that of the rotating magnetic field of the stator as shown in Fig 3. As such the rotor follows the stator field in the same direction by rotating at a speed lesser than the synchronous speed of the stator rotating field.

At higher speeds of the rotor nearing to synchronous speeds, the relative speed between the rotor and the rotating magnetic field of the stator reduces and results in a smaller induced emf in the rotor. Theoretically, if we assume that the rotor attains a speed equal to the synchronous speed of the rotating magnetic field of the stator field and the rotor and thereby no induced emf or current will be there in the rotor.

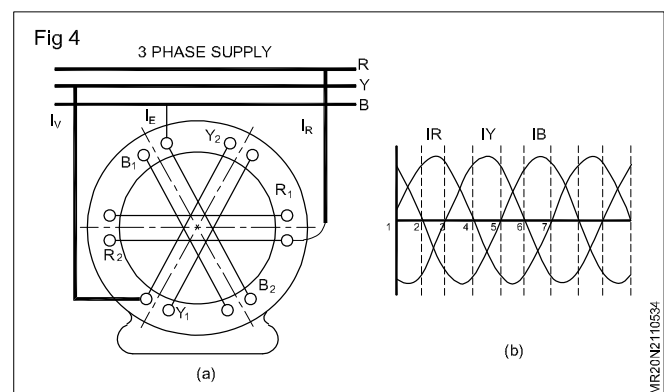
Consequently, there will not be any torque in the rotor. Hence the rotor of the induction motor cannot run at a synchronous speed at all. As the motor is loaded, the motor speed has to fall to cope up with the mechanical force, thereby the relative speed increased, and the induced emf and current increases in the rotor resulting in an increased torque.

Rotating magnetic field

A rotating magnetic field is that which rotates in space at synchronous speed, inside an induction motor starter.

Rotating magnetic field from 3 phase stator (Fig 4ab)

The operation of the induction motor is dependent on the presence of a rotating magnetic field in the stator. The stator of the induction motor contains 3 phase windings placed at 120 degree electrical apart from each other. These windings are placed on the stator core to form non-salient stator field poles when the stator is energized from the three phase voltage supply each phase winding will step up a pulsating field, however, by virtue of spacing between the windings and the phase difference the magnetic fields combine to produce a field rotating at a constant speed around the inside surface of the stator core. This resultant movement of a flux is called the rotating magnetic field and its speed is called the "Synchronous speed".



The manner in which the rotating field is set up may be described by considering the direction of the phase currents at successive instants during a cycle.

Fig 4 shows a simplified star-connected, three phase stator winding. The winding shown is for a two-pole induction motor. Fig 4 shows the phase currents for the three phase windings.

The phase currents will be 120 electrical degrees apart as shown in Fig 4. The resultant magnetic field produced the combined effect of the three currents is shown at increments of 60 degree for the cycle of the current.

Constructional details of induction motor

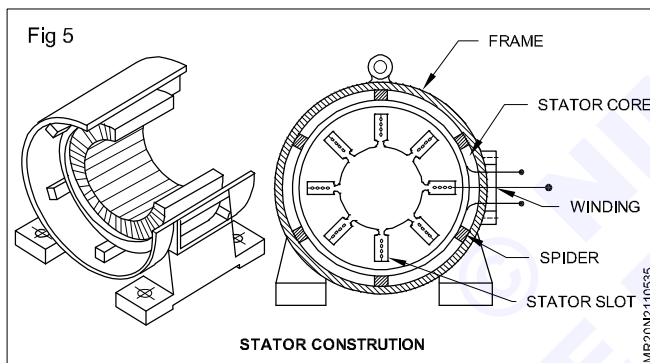
Three phase induction motors are constructed into two major types:

- 1 Squirrel cage induction motors
- 2 Slip ring induction motors

Squirrel cage motor

(a) stator construction

The induction motor stator resembles the stator of a revolving field, three phase alternator. The stator or the stationary part consists of three phase winding held in place in the slots of a laminated steel core which is enclosed and supported by a cast iron or a steel frame as shown in Fig 5.



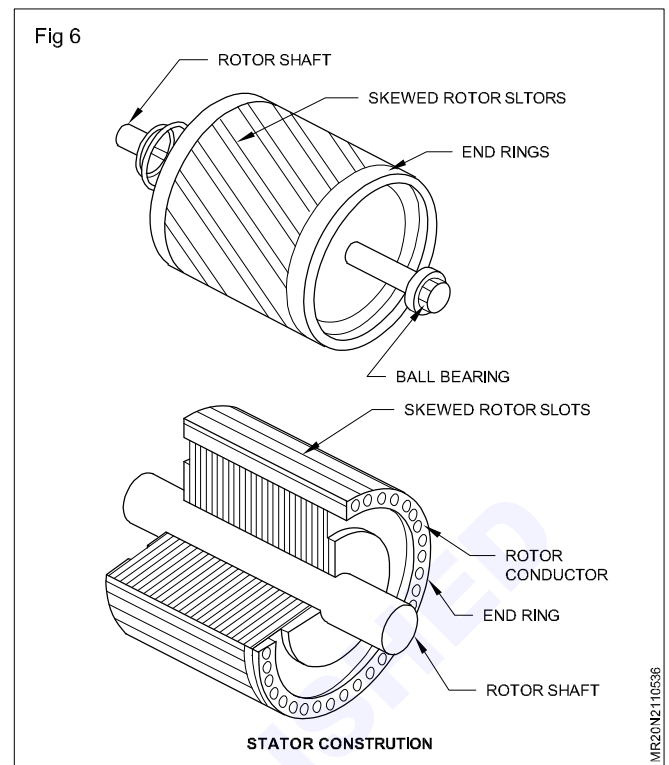
The phase windings are placed 120 electrical degree apart and may be connected in either star or delta externally, for which six leads are brought out to a terminal box mounted on the frame of the motor. When the stator is energized from a three phase voltage it will produce a rotating magnetic field in the stator core.

Rotor of a squirrel cage induction motor

The rotor of the squirrel cage motor shown in Fig 6. contains no windings. Instead it is a cylindrical core constructed of steel laminations with conductor bars mounted parallel to the shaft and embedded near the surface of the rotor core.

These conductor bars are short circuited by an end rings at both end of the rotor core. In large machines, these conductor bars and the end rings are made up of copper with the bars brazed or welded to the end rings shown in Fig 6.

In small machines the conductor bars and end rings are sometimes made of aluminium with the bars and rings cast in as part of the rotor core.



Types of single phase & 3 phase motors

One of the most common electrical motor used in most applications which is known as induction motor. This motor is also called as asynchronous motor because it runs at a speed less than synchronous speed. In this, we need to define what is synchronous speed. Synchronous speed is the speed or rotation of the magnetic field in always runs at a speed less than synchronous speed because the rotating magnetic field which is produced in the stator will generate flux in the rotor which will make the rotor to rotate, but due to the lagging of flux magnetic field speed i.e. the synchronous speed. There are basically two types of induction motor that depends motor is not a self starting motor which we will discuss later and three phase induction motor is a self starting motor. Now in general we need to give two supply i.e double excitation to make a machine to rotate. For example, if we consider a DC motor, we will give one supply to the stator and another to the rotor through brush arrangement.

Working Principle of Induction Motor

But in induction motor we give only one supply, so it is really interesting to know that how it works. It is very simple from the name itself we can understand that there is induction process occurred. Actually when we are giving the supply to the stator winding, flux will generate in the coil due to flow of electric current in the coil. Now the rotor winding is arranged in such a way that it becomes short circuited in the rotor itself. The flux from the stator will cut the coil in the rotor and since the rotor coils are short circuited, according to Faraday's law of electromagnetic induction, electric current will start flowing in the coil of the rotor. When the electric current will flow, another flux will get generated in the rotor. Now there will be two flux, one

is stator flux and another is rotor flux and the rotor flux will be lagging to the stator flux. Due to this, the rotor will feel a torque which will make the rotor to rotate in the direction of rotating magnetic flux. So the speed of the rotor will be depending upon the ac supply and the speed can be controlled by varying the input supply. This is the working principle of an induction motor of either type.

Types Induction Motor

Single phase induction motor

- 1 Split phase induction motor
- 2 Capacitor start induction motor
- 3 Capacitor start capacitor run induction motor
- 4 Shaded pole induction motor

Three phase induction motor

- 1 Squirrel cage induction motor
- 2 Slip ring induction motor

We had mentioned above that single phase induction motor is not a self starting and three phase induction motor is self starting. So what is self starting? When the machine starts running automatically without any external force to the machine, then it is called as self starting. For example we see that when we press the key the fan starts to rotate automatically. so it is self starting. Point to be note that fan used in home appliances : Single phase induction motor but is self starting. How? We will discuss it how.

Why is three phase induction motor self starting?

In three phase system, there are three single phase line with 120° phase difference. So the rotating magnetic field is having the same phase difference which will make the rotor to move. If we consider three phases a, b, and c when phase a is magnetized, the rotor will move towards the phase a winding, in the next moment phase b will get magnetized and it will attract the rotate and then phase c. So the rotor will continue to rotate.

Working Principle of Three phase induction motor

Why single phase induction motor is not self-starting?

But what about single phase, it will be having only one phase still it makes the rotor to rotate, so it is quite

Three - phase, slip - ring induction motor

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

- explain briefly the construction and working of a three-phase, slip-ring induction motor
- explain how the starting torque is high due to insertion of rotor resistance
- state the characteristic of the slip-ring induction motor
- compare the slip-ring induction motor with the squirrel cage induction motor.

Construction: The slip-ring induction motor could be used for industrial drives where variable speed and high starting torque are prime requirements. The stator of the slip-ring induction motor is very much the same as that for a squirrel cage motor but the construction of its rotor is very much different. Stator windings can be either star or delta connected depending upon the design. The rotor consists

of three-phase windings to form the same number of poles as in a stator. The rotor winding is connected in star and the open ends are connected to three slip-rings mounted in the rotor shaft, as shown in Fig 1. The rotor circuit is, in turn, connected to the external star-connected resistances through the brushes, as shown in Fig 2.

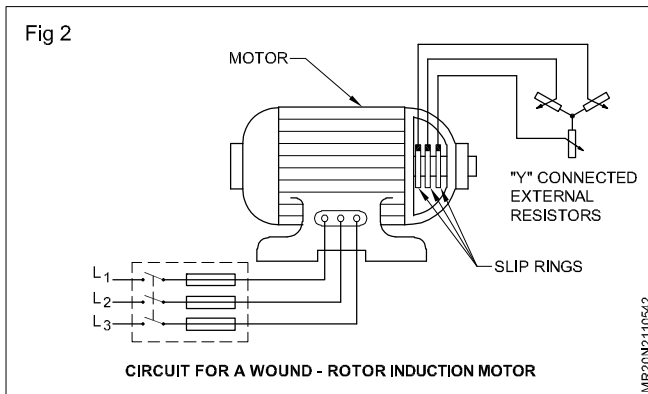
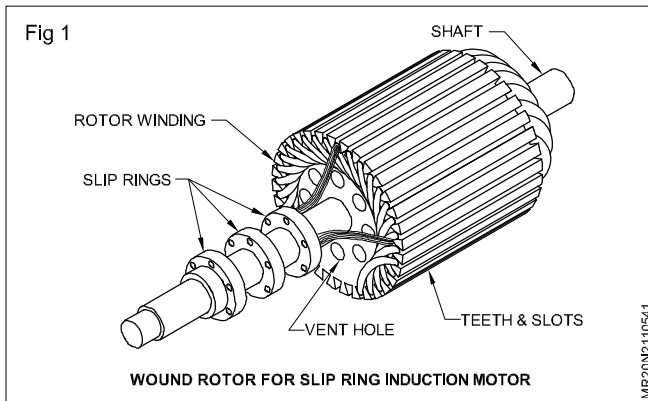
interesting. Before that we need to know why single phase induction motor is not a self-starting motor and how the problem is overcome. We know that the ac supply is a sinusoidal wave and it produces pulsating magnetic field in uniformly distributed stator winding. Since pulsating magnetic field can be assumed as two oppositely rotating magnetic fields, there will be no resultant torque produced at the starting and due to this the motor does not run. After giving the supply, if the rotor is made to rotate in either direction by external force, then the motor will start to run. This problem has been solved by making the stator winding into two winding one is main winding and another is auxiliary winding and a capacitor is fixed in series with auxiliary winding. This will make a phase difference when electric current will flow through the both coils. When there will be phase difference, the rotor will generate a starting torque and it will start to rotate. Practically we can see that the fan does not rotate when the capacitor is disconnected from the motor but if we rotate with hand it will start to rotate. So this is reason of using capacitor in the single phase induction motor. There are several advantages of induction motor which makes this motor to have wider application. It is having good efficiency up to 97%. But the speed of the motor varies with load given to the motor which is an disadvantage of this motor. The direction of rotation of induction motor can easily be changed by changing the sequence of three phase supply, i.e. if RYB is in forward direction, the RBY will make the motor to rotate in reverse direction. This is in the case of three phase motor but in single phase motor, the direction can be reversed by reversing the capacitor terminals in the winding.

How do you reverse rotation of a 3 phase dc motor?

Change the pole of magnet in the DC motor. Example if the south at the right and north at the left, the rotation will rotate clockwise but if u change the pole, rotation will be reverse

How do you change the direction of rotation a 3-phase induction motor?

Swap any two phase connections you may need to adjust the starting connections/ mechanism as well.



Working: When the stator-winding of the slip-ring motor is connected to the 3-phase supply, it produces a rotating magnetic field in the same way as a squirrel cage motor. This rotating magnetic field induces voltages in the rotor windings, and a rotor current will flow through the closed circuit, formed by the rotor winding, the slip-rings, the brushes and the star-connected external resistors.

At the time of starting, the external resistors are set for their maximum value. As such, the rotor resistance is high enabling the starting current to be low. At the same time, the high resistance rotor circuit increases the rotor power factor, and thereby, the torque developed at the start becomes much higher than the torque developed in squirrel cage motors.

As the motor speeds up, the external resistance is slowly reduced, and the rotor winding is made to be short-circuited at the slip-ring ends. Because of the reduced rotor resistance, the motor operates with low slip and high operating efficiency. The motor could be started for heavy loads with higher resistance or vice versa. However, at increased rotor resistance, the motor's slip will be greater, the speed regulation poorer and it will have low efficiency. The resistance in the external circuit could be designed and varied to change the speed of the slip-ring motor between 50 to 100 percent of the rated speed. However, the I²R losses in the rotor due to increased resistance is inevitable.

Starting torque: The torque developed by the motor at the instant of starting is called the starting torque. In some cases it is greater than the normal running torque whereas in some other cases it is somewhat less.

Let E_2 be the rotor emf per phase at standstill

X_2 be the rotor reactance per phase at standstill and R_2 be the rotor resistance per phase.

Therefore $Z_2 = \sqrt{(R_2)^2 + (X_2)^2}$ = rotor impedance per phase at standstill.

$$\text{Then } I_2 = \frac{E_2}{Z_2}, \cos \theta_2 = \frac{R_2}{Z_2}$$

Standstill or starting torque $T_{st} = K_1 E_2 I_2 \cos \theta_2$ or

$$T_{st} = K_1 E_2 = \frac{E_2}{\sqrt{(R_2)^2 + (X_2)^2}} \times \frac{R_2}{\sqrt{(R_2)^2 + (X_2)^2}}$$

If the supply voltage V is constant, then the flux, ϕ and hence E_2 is constant.

$$\text{Therefore } T_{st} = K_2 \frac{R_2}{Z_2} \text{ where } K_2 \text{ is another constant.}$$

The starting torque of such a motor is increased by adding external resistance in the rotor circuit. The resistance is progressively cut out as the motor gain speed.

Rotor emf and reactance under running condition: When the starter is stationary i.e. $S = 1$, the frequency of the rotor emf is the same as that of the stator supply frequency. The value of emf induced in the rotor at stand still is maximum because the relative speed between the rotor and the rotating stator flux is maximum.

When the rotor starts running, the relative speed between the rotor and the rotating stator flux is decreased. Hence the rotor induced emf is also decreased. The rotor emf become zero if the rotor speed become equal to the speed of stator rotating flux.

Hence, for a slip (s), the rotor induced emf will be s times the induced emf at standstill.

$$\text{Therefore, under running condition } E_r = sE_2.$$

The frequency of induced emf will likewise become $f_r = sf_2$ where f_2 is the rotor current frequency at standstill.

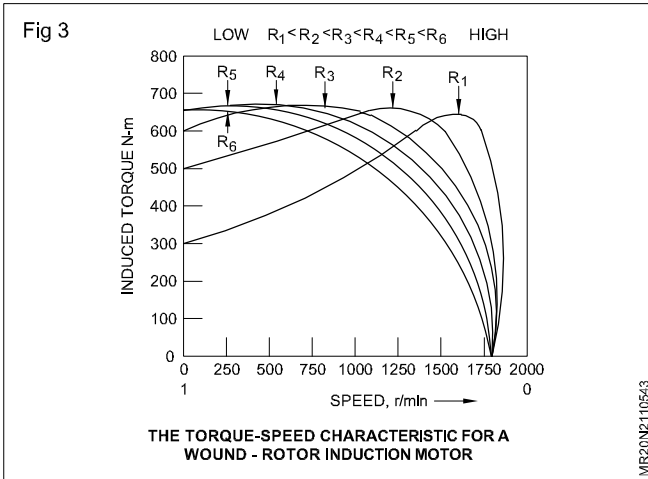
Due to decrease in frequency of the rotor emf, the rotor reactance will also decrease.

$$\text{Therefore } X_r = sX_2.$$

Characteristic and application of slip-ring induction motor: Insertion of higher, external resistance alters the starting torque to a higher value, as shown in Fig 3, by the torque speed characteristic.

By inserting the suitable value rotor resistance, the speed of the slip ring motor could be controlled in spite of power less in resistance.

As shown in the curve, higher, external resistance improves the starting torque to a higher value. However, the maximum torque remains constant for the variation of the rotor resistance.



By these curves, it is clear that the slip-ring motor could be used to start heavy loads by insertion of high resistance in the rotor to facilitate higher starting torque. At the same time the running efficiency of the motor could be achieved by cutting out the external resistance when the motor picks up its speed.

This motor could be used for drive which demands a higher starting torque and also a variable speed control - like compressors, conveyors, cranes, hoists, steel mills and printing presses.

Comparison between squirrel cage and slip-ring induction motors is given below.

Sl. No.	Property	Squirrel cage	Slip-ring motor
1	Rotor construction	Bars are used in rotor. Squirrel cage rotor is very simple, rugged and long lasting. No slip-rings.	Winding wire is used. Wound rotor requires attention. Slip-ring and brush gear need frequent maintenance.

2	Starting	Can be started by DOL star-delta, auto-transformer starters.	Rotor resistance starter is required.
3	Starting torque	Low	Very high
4	Starting current	High	Low
5	Speed variation	Not easy, but could be varied in larger steps by pole-changing or smaller incremental steps through thyristors or by frequency variation.	Easy to vary speed, but speed change through pole-changing is not possible. Speed change possible by - insertion of rotor resistance - using thyristors - using frequency variation - injecting emf in the rotor circuit - cascading.
6	Acceleration on load	Just satisfactory	Very good
7	Maintenance	Almost nil	Requires frequent maintenance.
8	Cost	Low	Comparatively high

Construction of A 3-phase squirrel cage induction motor - relation between slip, speed, rotor frequency, copper loss and torque

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

- describe the construction of a 3-phase, squirrel cage induction motor
- describe the construction of double squirrel cage motor and its advantage
- explain slip, speed, rotor frequency, rotor copper loss, torque and their relationship.

Three-phase induction motors are classified according to their rotor construction. Accordingly, we have two major types.

- Squirrel cage induction motors
- Slip ring induction motors.

Squirrel cage motors have a rotor with short-circuited bars whereas slip ring motors have wound rotors having three windings, either connected in star or delta. The terminals of the rotor windings of the slip ring motors are brought out

through slip-rings which are in contact with stationary brushes.

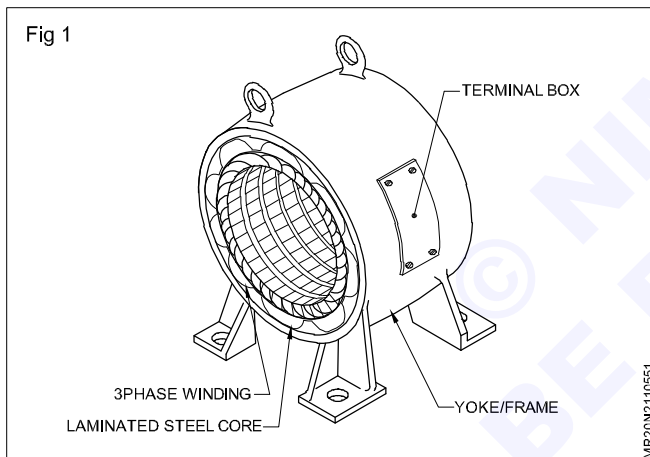
Development of these two types of induction motors is due to the fact that the torque of the induction motor depends upon the rotor resistance. Higher rotor resistance offers higher starting torque but the running torque will be low with increased losses and poor efficiency. For certain applications of loads where high starting torque and sufficient running torque are the only requirements, the rotor resistance should be high at the time of starting, and low

while the motor is running. If the motor circuit is left with high resistance, the rotor copper loss will be more, resulting in low speed and poor efficiency. Hence it is advisable to have low resistance in the rotor while in operation.

Both these requirements are possible in slip-ring motors by adding external resistance at the start and cutting it off while the motor runs. As this is not possible in squirrel cage motors, the above requirements are met by developing a rotor called double squirrel cage rotor where there will be two sets of short circuited bars in the rotor.

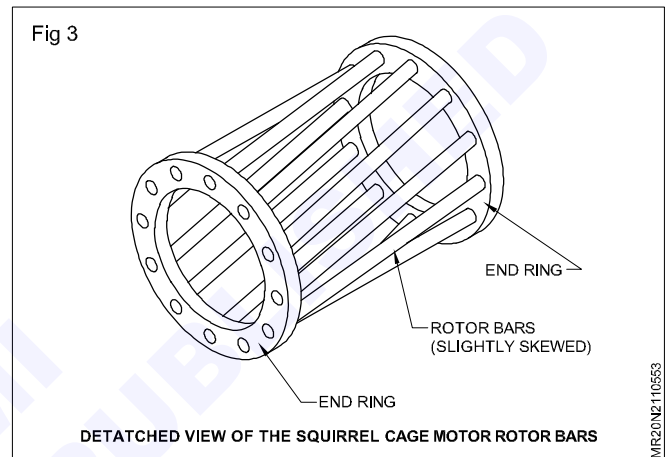
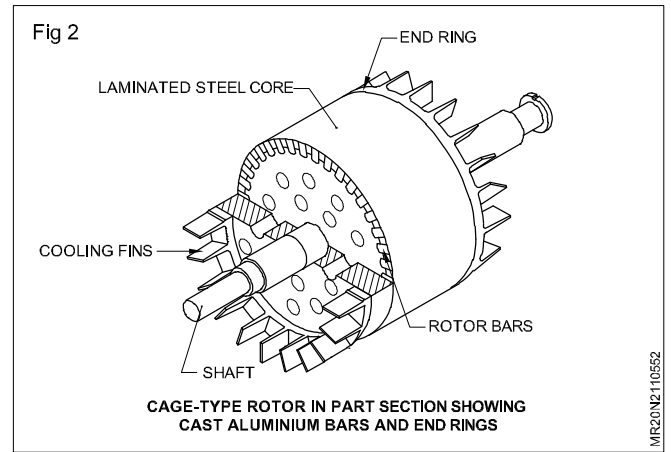
Stator of an induction motor: There is no difference between squirrel cage and slip-ring motor stators.

The induction motor stator resembles the stator of a revolving field, three-phase alternator. The stator or the stationary part consists of three-phase winding held in place in the slots of a laminated steel core which is enclosed and supported by a cast iron or a steel frame as shown in Fig 1. The phase windings are placed 120 electrical degrees apart, and may be connected in either star or delta externally, for which six leads are brought out to a terminal box mounted on the frame of the motor. When the stator is energised from a three-phase voltage it will produce a rotating magnetic field in the stator core.



Rotor of a squirrel cage induction motor: The rotor of the squirrel cage induction motor shown in Fig 2 contains no windings. Instead it is a cylindrical core constructed of steel laminations with conductor bars mounted parallel to the shaft and embedded near the surface of the rotor core. These conductor bars are short circuited by an end-ring at either end of the rotor core. On large machines, these conductor bars and the end-rings are made up of copper with the bars brazed or welded to the end rings as shown in Fig 3. On small machines the conductor bars and end-rings are sometimes made of aluminium with the bars and rings cast in as part of the rotor core.

The rotor or rotating part is not connected electrically to the power supply but has voltage induced in it by transformer action from the stator. For this reason, the stator is sometimes called the primary, and the rotor is referred to as the secondary of the motor. Since the motor operates on the principle of induction; and as the construction of the rotor, with the bars and end-rings resembles a squirrel cage, the name squirrel cage induction motor is used. (Fig 3)



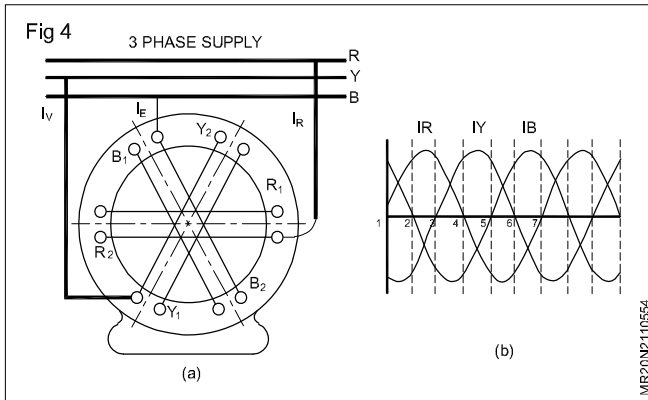
The rotor bars are not insulated from the rotor core because they are made of metals having less resistance than the core. The induced current will flow mainly in them. Also, the bars are usually not quite parallel to the rotor shaft but are mounted in a slightly skewed position. This feature tends to produce a more uniform rotor field and torque; also it helps to reduce some of the internal magnetic noise when the motor is running.

End shields: The function of the two end shields which are to support the rotor shaft. They are fitted with bearings and attached to the stator frame with the help of studs or bolts.

Double squirrel cage induction motor

Rotor construction and its working: This consists of two sets of conductor bars called outer and inner cages as shown in Fig 4. The outer cage consists of bars of high resistance metals like brass, and is short-circuited by the end-rings. The inner cage consists of low resistance metal bars like copper, and is short-circuited by the end-rings. The outer cage has high resistance and low reactance, whereas the inner cage has low resistance but being situated deep in the rotor core, has a large ratio of reactance to resistance.

At the time of starting, the rotor frequency is the same as the stator frequency. Hence the inner cage which has higher inductive reactance offers more resistance to the current flow. As such very little current flows through the inner cage at the time of starting.



The major part of the rotor current at the time of starting could flow through the outer ring which has high resistance. This high resistance enables to produce a high starting torque.

As the speed increases, the rotor frequency is reduced. At low frequency, the total resistance offered for the current flow in the inner cage reduces due to reduction of reactance ($X_L = 2\pi f_r L$), and the major part of the rotor current will be in the inner cage rather than in the highly resistant outer cage.

As such, the low resistance of the inner cage becomes responsible for producing a torque just sufficient to maintain the speed.

Slip and rotor speed: We have already found that the rotor of an induction motor must rotate in the same direction as the rotating magnetic field, but it cannot rotate at the same speed as that of the magnetic field. Only when the rotor runs at a lesser speed than the stator magnetic field, the rotor conductors could cut the stator magnetic field for an emf to be induced. The rotor current could then flow and the rotor magnetic field will set up to produce a torque.

The speed at which the rotor rotates is called the rotor speed or speed of the motor. The difference between the synchronous speed and the actual rotor speed is called the 'slip speed'. Slip speed is the number of revolutions per minute by which the rotor continues to fall behind the revolving magnetic field.

When the slip speed is expressed as a fraction of the synchronous speed, it is called a fractional slip.

Therefore, fractional slip S

$$= \frac{N_s - N_r}{N_s}$$

Then percentage slip (% slip)

$$= \frac{N_s - N_r}{N_s} \times 100$$

where N_s = synchronous speed of the stator magnetic field

N_r = Actual rotating speed of the rotor in r.p.m.

Most squirrel cage induction motors will have a percentage slip of 2 to 5 percent of the rated load.

Example

Calculate the percentage slip of an induction motor having 6 poles fed with 50 cycles supply rotating with an actual speed of 960 r.p.m.

Given:

Poles = 6

N_r = Rotor speed = 960 r.p.m.

F = frequency of supply = 50 Hz

N_s = Synchronous speed

$$= 120 \frac{f}{P}$$

$$= \frac{120 \times 50}{6} = 1000 \text{ r.p.m.}$$

$$\% \text{ slip} = \frac{N_s - N_r}{N_s} \times 100$$

$$= \frac{1000 - 960}{1000} \times 100 = 4\%$$

Generated voltage in the rotor and its frequency: As the rotor cuts the stator flux, it induces voltage in rotor conductors and it is called the rotor voltage. The frequency of this rotor voltage is equal to the product of the slip and stator (supply) frequency.

Frequency of the rotor voltage

f_r = Fractional slip \times stator frequency

$$= \frac{N_s - N_r}{N_s} \times f \text{ or } sf$$

From the above, we find that, at the time of starting, the rotor is at rest, and the slip will be equal to one and the rotor frequency will be the same as the stator frequency. When the motor is running at high speed, the slip will be low and the frequency of the rotor will also be low.

Torque: The torque production in an induction motor is more or less the same as in the DC motor. In the DC motor the torque is proportional to the product of the flux per pole and the armature current. Similarly, in the induction motor the torque is proportional to the flux per stator pole, the rotor current and also the rotor power factor.

Thus we have,

Torque is proportionally = Stator flux \times rotor current \times rotor power factor.

Let E_1 be the applied voltage

\emptyset be the stator flux which is proportional to E_1

S be the fractional slip

R_2 be the rotor resistance

X_2 be the rotor inductive reactance at standstill

SX_2 be the rotor inductive reactance at fractional slip S

K be the transformation ratio between stator and rotor voltages

E_2 be the rotor induced emf and equal to SKE_1

I_2 be the rotor current,

$\cos\theta$ be the rotor power factor.

Z_2 be the rotor impedance.

We can conclude mathematically the following final results.

$$T \propto \phi I_2 \cos\theta_2$$

This can be deduced in to a formula

$$T \propto \frac{SKE_1^2 R_2}{R_2^2 + S^2 X_2^2}$$

$$T \propto \frac{\text{Rotor copper loss}}{\text{Fractional slip}}$$

$$\text{Starting torque} \propto \frac{R_2}{R_2^2 + X_2^2} \text{ as fractional slip } S = 1$$

$$\text{Maximum torque} \propto \frac{1}{X_2}$$

where X_2 in inductive reactance of the rotor at standstill and is constant.

Motor torque calculation: Since the stator flux and induced rotor current for an induction motor are not easily measured, the torque equation $T = K\phi_s I_R \cos\theta_R$ is not the most practical equation to be used for determining a motor torque. Instead the Prony Brake torque equation described earlier may be used, provided the motor's output power and Rev/min are known.

$$\text{Output power in watts} = \frac{2\pi \times \text{torque} \times \text{Rev/min}}{60}$$

$$\begin{aligned} \text{Torque (newton metres)} &= \frac{(60 \times \text{output watts})}{(2\pi \times \text{Rev/min})} \\ &= \frac{(9.55 \times \text{output watts})}{(\text{Rev/min})} \end{aligned}$$

A motor's power may also be stated in British horsepower (hp). In this case the output power in watts will be equal to the output horsepower multiplied by 746 (1 hp = 746w).

In case the motor power is given in metric horsepower, the output power in watts will be equal to the metric horsepower, multiplied by 735.6 (1 metric horsepower = 735.6 watts).

Squirrel cage induction motor

Slip ring induction motor or wound induction motor or phase wound induction motor.

The construction of stator for both the kind of three phase induction motor remains the same and is discussed in brief in next paragraph.

Stator of three phase induction motor

The stator of the three phase induction motor consists of three main parts

- a Stator frame
- b Stator core

Stator winding or field winding

Stator frame: It is the outer most part of the three phase induction motor. Its main function is to support the stator core and the field winding. It acts as a covering and provide protection and mechanical strength to all the inner parts of

the machine. The frame is either made up of die cast or fabricated steel. The frame of three phase induction motor should be very strong and rigid as the air gap length of three phase induction motor is very small, otherwise rotor will not remain concentric with stator which will give rise to unbalanced magnetic pull.

Stator core: The main function of the stator core is to carry alternating flux. In order to reduce the eddy current losses the stator core is laminated. This laminated type of structure are made up of stamping which is about 0.4 to 0.5mm thick. All the stamping are stamped together to form stator core, which is then housed in stator frame. The stamping are generally made up of silicon steel, which reduces the hysteresis loss.

Stator winding or field winding: The slots on the periphery of stator core of the three phase induction motor carries three phase windings. This three phase winding is supplied by three phase ac supply. The three phases of the winding are connected either in star or delta depending upon which type of starting method is used. The squirrel cage motor is mostly started by star- delta stator and hence the stator of squirrel cage motor are delta connected. The slip ring three phase induction motor are started by inserting resistance so, the stator winding can be connected either in star or delta. The winding wound on the stator of three phase induction motor is also called field winding and when this winding is excited is excited by three phase ac supply it produces rotating magnetic field.

Compressor Terminals

Compressor terminals can be identified without the use of an ohmmeter. You read them like you would a boo starting from the left and reading to the right, then dropping down to the next line reading left to right. The order of the compressor terminals is common, start and run.

How a compressor motor is wound?

Most motors used for residential air conditioning, such as condenser fan motors and blower motors are PSC motors, and required a low starting torque. Their construction consists of a set of start windings and run windings that are wound with the same size wire. In the condenser fan motor, in particular windings are both wound with the same number of turns and wire size. This makes the condenser fan motor reversible by changing the function of the windings. A residential compressor, however requires much higher starting torques. For this reason, the start windings are constructed much differently for a compressor. They are wound with smaller wire than the run windings and have start to run turn ratio range of 1:2 to 1:6. This results in a resistance of 20 to 6 times that of the run windings.

Proper continuity and resistance checks

Continuity check

To properly check the continuity and resistance of a compressor, make sure there is continuity across all three terminals. If any or all the terminals are open, and the compressor is hot, then allow the Thermal protector to

reset. For some compressors, the internal thermal protector may take as long as an hour to reset. If waiting is not an option, the compressor can be cooled down quickly with ice in a plastic bag set on top of the compressor. This will reset the internal overload very quickly.

What is a three phase induction motor?

A three phase induction motor is device in which the rotor rotates at speed slightly less than the synchronous speed the difference between the synchronous speed and the rotor speed is called slip which ranges from 2-5%.

Application of 3 ϕ motor starters, Manual star delta switch/starter

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

- state the necessity of a star delta starter for a 3 phase squirrel cage induction motor
- draw and explain the construction, connection and working of a star delta switch and starter
- specify the backup rating of the fuse in the motor circuit
- compare voltages across the windings of the motor, current taken, power absorbed and torque produced in star and delta positions of the starter.

Necessity of star delta starter for 3 phase squirrel cage motor: If a 3 phase squirrel cage motor is started directly, it takes about 5-6 times the full load current for a few seconds, and then the current reduces to normal value once the speed accelerates to its rated value. As the motor is of rugged construction and the starting current remains for a few seconds, the squirrel cage induction motor will not get damaged by this high starting current.

However, with large capacity motors, the starting current will cause too much voltage fluctuations in the power lines and disturb the other loads. On the other hand, if all the squirrel cage motors connected to the power lines are started at the same time, they may momentarily overload the power lines, transformers and even the alternators.

Because of these reasons, the applied voltage to the squirrel cage motor needs to be reduced during the starting periods, and regular supply could be given when the motor picks up its speed.

Following are the methods of reducing the applied voltage to the squirrel cage motor at the start.

- Star delta switch or starter
- Auto transformer starter
- Step down transformer starter

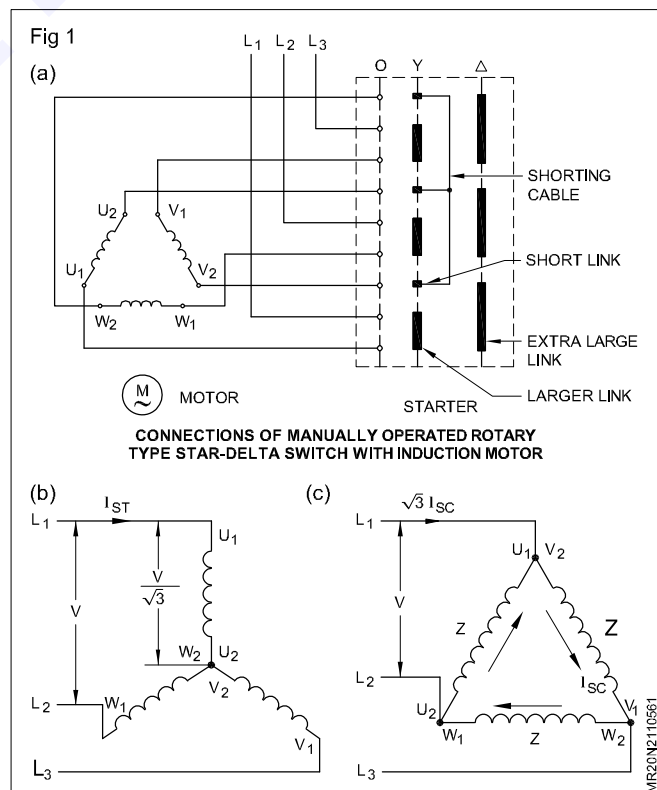
Star delta starter (Fig 1): A star delta switch is a simple arrangement of a cam switch which does not have any additional protective devices like overload or under voltage relay except fuse protection through circuit fuses, whereas the star delta starter may have overload relay and under voltage protection in addition to fuse protection. In a star delta switch/starter, at the time of starting, the squirrel cage motor is connected in star so that the phase voltage is reduced to times the line voltage, and then when the motor picks up its speed, the windings are connected in delta so that the phase voltage is the same as the line voltage. To connect a star delta switch/starter to a 3 phase squirrel cage motor, all the six terminals of the three phase winding must be available.

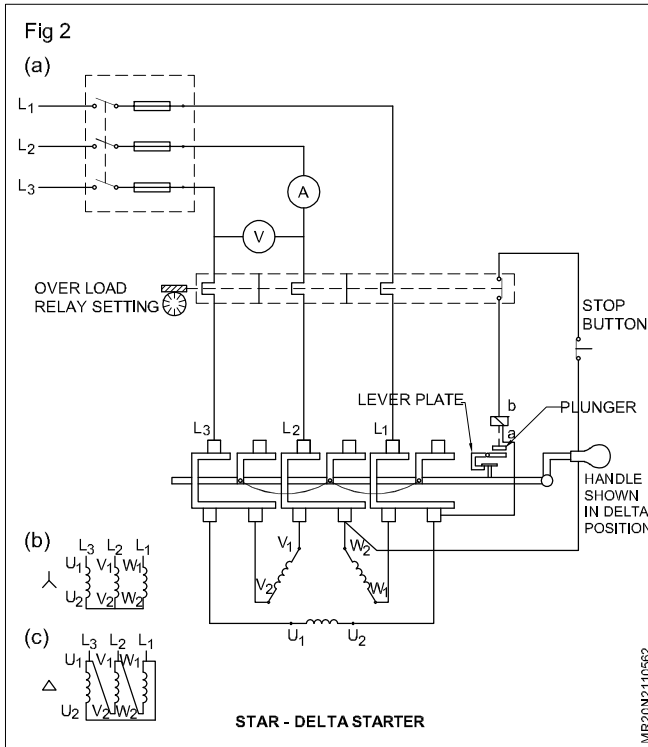
As shown in Fig 1a, the star delta switch connection enables the 3 windings of the squirrel cage motor to be connected in star, and then in delta. In star position, the line supply L_1, L_2 and L_3 are connected to the beginning of windings U_1, W_1 and V_1 respectively by the larger links, whereas the short links, which connect V_2, U_2 and W_2 , are

shorted by the shorting cable to form the star point. This connection is shown as a schematic diagram. (Fig 1b)

When the switch handle is changed over to delta position, the line supply L_1, L_2 and L_3 are connected to terminals U_1, V_2, W_1, U_2 and V_1, W_2 respectively by the extra large links to form a delta connection. (Fig 1c)

Manual star delta starter: Fig 2 shows the conventional manual star delta starter. As the insulated handle is spring loaded, it will come back to OFF position from any position unless and until the no volt (hold on) coil is energised. When the hold on coil circuit is closed through the supply taken from U_2 and W_2 , the coil is energised and it holds the plunger, and thereby the handle is held in delta position against the spring tension by the lever plate mechanism. When the hold on coil is de energised the plunger falls and operates the lever plate mechanism so as to make the handle to be thrown to the off position due to spring tension.





The handle also has a mechanism (not shown in Fig) which makes it impossible for the operator to put the handle in delta position in the first moment. It is only when the handle is brought to star position first, and then when the motor picks up speed, the handle is pushed to delta position.

The handle has a set of baffles insulated from each other and also from the handle. When the handle is thrown to star position, the baffles connect the supply lines L_1 , L_2 and L_3 to beginning of the 3 phase winding W_1 , V_1 and U_1 respectively. At the same time the small baffles connect V_2 , W_2 and U_2 through the shorting cable to form the star point. (Fig 2b)

When the handle is thrown to delta position, the larger end of the baffles connects the main supply line L_1 , L_2 and L_3 to the winding terminals W_1 , U_2 , V_1 , W_2 and U_1 , V_2 respectively to form the delta connection. (Fig 2c)

The overload relay current setting could be adjusted by the worm gear mechanism of the insulated rod. When the load current exceeds a stipulated value, the heat developed in the relay heater element pushes the rod to open the hold on coil circuit, and thereby the coil is de energised, and the handle returns to the off position due to the spring tension.

The motor also could be stopped by operating the stop button which in turn de energises the hold on coil.

Back up fuse protection: Fuse protection is necessary in the star delta started motor circuit against short circuits. In general, as a thumb rule for 415V, 3 phase squirrel cage motors, the full load current can be taken as 1.5 times the H.P. rating. For example, a 10 HP 3 phase 415V motor will have approximately 15 amps as its full load current.

To avoid frequent blowing of the fuse and at the same time for proper protection, the fuse wire rating should be 1.5 times the full load current rating of the motor. Hence for 10 HP, 15 amps motor, the fuse rating will be 23 amps, or say 25 amps.

Comparison of impact of star and delta connections on starting current and torque of the induction motor: When the three phase windings of the squirrel cage motor are connected in star by the starter, the phase voltage across each winding is reduced by a factor of of the applied line voltage (58%), and hence the starting current reduces to 1/3 of that current which would have been drawn if the motor were directly started in delta. This reduction in starting current also reduces the starting torque to 1/3 of the starting torque which would have been produced in the motor, if it were started directly in delta.

CHART 1

Common faults caused and remedies in three phase AC motor

S.No	Cause	Test	Remedy
1	Overload relay tripped.	Wait for overload coils to cool. Push the reset button if separately provided. In some starters the stop button has to be pushed to reset the overload relay.	If motor could not be started check the motor circuit for other causes as outlined in this chart.
2	Failure of power supply.	Test the power supply at the starter incoming terminals.	If the supply is present in the incoming terminals of the starter, check the starter for fault. If not, check the main switch and fuses. Replace the fuses if necessary or restore power supply.
3	Low voltage.	Measure the voltage at the mains and compare with the name-plate rating.	Restore normal supply or check the cables for underrating.

4	Wrong connection.	Compare the connection with the original diagram of the motor.	Still if motor does not start, reconnect, after disconnecting the connection of the motor.
5	Overload.	Measure the starting torque required by load.	Reduce load, raise tapping on auto-transformer, install a motor of a higher output.
6	Damaged bearings.	Open the motor and check the play of bearings.	Replace if required.
7	Faulty stator winding.	Measure current per phase and they should be equal, if required measure resistance per phase; check insulation resistance between winding and earth.	Repair the fault if possible or rewind stator.
8	Wrong control connections.	Check the control circuit and compare it with the circuit diagram.	Reconnect the control circuit according to the manufacturer's circuit diagram.
9	Loose terminal connections at mains or at starter or at motor.	Check the terminal connection of the main switch, starter and motor for discolouring and loose nuts.	Tighten the terminals.
10	Driven machine is locked.	Disconnect the motor from the load.	If the motor starts satisfactorily check the driven machine and rectify the defect.
11	Open circuit in stator or rotor.	Check visually and then with multimeter / megger.	Rectify the defect or wind.
12	Short circuit in stator winding.	Check the phases and coil groups with the help of an ohmmeter or use internal growler.	Repair the winding or rewind.
13	Winding is grounded.	Test with a Megger or test lamp.	If the fault is found, repair or rewind.
14	Bearing stiff.	Rotate the rotor by hand.	If the rotor is stalled, dismantle the motor and rectify the defect.
15	Overload.	Check the load and belt tension.	Reduce the load or loosen the tight belts.

CHART 2

Motor starts but does not share load (Runs at low speed when loaded)

S.No	Cause	Test	Remedy
1	Too low a voltage.	Measure voltage at the motor terminals and verify it with the name-plate.	Renew bad fuses; repair circuit and remove the cause of low voltage, like loose or bad contacts in starter, switches, distribution box, etc.
2	Bad connection.	Check the connection and contact of starter for loose contact.	Remove the fault as required.
3	Too low or high tension on driving belt.	Measure the tension and verify it with the instruction of the manufacturer.	Adjust the belt tension.
4	Open circuit in rotor winding.	Examine the rotor bars and joints.	Re-solder the rotor bars.
5	Faulty stator winding.	Check for continuity, short circuit and leakage.	Repair the circuit if possible or rewind the stator.

6	Defective bearings.	Examine bearings for play.	Replace the bearings.
7	Excessively loaded.	Measure the line current of the motor and compare it with its rated current.	Reduce the mechanical load on the motor.
8	Low frequency.	Measure the line frequency with a frequency meter.	If the line frequency is low inform the supply authorities and get it corrected.

CHART 3

Motor blows off fuses

S.No	Cause	Test	Remedy
1	Incorrect size of fuses	Check the size of the fuse wire (it should be rated for 1½ times its normal current); connect the ammeter in the circuit and test for excess load current.	Replace the fuse wire if necessary; repair the motor if it is due to electrical fault of stator or rotor.
2	Low voltage	Measure the line voltage.	Remove the cause of low voltage.
3	Excessively loaded	Measure the line current and compare it with its rated current.	Rectify the cause of overload or install a motor of higher output rating .
4	Faulty stator winding	Check for open circuit, short circuit or leakage of the stator as explained earlier.	Repair the fault; if not possible then rewind the stator.
5	Loose connection in starter	Check for loose or bad connection in the starter because it may cause unbalancing of current.	Rectify the loose connection; loose all the contact points of the starter with sandpaper and align the contacts.
6	Wrong connection	Check the connection with the original diagram.	Reconnect the motor if it still does not start.

CHART 4

Over Heating of the motor

S.No.	Cause	Test	Remedy
1	Too high or low voltage or frequency.	Check the voltage and frequency at the terminal of the motor.	Rectify the cause of low or high voltage or frequency as the case may be.
2	Wrong connection.	Compare the connection with the given circuit diagram.	Reconnect the connection if required.
3	Open circuit in rotor.	Loose joints of rotor bars cause heat.	Resolder the joints of rotor bars and end rings.
4	Faulty stator winding.	Check for continuity, short circuit and leakage as stated before.	Remove the fault if possible; otherwise rewind the stator winding. Remove dirt and dust from them if any.
5	Dirt in ventilation ducts.	Inspect ventilation ducts for any dust or dirt in them.	Reduce the load or loosen the belt. Rectify the single phasing defect.
6	Overload.	Check the load and the belt.	If the defect is with the driven machine repair it. If the problem is with the bearing, investigate and repair or replace with new one.

7	Unbalanced electrical supply.	Check the voltage for single phasing. Check the connections and fuses. Remove the load and check the rotor for free rotation.	If required replace the motor designed for this purpose.
8	Motor stalled by driven machine or tight bearing.	Check the motor - starter contactor	Loose the machine bearing or grease the bearing or replace the bearing.
9	Motor when used for reversing heats up.	Check the connection	Check the manufacturer's instructions.

Do's	Don'ts
<p>Do use clean solvents and flushing oils.</p> <p>Do lay bearings out on clean paper.</p> <p>Do protect disassembled bearings from dirt and moisture.</p> <p>Do use clean, lint-free rags to wipe the bearings.</p> <p>Do keep the bearing lubricants clean when applying and cover containers when not in use.</p> <p>Do clean outside of housing before replacing bearings.</p> <p>Do keep bearing lubricants clean when applying and cover containers when not in use.</p> <p>Do be sure the shaft size is within specified tolerances recommended for the bearing.</p> <p>Do store the bearing in original unopened cartons installation.</p> <p>Do use a clean, short-bristle brush with firmly embedded bristles to remove dirt, scale or chips.</p> <p>Do be certain that, when installed, the bearing is square with and held firmly against the shaft shoulder.</p> <p>Do follow lubricating instructions supplied with the machinery. Use only grease where grease is specified. Use only oil where oil is specified. Be sure to use the kind of lubricant called for. bearings operate at high speeds.</p> <p>Do handle grease with clean paddles or grease guns. Store grease in clean containers. Keep the grease containers covered.</p>	<p>Don't spin uncleaned bearing.</p> <p>Don't spin any bearings with compressed air.</p> <p>Don't use the same container for cleaning and final rinse of bearings.</p> <p>Don't scratch or nick bearing surfaces.</p> <p>Don't remove grease or oil from new bearings.</p> <p>Don't use incorrect kind or amount of lubricant.</p> <p>Don't use a bearing as a gauge to check either the housing bore or the shaft fit.</p> <p>Don't install a bearing on a shaft that shows excessive wear.</p> <p>Don't open the carton until bearing is ready place. in dry for</p> <p>Don't judge the condition of a bearing until after it has been cleaned.</p> <p>Don't pound directly on a bearing or ring, when installing, as this may cause damage to the shaft and bearing.</p> <p>Don't overfill when lubricating. Excess greases and oil will ooze out of the over-filled housings past seals and closures, collect dirt and cause trouble. Too much exact lubricant will also cause over heating, particularly where</p> <p>Don't permit any machine to stand inoperative for months without running it over periodically. This prevents moisture which may condense in a standing bearing from causing corrosion.</p>

In addition to the bearing faults the motor may develop certain troubles like vibration and noise which may be due to electrical or mechanical faults.

Troubleshooting Chart 6 given here illustrates the possible causes, areas of fault and remedies for the faults like vibration and noise.

CHART 6

Vibration and noise in motors

S.No.	Cause	Test	Remedy
1	Loose foundation bolts or nuts.	Inspect nuts and bolts of foundation for loose fittings.	Tighten the foundation nuts.
2	Wrong alignment of coupling.	Check alignment with a spirit level or	Realign the coupling system through dial test indicator.
3	Faulty magnetic circuit of stator or rotor.	Measure the current in each phase and they should be equal. Check also per-phase resistance and they should be equal. Check the insulation resistance between the windings and the frame. In a newly wound motor there may be reversed coils in a pole-phase group which can be detected by the compass test.	Repair fault if possible or rewind the motor.
4	Motor running on single phase.	Stop the motor, then try to start. (It will not start on single phase). Check for open in one of the lines or circuits.	Rectify the supply.
5	Noisy ball bearing.	Check the lubrication for correct grade and low noise in the bearing.	If found, replace the lubricant or replace the bearing.
6	Loose punching or loose rotor on shaft.	Check the parts visually.	Tighten all the holding bolts.
7	Rotor rubbing on the stator.	Check for rubbing marks on the stator and rotor.	If found, realign the shaft to centre it or replace the bearings.
8	Improper fitting of end-covers.	Measure the air gap at four different points for uneven position of rotor covers.	Open the screws of the side covers, and then tighten one by one. If trouble still persists, remove the end cover, shift for next position and tighten the screws again.
9	Foreign material in air-gap.	Examine the air-gap.	File or clean out air-gap.
10	Loose fan or bearings.	Check looseness of the fan screw or bearings.	Tighten the fan screws or refit new bearings, if necessary.
11	Slackness in bearing on shaft or in housing.	Remove the bearings and inspect the inner looseness of the race on the shaft and outer race in the housing.	Send the motor to the repair shop for removing the looseness of the shaft and housing, if any.
12	Improper fitting of bearings.	Remove the end-covers and examine the assembly of bearings on the shaft or in the housing.	Refit the bearings on the shaft or in the housing.
13	Minor bend in shaft.	Check for alignment on the lathe.	Remove the bend or replace the shaft, if required.

Water cooled condenser types, construction & working

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

- explain water cooled condenser
- explain the types of water cooled condenser
- explain the factors affecting the condenser capacity
- explain fouling factor.

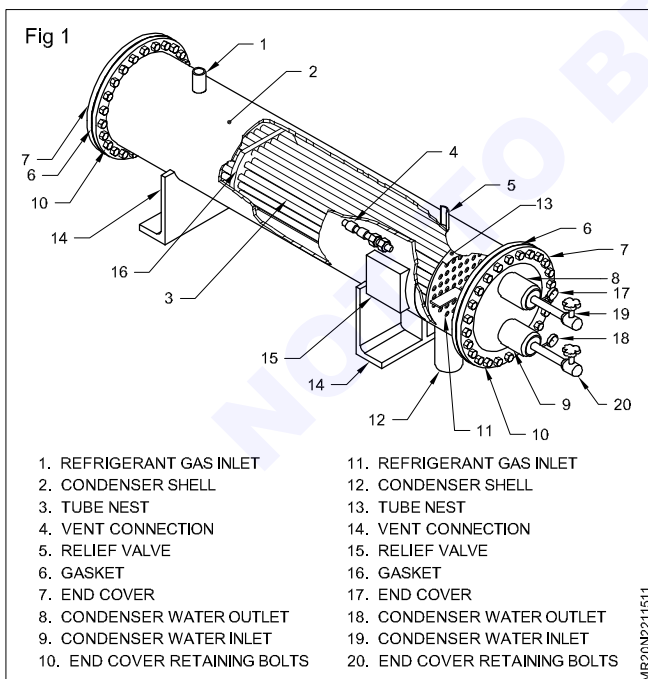
Water cooled condenser

A water cooled condenser is one in which water is used as the cooling medium. They are always preferred where an adequate supply of clear inexpensive water and means of water disposal are available. These condensers are commonly used in commercial and industrial refrigerating units. Condensing temperature 4°C to 12°C above water temperature. Capacity of water to be circulated is 5 to 20 litres/min/ton, velocity of air 120 to 175 mtr/min. There are three types of water cooled condenser.

- 1 shell and tube condenser
- 2 shell and coil type condenser
- 3 tube in tube type condenser

SHELL AND TUBE CONDENSER (Fig 1)

A shell and tube condenser consists of a shell, tube sheet and tubes, water boxes and refrigerant connections. In the smaller sizes shell may be standard pipe but welded shells are used in large sizes. The tube sheets usually 25 to 30mm thick are welded to the shell and drilled to receive tubes with ground or polished ends are inserted through their respective tube boxes to provide a gas tight joint.



The refrigerant vapour flows into the shell and around the tube while water flows through the tubes.

SHELL AND COIL TYPE CONDENSER

Shell and coil condensers are usually used on smaller tonnage low pressure units. They consist of a shell that contains a coil for circulating the water. They do not have removable heads so the water side of the coil may be cleaned only with chemicals. In case of a coil leakage occurs the entire coil bank must be replaced.

TUBE IN TUBE CONDENSER

A double pipe condenser has the condensing water tube inside the refrigerant tube. The refrigerant flows in the space between the tubes while the water is piped through the inner tube. Water flows in the opposite direction to the refrigerant, with the coolest water in contact with the warmest refrigerant and thus heat transfer occurs.

Factors affecting the condenser capacity

The condenser capacity is the ability of the condenser to transfer heat from the hot vapour refrigerant to the condensing medium.

Factors affecting condenser capacity are.

- A Material
- B Area of contact
- C Temperature difference between the cooling medium and refrigerant

Heat Rejection Factor (HRF)

The condenser has to remove

- 1 Heat absorbed by the refrigerant in the evaporator
- 2 Heat absorbed by the vapour in the suction line, the compressor body and compressor motor windings.
- 3 Heat of compression added to the gas during compression.

Hence the amount of heat the condenser has to reject is always higher than the heat absorbed in the evaporator, the ratio is called heat rejection factor of the system. This ratio gives the heat rejected in the condenser per unit load of refrigerant handled by the evaporator.

CONDENSER CAPACITY

The capacity of the condenser is the rate at which the cooling medium is able to absorb heat from the refrigerant through the walls of the condenser tubes.

$$Q = A \times U \times TD$$

- Q = Capacity of heat transferred by the condenser in kcal/hr
- A = Area of heat transfer surface in sqmtr
- U = Overall conductance factor in kcal/hr .sq mtr of heat transfer/degree temperate difference
- TD = Temperature difference between refrigerant and cooling media in degree centigrade.

FOULING FACTOR

The water used in water cooled condenser always contains a certain amount of minerals and other foreign materials depending upon its source. These materials forms deposits in the inside surface of the condenser water tube. This is called water fouling, the deposit insulates the tubes, reduces the heat transfer rate and restrict the water flow. The process of removing these deposit is known as descaling.

Quantity of water required per ton of refrigeration in shell and tube water cooled condenser

The amount of water required will vary with the incoming temperature of water, allowable raise in temperature through the condenser.

$$\text{Condenser capacity (Kcal/hr)} = mf \times Cp \times dT$$

where

mf = Mass flow of water (Kg/hr)

Cp = Specific heat of water (1 Kcal/Kg°C)

dT = Temperature difference between inlet and outlet of water (°C)

Calculation:

3025 Kcal/hr (1 ton of refrigeration) =

mf(Kg/hr) x 1 (Kcal/Kg°C) x (32.2 - 26.6)°C

$$\therefore mf = \frac{3025}{1 \times (32.2 - 26.6)} = 540 \text{ Kg/hr}$$

Assuming the density of water is equal to 1 Kg = 1lt

$$540\text{Kg/hr} = 540 \text{ lts/hr} = 9 \text{ lts/min.}$$

To calculate the water flow required for 5 TR condenser, the flow will be five times more than the above value (9 x 5 = 45 lts/min) with 'dT' remains same.

Parts of a shell and tube water cooled condenser

The shell and tube water cooled condenser consists of

- A shell
- Tube sheet and tubes
- Water boxes
- Refrigerant connections

In smaller sizes the shell may be of standard pipes but in large sizes the sheets are rolled and welded. The tube

sheet usually are 25mm to 30mm in thickness they are welded to the shell and drilled to the tube size outer diameter to receive the tubes.

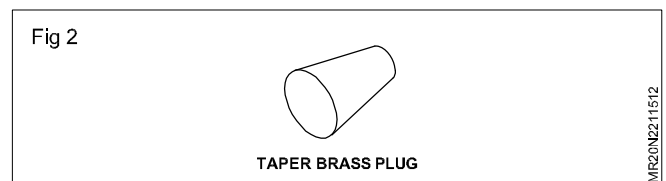
Tubes with ground or polished ends are inserted through their respective tube sheet holes and expanded or welded to provide a gas tight joint. The refrigerant vapour flows into the shell and around the tubes, while water flows through the tubes. The material of construction of tube will be copper (except for ammonia) tube sheet mild steel or carbon steel, shell mild steel or carbon steel. (Fig 1)

Function of a shell and tube condenser

- The hot refrigerant vapour is discharged by the compressor
- Enters the top of the condenser and is contained in the shell.
- The water flows through the tubes from the water box through the passes.
- Thus the hot refrigerant vapour is cooled and condensed to liquid.
- The liquid nozzle is at the bottom of the condenser near to the water box.
- The water inlet should also be at the bottom so that the liquid outlet should be cooled by the coldest water first.
- The liquid refrigerant is ready to pass through the metering device to cool the medium.
- The water picks up the heat from the liquid refrigerant and releases the heat at the cooling tower.

Refer Table 1 for the parts and functions of shell and tube condenser.

TUBE LEAKS: If it leaks from inside of tube then use a taper brass plug and fit it tight to the leaky tube (Fig 2)



If leaks at the outer i.e at the expansion joint it could be expanded with tube expander. (Fig 3)

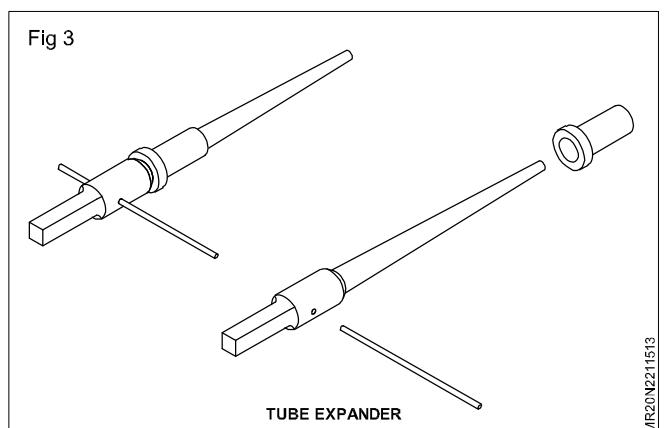


Table 1

Sl.No	Name of the parts	Function
1	Refrigerant gas inlet	The hot gas inlet
2	Condenser shell	Gas hold up space
3	Tube nest	To allow the water to pass
4	Vent connection	For purging non-condensables
5	Relief valve	Release excess pressure (safety)
6	Gasket	Seals the water from leaking
7	End cover	Seals the presses and holds water
8	Condenser water outlet	Deliver the hot water to tower
9	Condenser water inlet	Receives the cold water from pump
10	End cover retaining bolts	Hold up the cover to tube sheet
11	Corrugated portion baffle	Separates the passes of water
12	Liquid refrigerant outlet	Connection for the flow control
13	Tube sheet	Seals the tube outer from shell gas
14	Mounting saddle	For fixing to the mating surface
15	Design data plate	Records the condenser design
16	Tube support baffle plate	Supports the tubes and directs gas flow
17	Outlet pressure gauge	For reading outlet cooler pressure
18	Inlet pressure gauge	For reading inlet water pressure
19	Outlet water valve	To adjust and isolate water flow
20	Inlet water valve	To isolate the water flow

Descaling of shell and tube condenser

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

- explain the necessity of descaling
- explain the method of descaling & assembly.

Copper is not permissible in an ammonia system because of its damaging chemical action with ammonia.

Necessity of descaling

The quality of circulation water in a water cooled condenser varies with almost every place. It is possible that the water used may cause corrosion and scale deposits inside of the tubes where the water circulates.

The scale coating prevents the heat transfer from the hot gas to the water.

Thus due to this the hot gas will not be condensed (Head pressure increases.)

This reduce the cooling effect on the medium cooled (tonnage of the plant).

While the plant in operation ensure that the water flow is sufficient.

Method of descaling:

Ensure that the inlet and outlet valves are opened and regained pressure drop is indicated between inlet and outlet water pressure gauges mounted on the condenser.

Check inlet water reading in the thermometer mounted on the inlet pipe of the condenser.

It should read the ambient temperature.

Check the reading on the outlet thermometer mounted on the outlet pipe of the condenser. This should read 5°C above the inlet water temperature.

If it reads below 5°C and the compressor discharge pressure is above the operating pressure. Observe the operating pressure. Feel the liquid outlet pipe by placing your palm. You should feel the pipe temperature at ambient or 2°C higher.

If it is below then the condenser needs descaling, ensure the system is not overcharged.

Descal the condenser tube side (inner)

Stop the compressor and put off the main supply.

Drain out the holdup water in the condenser.

Remove all the bolts holding the end cover and flanges

Take care of gasket in the end cover and flange joints.

Inspect all tubes visually.

Clean each tube with brass tube cleaning brush - care should be taken that the condenser tubes do not get damaged. The tube cleaning brush should be let at one end of the tube and it should come out at the other end after removing the brush. The same tube should be flushed with water.

This process of cleaning is to be continuing till all the tubes are completed.

After completed the cleaning with brush, then inspect all the tubes visually. If the tubes are cleaned so that the parent metal can be seen or if the tube has scale coating, then the tubes has to be descaled chemically.

Fix lock end covers and flanges with new gaskets.

Connect the descaling system to the condenser in and out flanges fill the mixing tank with required amount of water and add the hydro chloric acid and inhibitor to the water.

Circulate the solution for 4 hours.

Then stop the circulation by putting off the pump.

Drain the solution to the movable barrel.

The drained solution should be let out at the isolated place or in running lake water.

Fill the system with fresh water and start circulation and add water to system till the pH reaches 7 to 7.5.

Stop circulation and drain the water outside the building.

Disconnect the descaling system.

Always wear gloves and goggles.

Check the tubes for leak and arrest. Remove both sides end cover of the condenser.

Plug inside tubes fully with rubber corks.

Apply soap solution on the other side tubes inside and outside of each tube.

If the soap solution bubbles then it indicates leak If leak exists, follow the instructions given in previous lesson.

Evaporative condensers

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

- explain the construction and types of evaporative condensers
- explain the functions, advantage and disadvantage of evaporative condensers.

Construction and types of evaporative condensers

The evaporative condenser was developed to overcome the problems arising from the use of many water cooled condensers in air-conditioning or Refrigeration systems.

The evaporative condenser is a condenser built like a cooling tower which condenses the gas by evaporating water over the condensing tubes. The condenser consists with round tube or coil is used in freon refrigerant. The distance between these tubes are more, it increase the air capacity. Bottom of the condenser a water tank is provided with float system for water inlet. A screen is provided where the air intake, water circulating pump is at the side to recirculate the cooling water to nozzles which is located on top. The eliminator fitted on top of the nozzles.

There are two alternate fan arrangements. In one type of model the fan or blower fitted above the water spray headers and suck the water vapour and air.

The other type of fan arrangements are mounted at the side of the casings and draw fresh air send it in. The air discharge being vertical in both the types.

Usually the evaporative condenser is mounted outdoors and it may be used indoors, if air ducts are provided to the outside, and the selected fan for sufficient air flow.

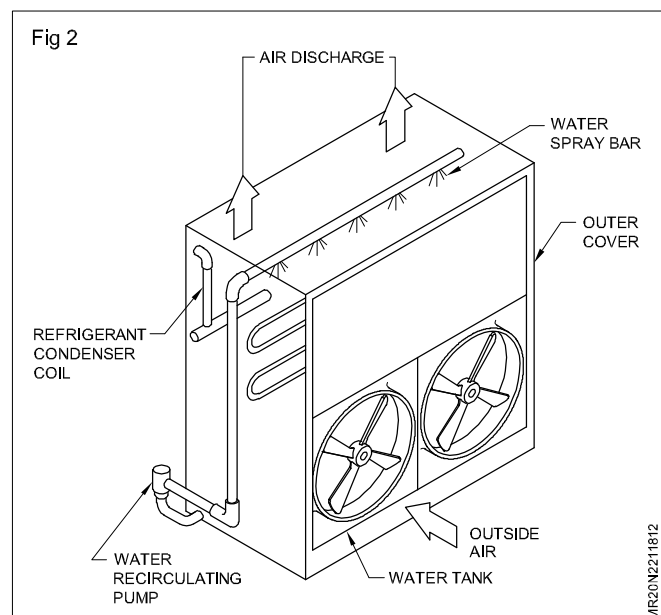
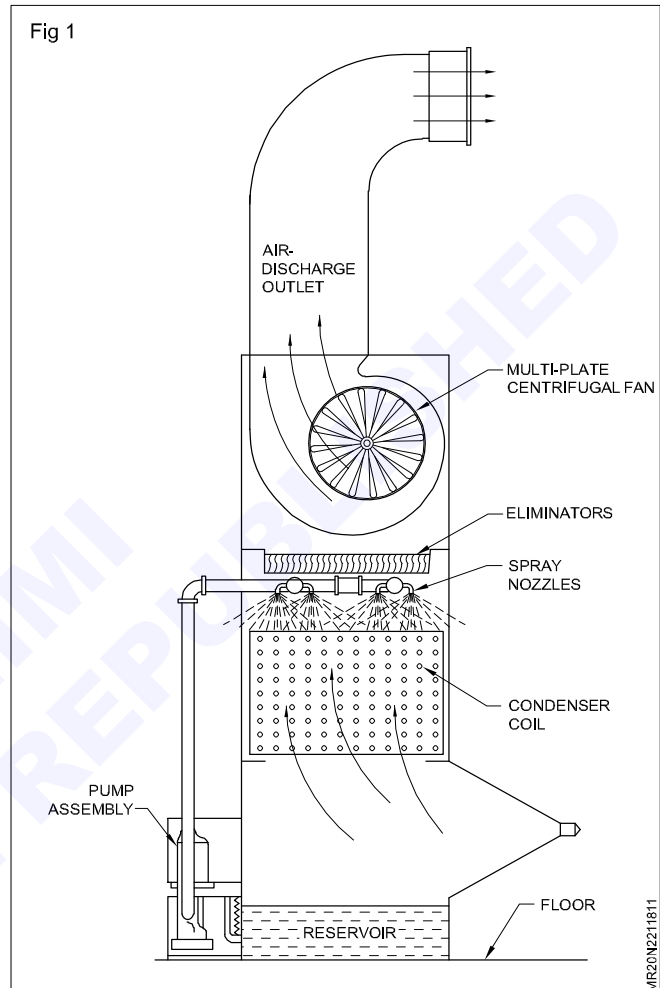
In multi storage buildings, when the refrigeration plant is erected on the top most floor. Due to the high velocity of the open space air, the evaporative condensers are provided in the open space and the natural air force itself cool the condenser while the cooling water dripping on it.

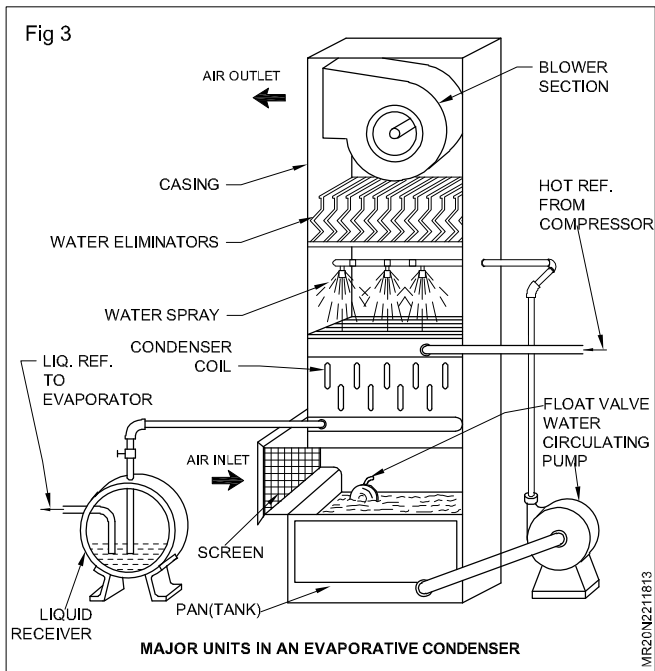
Function, Advantages and disadvantages of Evaporative condensers (Fig 1 &2)

The water pump circulate the tank water through nozzles. It sprays the water on the condenser tubes. Cold water sprayed downward over the condensing coil. The spray water falling into the water tank, to be picked up by the pump and returned to the spray nozzles. (Fig 3)

The air is drawn outside at the bottom of the condenser by the action of blower. The blower discharge the warm air to outside at the top of the condenser.

The float valve maintain the uniform of water level. The cold water spray on the hot condensing tubes, the refrigerant vapour transfer heat through the tube surface to the cold water and also in air, and changes into liquid phase into liquid and water store again in tank. A screen is located to the air inlet, the fresh air enters to the upward of the coil, and water to be cooled.





The eliminator plates prevent the moisture in air and allows to go out dry air only, leaving behind the moisture from it. The moisture with the air after striking the eliminator releases its heat and condenses to water droplets which in turn comes back to the storage tank. The small quantity of water is evaporated and the loss of water can make up by float valve - water inlet. When air passes through the water, its temperature increases, on account of the hotness of water. This heat is transferred from condenser.

Air has three temperatures. Dry bulb, wet bulb and dew point temperatures. The hotness of air reduced by moisture and loose temperature. This temperature can be shown by dry bulb thermometer. This moisture is mixed in air and is to be reduced the temperature but to evaporate the water.

The hotness is combined again with moist air and now the temperature of damp air became to increase. This temperature is called wet bulb temperature, which is indicated by wet bulb thermometer.

This temperature is constant at a point. This point is called saturated point. This temperature is same as the temperature of dry bulb thermometer. The difference of both temperature is called wet bulb depression.

When the saturated air is cooled down, the moisture present in it becomes dew and the air gets unsaturated again. It is important to find out the percent of moisture present in the air from the psychometric chart relating DBT and WBT. The temperature is to be constant this temperature is called dew point.

Advantages: The evaporative condenser combines the functions of the water cooled condenser and cooling tower, hence occupies less space and needs less horse power than a water cooled condenser.

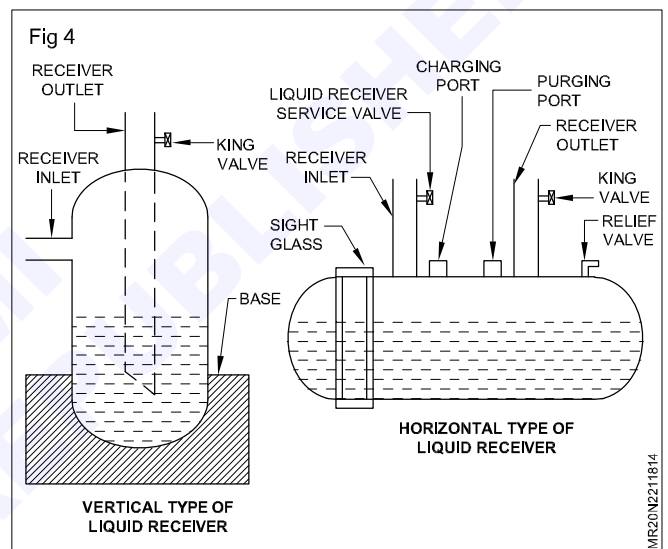
The evaporative condenser may operate with only fan system in the winter season. No need to operate the pump for water spray until the outside temperature rises to 70°F to 80°F (21°C to 26.5°C). At that point an outside air thermostat activates the water system.

Disadvantages: The difficulty of keeping the surface of the condenser coil clean. It is hot and wet in operation, the dirt carried along with the air stream forms a hard layer if hard water used.

Once this layers are formed it is very hard to clean the coil effectively. So the capacity of the condensers gets affected substantially.

These condensers require the same water treatment and bleed off as the cooling tower in order to prevent the accumulation of solids.

Liquid receiver (Fig 4): 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 low 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.

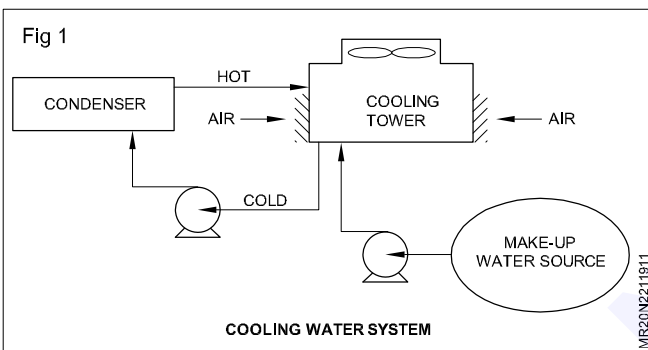
In commercial plant liquid receivers, there are some additional fittings provided.

Cooling tower, types, Construction, efficiency, approach and Cooling tower range

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

- explain the function of cooling towers
- explain the types of cooling towers
- explain construction and function of natural draft cooling tower, forced draft CT and induced draft CT.

Introduction: Cooling towers are a very important part of R&AC plants. They represent a relatively inexpensive and dependable means of removing low-grade heat from cooling water. The make-up water source is used to replenish water lost to evaporation. Hot water from condenser is sent to the cooling tower. The water exits the cooling tower and is sent back to the condenser or to other units for further cooling. Typical closed loop cooling tower system is shown in Fig 1



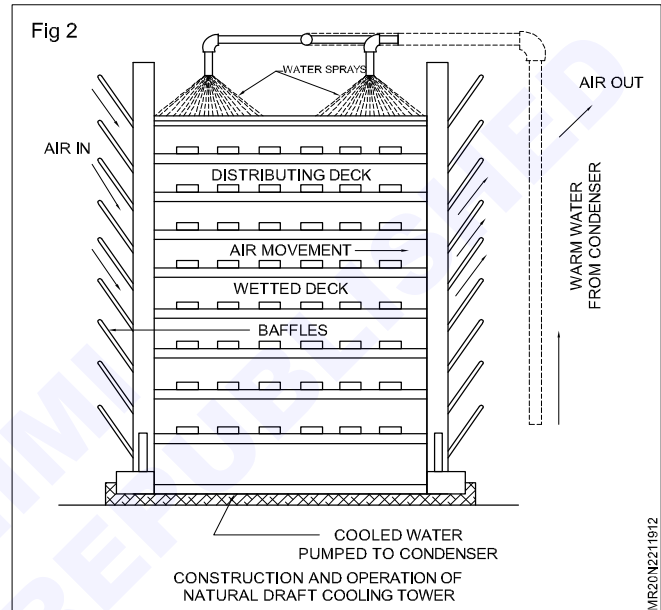
Cooling tower types: Cooling towers fall into two main categories. Natural draft and mechanical draft. Natural draft towers use very large concrete chimneys to introduce air through the media. Due to large size of these towers, they are generally used for water flow rates above 45000 m³/hr.

Mechanical draft towers utilize large fans to force or suck air through circulated water. The water falls down ward over fill surfaces, which help increase the contact time between the water and the air this helps maximise heat transfer between the two. Cooling rates of mechanical draft towers depend upon their fan diameter and speed of operation.

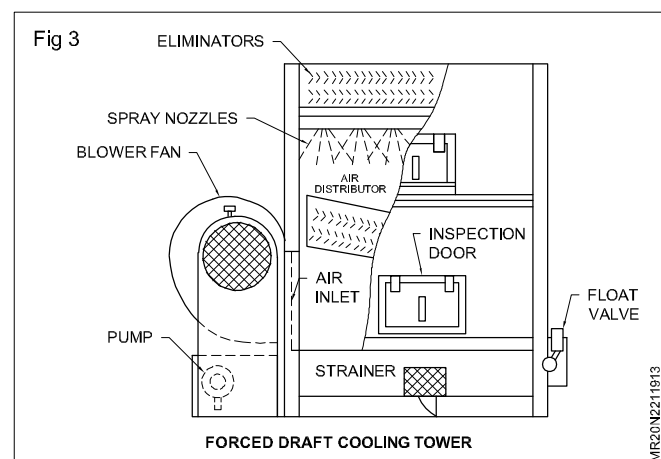
Natural draft cooling towers : The towers are built of heavy wood or steel frame work. According to the capacity of the unit, the height and the area of the natural draft cooling tower will vary. The towers are usually made of cypress or red wood timbers tower have a number of wooden decks, constructed with equal space between in different heights. The open space between the decks for free air flow and the water will drip or run freely from deck to deck. (Fig 2)

In certain models water distributed through the header line and it will have spray nozzles with fine holes. The nozzles helps to force the water to spray, throughout the area of the cooling tower. Air-circulation within the tower, cools the water by natural air convection. Heat transfer from water to air. The hot air floats on top and vent out. The small quantity

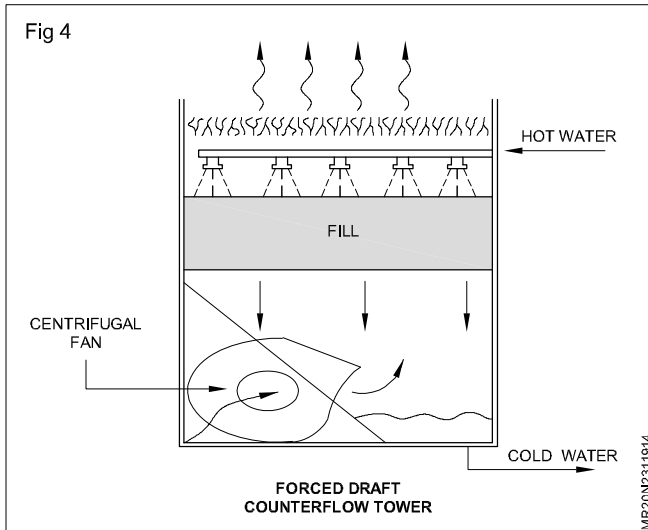
of water evaporates, the lack of water level can be adjusted by make-up float valve and maintain the tank level.



Forced draft cooling tower : Forced draft cooling water gets its name from that air is forced by a fan through the tower. Small towers may be located indoors and connected to the source of outdoor air. Larger towers, because of their height, are generally located on a building roof. (Fig 3&4)



The larger forced draft towers are constructed with wooden timbers or boards, spaced at regular intervals to break the fall of the water and to spread it out over a large surface. The side of the towers are totally covered by a wooden or metal shell. Fans are located at the side or at the bottom of the tower. Eliminators on top allow only air and avoid water particles, the water drops in the tank itself.



Parts of forced draft cooling tower

The basic parts of a forced draft cooling tower are

- Frame and casing
- Cold water basin
- Air inlet
- Fans
- Fill
- Drift eliminators
- Dazzles

Frame and casing : Most towers have structural frames that support the exterior enclosures (casings), motors, fans and other components.

Fill : Most towers employ fills (made of plastic or wood) to facilitate heat transfer by maximising water and air contact. Fill can either be splash or film type. With splash fill, water falls over successive layers of horizontal splash bars, continuously breaking into small droplets. Plastic splash fill promotes better heat transfer than the wood splash fill. Film fill consists of thin, closely spaced plastic surfaces over which the water spreads, forming a thin film in contact with the air. The film type of fill is the more efficient and provides same heat transfer in a smaller volume than the splash fill.

Cold water basin : It is located at or near the bottom of the tower, receives the cooled water that flows down through the tower and fill. The basin usually has a sump for cold water discharge connections.

Drift eliminators : This part will capture water droplets entrapped in the air stream that otherwise would be lost to the atmosphere.

Air inlet : This is the point of entry for the air in to the tower. It should be located lower on the side or the bottom of counter flow designs.

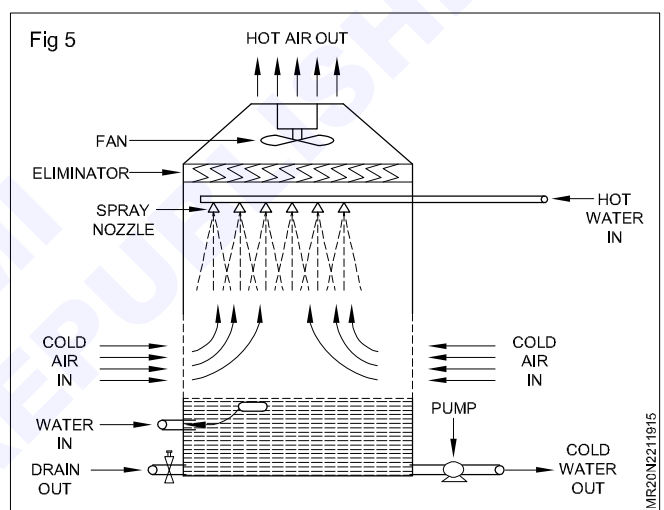
Nozzles : These provide the water sprays to wet the fill. Nozzles can either be fixed in place and have either round or square spray patterns.

Fans : Generally a centrifugal fan is used in forced draft cooling tower. Its function is to draw air from outside and force it from bottom to top of the cooling tower.

Tower materials : In the early days towers are constructed primarily of wood. Today tower manufacturers fabricate

towers and tower components from a variety of materials. These materials are used to enhance corrosion resistance reduce maintenance and promote reliability and long service life. Galvanised steel, various grades of stainless steel, glass fiber and concrete are widely used for the construction of forced draft cooling tower. Difference between natural draft and mechanical draft cooling towers.

Induced draft cooling tower (Fig 5) : This type of cooling tower come under mechanical draft cooling tower. In construction it has a water tank, float valve, water circulating pump, spray nozzles, eliminator and fan. Bottom has a water tank and water level is maintained by a float valve. The make up water inlet is connected to the float valve. The water out let is connected to the water circulating pump. The pump outlet is connected to the spray nozzles. through condenser The fan is located on the top of the cooling tower. The eliminators are fitted just below the fan and spray nozzles is fitted just below the eliminator.



After condensation hot water enters in to the spray nozzles. The spray nozzles sprayed the hot water and flows downward. In this time the fan suck the cold air from the bottom and flows upwards. The hot water and cold air will contact and water is cooled. The cold water collect in the water tank and re circulated in to the condenser. The hot air flows outside. The function of eliminator is prevent the flow of water particles. The function of float valve is maintain the water level in the water tank.

Natural draft cooling tower	Mechanical draft cooling tower
Water is cooled by natural air	Water is cooled by forcing or drawing through the tower by fan
Tower's sides are kept open	Tower's sides are closed
It should be installed where the natural air velocity is more	It can be installed anywhere
It occupies large space	It occupies less space
It is low expensive	It is more expensive
It is less efficient	It is more efficient

Cooling Tower: Approach is the difference between the cooling tower outlet cold water temperature and ambient wet bulb temperature.

Cooling tower range: Range is the difference between the cooling tower water inlet and outlet temperature.

Efficiency:

Efficiency = $\text{Range} / (\text{Range} + \text{Approach}) \times 100\%$

In summer the ambient air wet bulb temperature raises when compared to winter thus limiting the cooling tower efficiency.

Approach, Range & Efficiency

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Causes for water contamination and water treatment

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

- explain about bleed off algae and scales in water
- explain ozonisation of cooling tower water.

Water is generally classified as four groups as shown in table1 depending upon the calcium carbonate content. The calcium carbonate expressed in parts per million(ppm) is responsible for the scale formation. Softening plant for the treatment of condenser water is generally recommended a water of class 'C' of the table 1.

Table 1 Classification of water

Class	Calcium carbonate content ppm
A Soft	Less than 60
B Medium	60-120
C Hard	120-180
D Very hard	More than 180

Characteristics of water such as hardness, acidity, alkalinity (ph value), algae should green up when the water is exposed to sun it leads poor performance and life of the plant. Water contains lot of dissolved chemicals or salts (calcium carbonate and calcium sulphate) decreases as temperature rises. Because of this reason, water at high temperature causes to deposit these chemicals on the tube surfaces of water cooled condenser to become scales. Scale is a hard deposit which can only be removed by chemical treatment of water. Scale or fouling factor of a condenser represents the resistance offered by the scale or fouling to the heat flow from the refrigerant to the water in the condenser tubes. It will also becomes one of the important causes of increasing the discharge pressure.

Water being exposed to the atmosphere in a cooling tower, absorbs some gases making it acidic corrosion of metallic surfaces increases as acidity goes up (pH value of water decreases below 7) As the pH value rises up to above 7.5 or 8, water become alkaline, which accelerates the formation of calcium carbonate scale.

Bleed off

Over a period of operation, the salt accumulates in the tower basin will increasing the salt concentration in the cooling tower water which will accelerate scale formation. Bleed off is the process which is used to minimise the scale formation in cooling tower water.

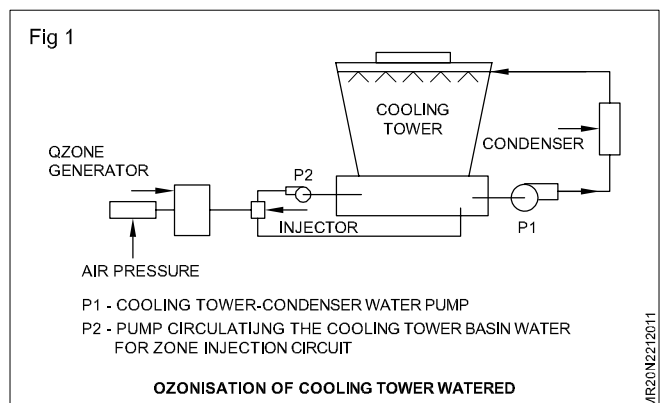
A small portion of condenser return water is continuously drained out during the operation of the plant. This is known as bleed off. The extra water is added to compensate this bleed off will help to reduce the salt concentration in water. The bleed off line is fixed on the return water line at a point higher than the water level in the cooling tower basin. A regulating hand value is provided in the bleed line to regulate the quantity of bleed. Generally, the bleed off rate is equal to the evaporation loss which is roughly 1% of the water in circulation for a range of 5.5°C.

Algae

Any wet surface exposed to atmosphere can develop algae (weed). It is a plant growth which grows rapidly in sunlight. Algae loosened from cooling tower surface enters the water system and blocks strainers and nozzles, restricting water circulation. Periodical scraping of the algae and cleaning of the tower will be the common AEN1207A3 solution to eliminate algae.

Ozone treatment of cooling tower water (Fig 1)

Ozone treatment is a type of water treatment to eliminate harmful contaminants from water. Automatically controlled and regulated ozone injection in to a side stream of water taken from the cooling tower basin by a separate pump and the ozonised water is return back in cooling tower basin. Ozone treatment of water will help to reduce the scale formation and increase the heat transfer rate in condenser tubes. It also helps to prevent corrosion of condenser tubes, destroying bacteria, viruses microbes and algae in water



Expansion valves - Types, construction & working

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

- explain the type of the expansion valve
- explain thermostatic expansion valve
- explain electronic expansion valve
- explain electric expansion valve
- explain level master control (LMC).

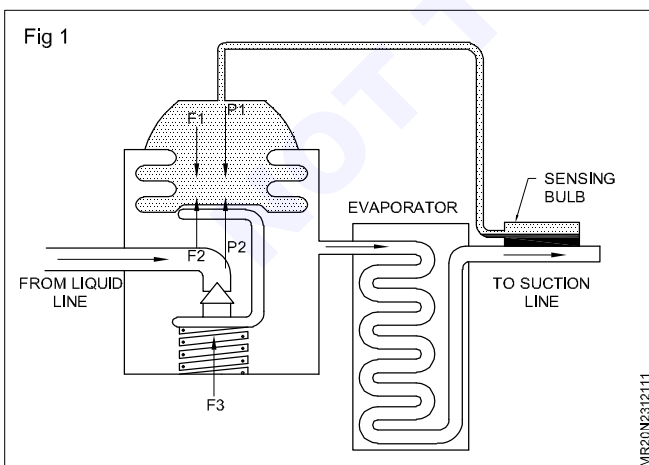
A refrigerant control is the device used in refrigeration system to change the pressure of the refrigeration. Refrigerant in the evaporator must be at low pressure to evaporate at low temperature. Liquid refrigerant in the condensing unit is at a relatively light pressure. So that the unit operate automatically an automatic refrigerant flow control must be used. This control is placed in the circuit between the liquid line and the evaporator. It reduce the light pressure in the liquid line to low pressure in the evaporator.

For getting proper refrigeration refrigerant control device is used in the liquid line. Its function is to reduce the high pressure liquid to a low pressure liquid refrigerant and to supply liquid refrigerant to evaporator in the desired quantity. The main expansion valves are

- 1 Automatic expansion valve
- 2 Thermostatic expansion valve
- 3 Electronic expansion valve
- 4 Low side float valve
- 5 High side float valve
- 6 Level master control

Thermostatic expansion valve (Fig 1)

Thermostatic expansion valve showing various pressures and temperatures within the valve which cause it to operate.



- F1 Sensing bulb pressure (force) tending to open the valve.
- F2 Low side pressure (force) tending to close valve.

F3 Spring force tending to close valve.

P1 Sensing bulb pressure tending to open valve.

P2 Suction pressure (low-side) tending to close valve;

T1 Sensing bulb temperature,

T2 Evaporator refrigerant temperature (low side) valve opens when F1 is greater than combined force of F2 and F3.

The valve closes when the combined F2 and F3 forces are greater than F1.

Parts and functions of thermostatic expansion valve. (Figs 2, 3 & 4)

- A Superheat spring (operates the valve)
- B Spring retainer (holds spring in position)
- C Body sealing gasket (prevents refrigerant from leaking out)
- D Body plug (holds the operating parts)
- E Adjustment cap (for adjusting superheat)
- F Adjusting stem (connects operating parts to cap)
- H Push rod and ball valve (transmits the diaphragm force to spring to control the flow)
- I Power element (temperature sensed operates bellows)

Functions of external equalizer through 3 way solenoid valve

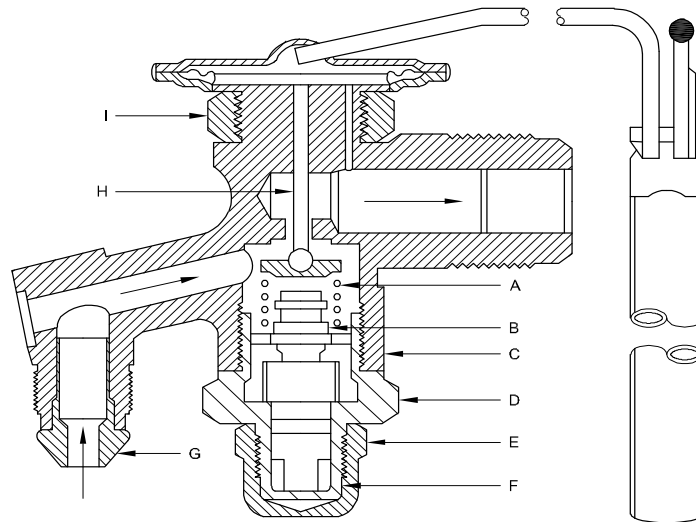
When the system is in operation the solenoid is energised the evaporator pressure passes through the equaliser line behind the power element bellows, So the actual evaporator pressure operates against the bellows; So that the valve side open and allow the actual volume of liquid refrigerant to the evaporator not allowing the liquid to flood the evaporator.

When the solenoid is off the head pressure passes through the equaliser line behind the power element bellows. There the valve is shut off tightly not allowing flow of liquid to evaporator. The electrical wiring should be interlocked with the device to carryout the operation.

Names and functions of thermostatic expansion valve with external equaliser. (Fig 3)

- A Liquid line connection - connects the liquid from condenser to liquid from condenser to inlet of expansion valve.

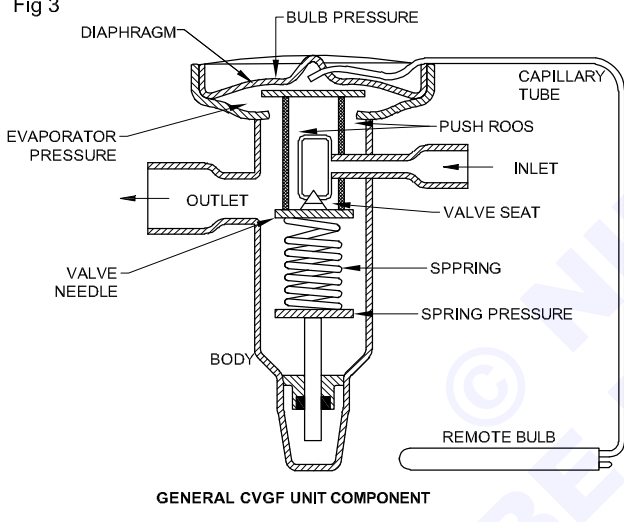
Fig 2



DIAPHRAGM TYPE THERMOSTATIC EXPANSION VALVE. NOTE A BALL IS USED AS THE VALVE, REPLACING NEEDLE. DIRECTION OF REFRIGERANT EXPANSION VALVE IS MARKED BY ARROWS.

MR20N2312112

Fig 3



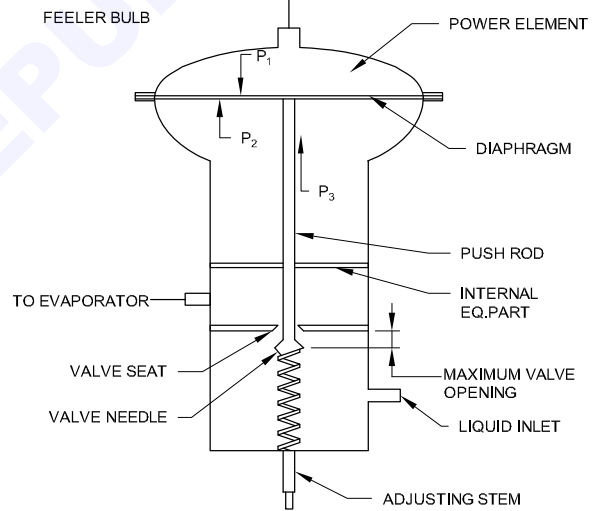
GENERAL CVGF UNIT COMPONENT

MR20N2312113

- B Suction line connection connects the expansion outlet to inlet of evaporator.
- C Sensing bulb - senses the temperature of the evaporator outlet and the gas inside expands or contracts accordingly.
- D Diaphragm - operates the diaphragm contact element according to the expansion or contraction of gas in the bulb assembly.
- E Diaphragm contact element - receives the action from the diaphragm and operates the push rod and the valve opens or closes as required.
- F Valve - allows the liquid flow accordingly.
- G Valve seat - shuts off the valve when the spindle come back
- H Push rod - moving part which contracts the liquid flow
- I Superheat adjustment - manual adjustment for superheat.
- J Superheat spring - tends to push the spindle against the diaphragm.

- K Equaliser tube connection - allows the refrigerant pressure behind the bellows of diaphragm.
- L Valve body - covers all external parts and prevents refrigerant leakage to atmosphere.

Fig 4



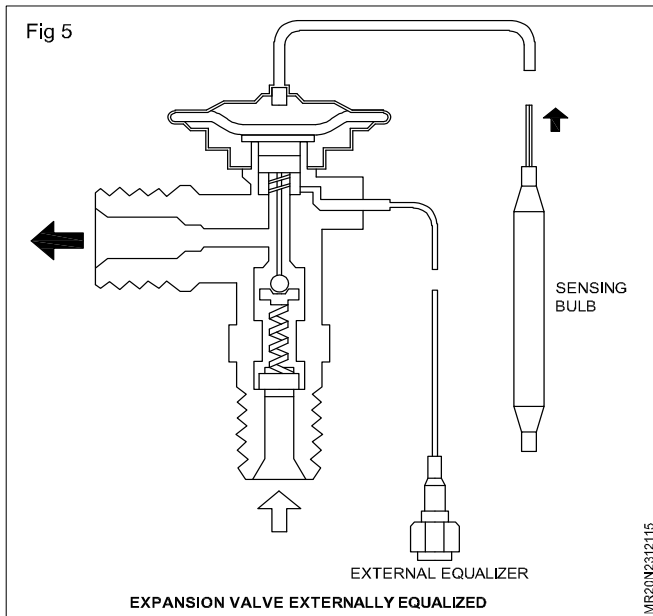
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Externally Equalised TEV : (Fig 5 & Fig 6)

Till now we have been dealing with a valve with an internal equalizer. We also use valve with an external equalizer or certain application. Let us see the purpose of the external equalizer.

Assume that a valve with an internal equalizer is used in an evaporator having a pressure drop of 0.42 kg/cm² (6psi). So to get the pressure of 2.46 kg/cm² G (35 psig) [corresponding to 4.4° c (40°F) for R-12] at the outlet of the evaporator, we have to adjust the valve to give 3.02 kg/cm² G (43 PSIG) pressure just at the outlet of the valve.

In a valve with the internal equalize, this 3.02 kg/cm² G (43 psig) pressure will be acting on the bottom of the

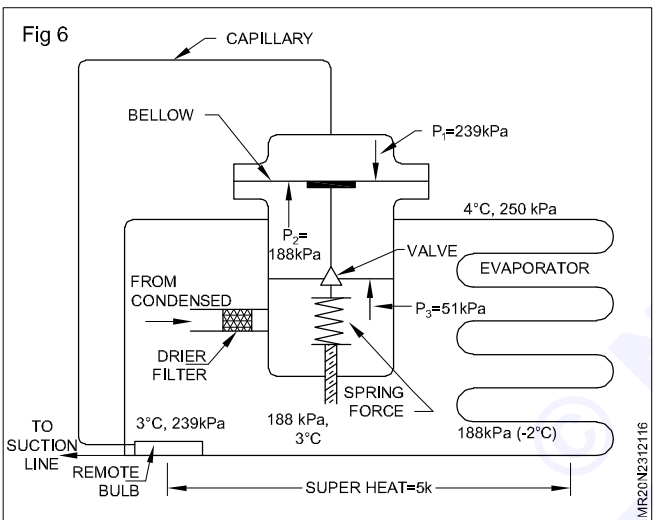


(or the valve outlet pressure) to the bottom side of the diaphragm.

In the externally equalized valve, the suction pressure is transmitted to the bottom side of the diaphragm through a drilled passage in the body of the valve, the end of which is connected to the suction line by an external equalizer line. The diaphragm is isolated from the outlet of the valve and the inlet of the evaporator. For this, gland packing is provided around the push rod of the needle valve where it passes through the partition wall between the diaphragm side and valve outlet portion.

It is obvious that valve with an external equalizer should not have the internal-equalizer passage and the packing around the push rods should also be proper.

The external-equalizer line from the valve should be connected to the suction line immediately downstream of the feeler bulb. In this position, the bulb temperature will not be affected by a possible small leak of the refrigerant past the gland packing of the push rod.



In multiplexed coils, pressure drop type of distributors is used which offer 2.11 to 2.46 kg/cm² (30 to 35psi) pressure drop. So to get a pressure of 2.46 kg/cm² G (35 psig) (R – 134a) in the evaporator, the pressure at the inlet to the distributor will be 2.46 + 2.11 = 4.57 kg/cm² G (30 + 35 = 65 psig). As the distributor is located at the outlet of the expansion valve, the pressure at the TEV outlet will be 4.57 kg/cm² G (65 psig). If we use a valve with an internal equalizer for this application, the valve will maintain an extremely high superheat. This is because the pressure at the outlet of the valve (i.e. the pressure acting at the bottom of the diaphragm) will be much higher than the evaporator pressure. Hence, wherever a refrigerant distributor is used, a valve with an external equalizer will have to be used.

diaphragm. In order to balance the closing pressure of 3.59 kg/cm² [51 psi) (43 lb + spring pressure of 8 lb.)], the feeler bulb temperature should rise to 12.2°C (54°F) i.e. a superheat of 7.8 C [14°F) = (54 – 40°F). For getting this superheat of 7.8 C (14°F) more surface of the evaporator has to be used up for superheating, and that much less surface will therefore be available for effective refrigeration. Obviously, we cannot afford this.

Generally, TEV s come adjusted from the manufacturer for a superheat of around 4.4 to 5.5° C (8 to 10 ° F). An expansion valve should never be adjusted in the field until it is ensured that all other parts of the plant are working satisfactorily. For example, the evaporator being only half active may not be due to valve maladjustment, but may be due to other reason, such as not enough refrigerant in the system, dirty liquid line filter, obstruction in the liquid line, flash gas in the liquid lines, etc.

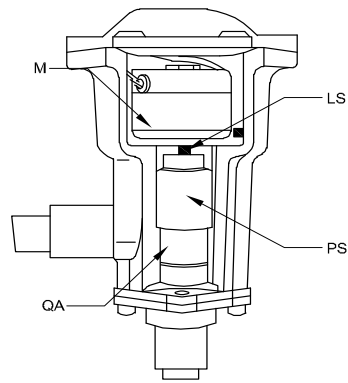
To overcome this defect due to pressure drop in the evaporator, a valve with an external equalizer is used. The external equalizer feeds the pressure at the outlet of the evaporator (or suction line) to the bottom of the diaphragm of the power element. Thus, the ill effect of the evaporator pressure drop is overcome. As a general rule, evaporator having a pressure drop of 0.14 kg/cm² (2 psi) and above should have externally equalized TEV.s The external equalizer does not reduce the pressure drop in the evaporator. But it offsets the bad effect of the pressure drop in the evaporator and keeps the evaporator. But it offsets the bad effect of an evaporator a with very small pressure drop.

Electronic expansion valve (Exv) (Fig 7): The electronic expansion valve also regulate and modulates the refrigerant feed according to the load requirements by maintaining a pre-selected constant suction gas super heat. In the electronic expansion valve, the regulation and modulation of the refrigerants feed through the valve is accomplished through a microprocessor based control (electronic temperature sensor) and an electric motor operating the valve orifice size. Another difference is that it senses and controls the suction gas super heat at the entry of the suction gas to the compressor cylinder.

In the externally equalized valve, a passage is provided within the valve to transmit the evaporator inlet pressure

Orifice of the valve is a series of finely machined small slots on the circumference of a circular orifice assembly over which a moving piston sleeve rides up and down. For regulating the refrigerant flow for the changing operating

Fig 7



M- MOTOR LS- LEAD SCREW PS- PISTON SLEEVE
OA- ORIFICE ASSEMBLY (WITHIN PISTON SLEEVE)

conditions, the orifice size is varied by the up and down movement of the sleeve over the orifice assembly. The sleeve is moved over a comparatively longer stroke by a motor, whose circular motion is converted to the linear up and down movement of the sleeve by a lead screw. The motor moves in steps and has a very number of steps. The longer stroke of the sleeve over the orifice and the larger number of steps ensure a very close and accurate regulation of the orifice size and thus the refrigerant flow even for a small range at load variation. Since the sleeve has to move over the orifice assembly, there cannot be a tight seal between the two.

The motor operation is controlled by microprocessor based control. Two thermistor temperature sensors are installed one located in the evaporator and the second located in the compressor suction passage just before the compressor cylinders. The difference between the two being the super heat of the suction gas as it enters the cylinder and it controls the operation at the valve.

Thus, the EXV controls the superheat of the suction gas as it enters the compressor cylinder. While the TEV controls only the suction as super heat at the evaporator outlet-where the feeler bulb is mounted on the suction line there is no control on the superheat of the suction gas as it enters the compressor cylinder, which ultimately influences compressor performance.

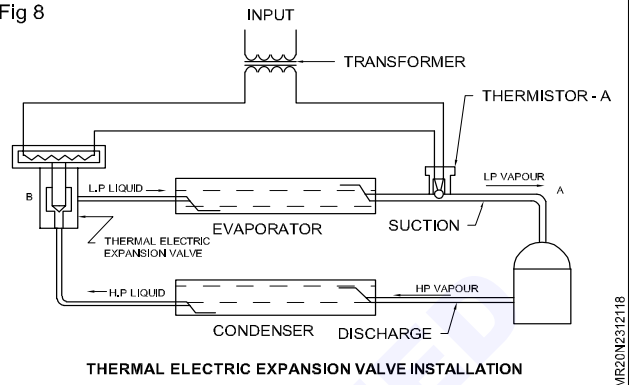
Another feature of EXV is that it can limit the evaporator working saturation temperature not to exceed 13°C (55°F) or in other words to the corresponding saturation pressure. In chiller applications, this helps the system to start at higher chiller fluid temperature without overloading the compressor motor.

Operation of the valve for proper functioning (maintenance of suction superheat and capacity modulation at varying working conditions) can be checked through the microprocessor control. Manufacturer provide the instructions. Superheat control is factory set and is not adjustable in the field.

Thermal electric expansion valve: The thermal electrical controlled expansion valve depends upon the use of thermistors, directly exposed to the refrigerant in the suction line, to control the expansion valve needle opening. It does not use a pressure element as in the thermostatic expansion valve. The resistance to electrical flow in the

thermistor changes with its temperature, increasing temperature reduces resistance. Therefore with a given voltage, it increases the rate of current. This increase current flow heats the bimetal in the valve body and makes the bimetal bend, opening the valve. In Fig 8. illustrates a typical thermal electric expansion valve installation.

Fig 8



The thermistor - A is placed in immediate contact with the refrigerant vapour inside the suction line from the evaporator.

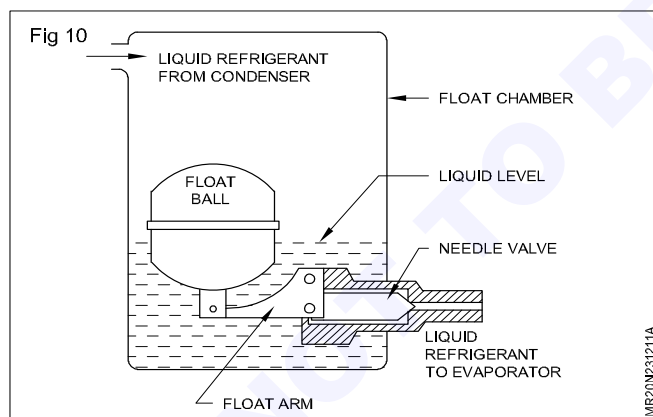
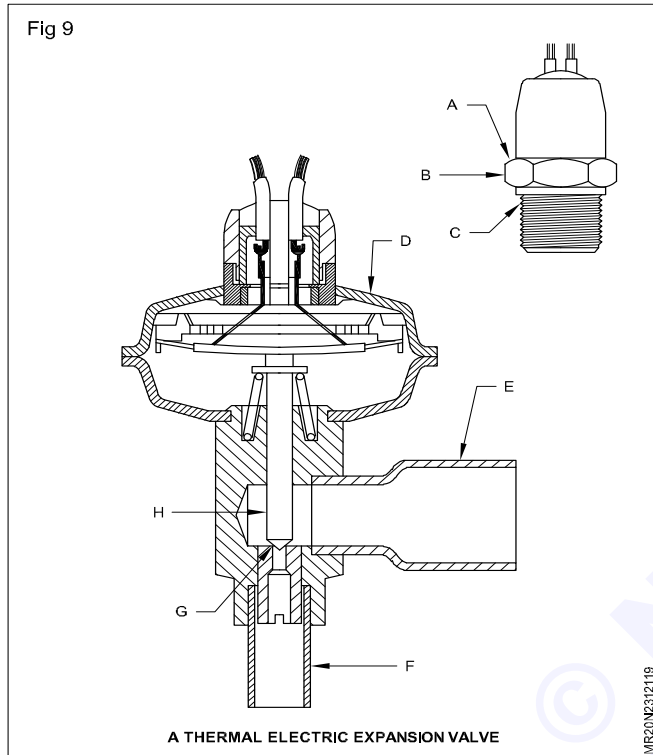
A low voltage transformer is the power source. This is connected in series with expansion valve control mechanism at B in such a way that increasing current flows through the thermistor increases the opening of the expansion valve and therefore, increases the rate of flow of the refrigerant into the evaporator. Increasing the current causes the valve needle to open while a decrease closes the valve. Thereby the refrigerant flow is controlled. The thermal electric expansion valve is not dependent on the flow of refrigerant and controls the suction line superheat in order to prevent flooding of the compressor, off cycle operation is possible in one or two ways. In one case the thermal electric expansion valve may be electrically connected in parallel to the operating system.

During the off cycle, the thermistor will be warmed and the thermal electric expansion valve will remain open. This unloading is similar to the pressure balancing effect when a capillary connected into the motor circuit (interlocked) in such a way that it is only energized when the compressor is running, with this type of connection, the valve will be closed on the off cycle. Functions of parts in thermal electric expansion valve Fig 9.

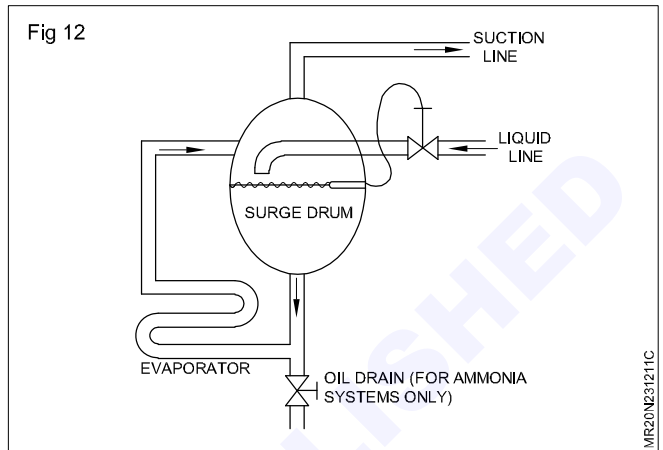
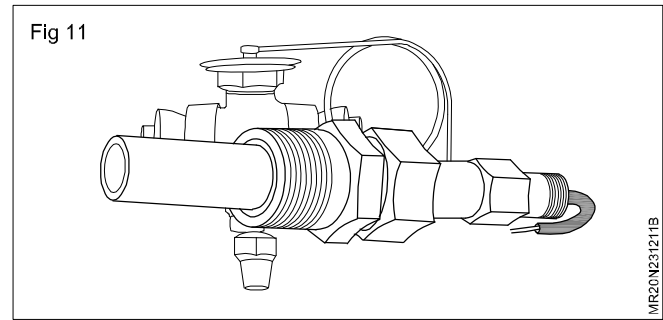
- A Hexagon head - for tightening (to fix spanner)
- B Sensing element - senses and transmits signal for valve operation
- C Self sealing thread - for fixing in position
- D Needle control mechanism - operates the needle
- E Evaporator - outlet of liquid from valve inlet to evaporator
- F Liquid line - liquid inlet line to valve.
- G Seat - Sealing point of valve (shut off)
- H Needle - Operating part of the valve which allows liquid to evaporator and closed the inlet seat to shut off.

High – Side Float valve (HSFV): (Fig 10): To make a high side float system operate, a float is located in the

liquid receiver tank or in a chamber in the high-pressure side. Liquefied refrigerant collects in the float chamber. When enough refrigerant has collected, the float will raise enough to open the needle valve. Liquid flows into the low pressure side or evaporator. The float controls the level of liquid refrigerant on the high-pressure side. The amount of refrigerant in a system must be carefully measured. The evaporator must receive the correct amount for the system to operate correctly. Extra refrigerant will overcharge the evaporator and cause frosting of the suction Line.

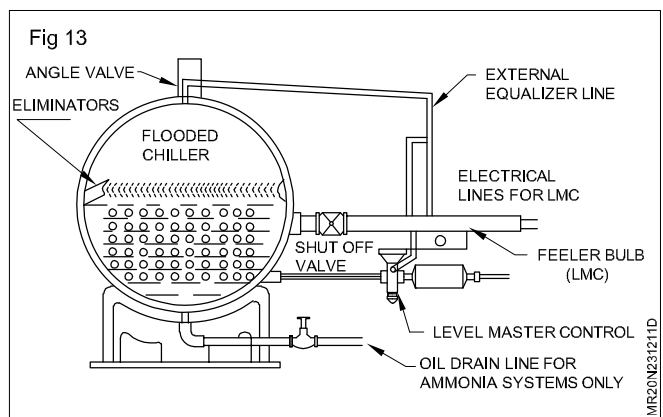


Level Master control (LMC): (Fig 11 & Fig 12): The LMC, manufactured by the sporrans valve co. USA, is another throttling device used in flooded chillers. It is a modified thermostatic expansion valve with an electrical heater incorporated in its feeler bulb. As the refrigerant vapour cannot get superheated in a flooded chiller, the heat necessary at the feeler bulb. The sensing bulb is fixed in the chiller so as to have direct contact with the refrigerant liquid in the chiller. It is located at a level at which the liquid level has to be maintained during operation. The level maintained should be such that it submerges the chiller tube bundle.



When the liquid level is below the sensing bulb, the vapour surrounding the bulb carries away the heat from the electric heater at a relatively slow rate. This increases the bulb temperature, thereby admitting more liquid refrigerant to the chiller. When chiller liquid level rises and comes in contact with the bulb, the heat generated by the heater is carried away by the liquid refrigerant at a much faster rate. This will reduce the bulb temperature and the valve gets throttled.

In operation, the valve modulates the flow of refrigerant and maintains a steady liquid level in the chiller. It is of the external-equalizer type. The LMC bulb is equipped with a special screwed fitting with gaskets for fixing it directly into a liquid level pipe provided on the chiller. A shut-off valve is provided in the liquid level pipe to facilitate the servicing of the LMC power element/bulb, without the necessity of removing the refrigerant from the chiller. As refrigerant shut off valves are half-way (globe) valves, the valve should be fixed with its spindle in the horizontal position to avoid liquid trapping and 'false' in the liquid level pipe. The heater is wired in parallel with the compressor motor. (Fig 13)



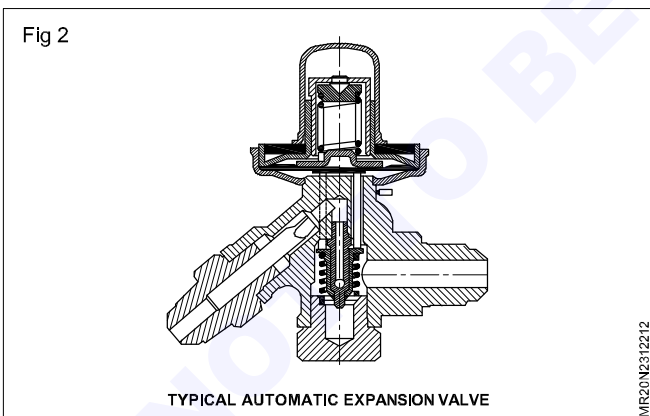
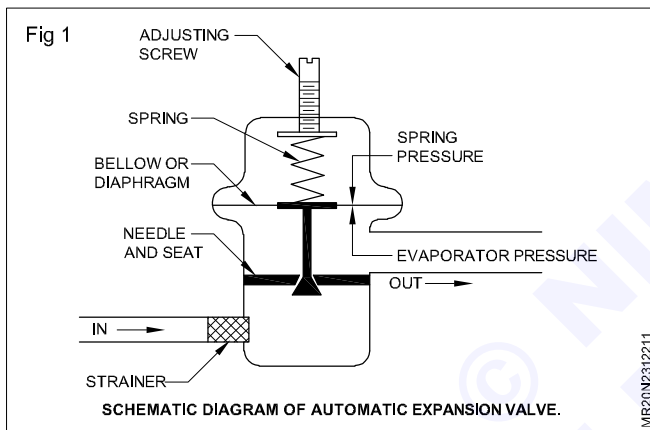
Automatic expansion valve

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

- explain the construction and working of automatic expansion valve.

Automatic expansion valve (Fig 1&2)

The automatic expansion valve functions to maintain a constant pressure in the evaporator. The constant pressure characteristic of the valve results from the interaction of two opposing forces the evaporator pressure and the spring pressure. The evaporator pressure, exerted on one side of the bellows or diaphragm acts to move the valve in a closing direction, whereas the spring pressure, acting on the opposite side of the bellows or diaphragm acts to move the valve in an opening direction. When the compressor is running, the valve functions to maintain the evaporator pressure in equilibrium with the spring pressure.



As the name implies, the operation of the valve is automatic and, once the tension of the spring is adjusted for the desired evaporator pressure, the valve will operate automatically to regulate the flow of liquid refrigerant into the evaporator so that the desired evaporator pressure is maintained, regardless of evaporator loading. For example, assume that the tension of the spring is adjusted to maintain a constant pressure in the evaporator of 10 psig. Thereafter, any time the evaporator pressure tends to fall below 10 psig. The spring pressure will exceed the evaporator pressure causing the valve to move in the opening direction, thereby increasing the flow of liquid to the evaporator and flooding more of the evaporator surface. As more of the evaporator surface becomes effective, the rate of vaporization increases and the evaporator pressure rises until equilibrium is established with the spring pressure. Should the evaporator pressure tend to rise above the desired 10 psig, it will immediately override the pressure of the spring and cause the valve to move in the closing direction, thereby reducing the flow of liquid into the evaporator. Normally this decreases the rate of vaporization and lowers the evaporator pressure until equilibrium is again established with the spring pressure. It is important to notice that the operating characteristics of the automatic expansion valve are such that the valve will close off tightly when the compressor cycles off it remain closed until the compressor cycles on again. As previously described, vaporization continues in the evaporator for a short time after the compressor cycles off and, since the resulting vapour is not removed by the compressor, the pressure in the evaporator rises. Hence, during the off cycle, the evaporator pressure will always exceed the spring pressure and the valve will be tightly closed. When the compressor cycles on, the evaporator pressure will be immediately reduced below the spring pressure, at which time the valve will open and admit sufficient liquid to the evaporator to establish operating equilibrium between the evaporator and spring pressures.

Low side float valve and High side float valve

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

- explain low side float valve
- explain high side float valve.

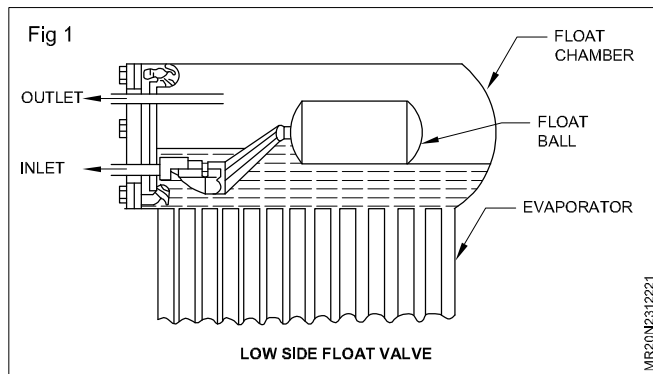
Float valve controls are of two types. Low side float valve and the other in high side. Float valve controls are used in flooded type of evaporator system

Low side float valve (Fig 1)

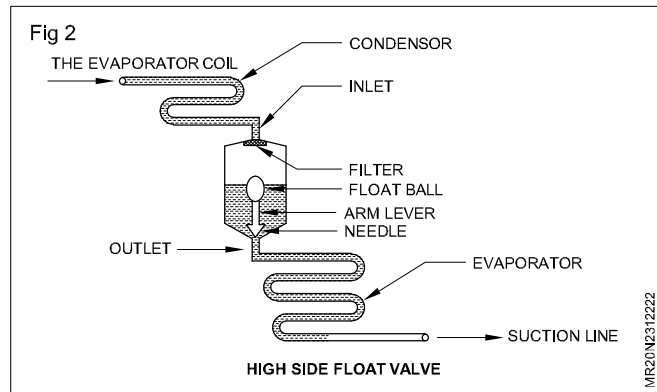
Low side float valve is used in flooded type evaporator and on the low side of the system. In construction it has a float chamber, float ball, pivoted arm lever, needle, strainer inlet,

outlet liquid eliminator and evaporator coil. The evaporator coil is fitted on the float chamber. The float ball is connected to the arm lever and arm lever is connected to the needle. A strainer is fitted at the inlet of the float valve. The inlet is connected with liquid line and outlet is connected to the suction line.

The operation of low side float valve depends upon rate of evaporation when evaporation increases the liquid level falls below the normal level. The float ball moves downwards open the valve and admit more liquid in to the float chamber and evaporator coil. Then liquid level increase and float ball moves upwards and reduce the flow of liquid refrigerant into the evaporator. When the rate of evaporation decreases the liquid level increase in the float chamber and float valve push the needle and prevent further entry of liquid



High side float valve (Fig 2)



High side float valve is a refrigeration control device in mechanical refrigeration system. It is located on the high side of the refrigeration cycle. The main parts are float chamber, float valve, arm lever, needle, strainer inlet and outlet. The inlet is located at the outlet of the condenser coil and outlet is located to the inlet of the evaporator coil.

Working

When rate of evaporation increased condensation also increase. Then more liquid refrigerant enters into the float chamber. The float ball moves upwards and open the valve. Then more liquid refrigerant enters into the evaporator coil. When rate of evaporation decrease, condensation also decreases. Then float ball moves downwards and needle reduces the orifice. Then reduce the flow of liquid refrigerant into the evaporator. In this way the float valve maintains the flow of liquid refrigerant into the evaporator.

Evaporator

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

- **define evaporator**
- **explain types of evaporator**
- **explain different types of evaporator.**

Evaporator is the heat absorbing part of the refrigeration system. This is also called cooling coil, freezer or chiller. These names are according to their function in the system. In evaporator the low pressure liquid refrigerant enters into the evaporator and the liquid refrigerant absorbs latent heat from the substances to be cooled and from inside space and changes into low pressure low temperature vapour. The evaporator is classified as follows. According to the cooling methods the evaporator is divided in to two types

i Direct cooling

ii Indirect cooling

The direct type evaporation cools the substance directly by absorbing latent heat from the surroundings or substance and is cooled. In indirect system the evaporator coil first cools the secondary refrigerant by absorbing latent heat and then the secondary refrigerant cools the air or substances by absorbing the sensible heat and it is cooled.

According to the temperature of evaporator coil, the evaporator is divided in to three types

- **Frosting type evaporator**
- **Defrosting type evaporator**
- **Non frosting type evaporator**

Frosting type of evaporator is a cooling coil which always operates at temperatures below 32°F. This coil frosts continuously and refrigerating system shut down at regular interval to remove the frost. This evaporator operates at very low temperature to produce the required refrigerating effect and it never become warm enough to permit the frost and ice to melt .

Defrosting type of evaporator is that in which frost accumulates on the cooling coil when the compressor operates and melts after the compressor stops. When the compressor is running the temperature of the coil remains at 20° to 22° F and frost accumulate on the coil surface. After the compressor stops the coil warms up to a temperature of 32°F and ice melts before the compressor starts again.

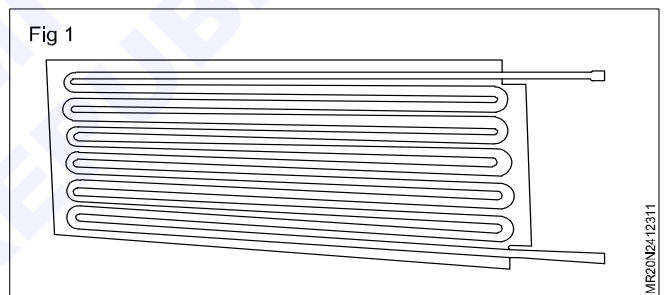
Non frosting coil always operates at temperature above 32°F. This type of method is used for the evaporators of high temperature as air conditioning. So this type evaporator coil has no frost.

According to construction of evaporator coil, the following types are used

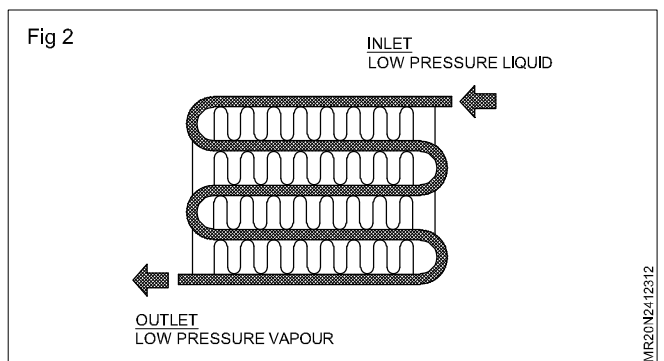
- Plate type evaporator
- Plate and tube type evaporator
- Fins and tube type evaporator
- Bare tube type evaporator
- Shell and tube type evaporator

Plate type evaporator is used in small systems like refrigerator, visi cooler, freezer etc. It has an inlet, an outlet, and evaporator coil. The refrigerant pass through the evaporation coil.

Plate and tube type evaporator is also used in small systems. It has one plate an evaporator coil. The evaporator coil is attached to the plate. (Fig 1)



Fin and tube type evaporator is used in window AC. Split AC, double door, no frost refrigerator etc. In construction it has fins and evaporator coil. Fins are provided over the evaporator coil. A fan is fitted near the evaporator coil for circulating air over the evaporator coil. (Fig 2)



Bare tube type evaporator is used in every refrigeration system. Now the use of these is limited for that where the temperature is lower then 32°F and is cooling with liquid. Its reason is that the collection of ice and frost on prime surface evaporator, there is a very low heat transfer rate than where fins are added. Shell and tube type evaporator is also known as chiller. It is used to chill the secondary refrigerant and used in large refrigeration and air conditioning systems.

The evaporator is again divided into two types.

- Dry type evaporator
- Flooded type evaporator

Dry type evaporator : This type of evaporator is mostly employed on system below 150 tons capacity less than 50% of the evaporator portion is filled with liquid refrigerant and can fill 90%. Generally hand expansion valve, or automatic expansion valve or thermostatic expansion valve is used as refrigerant control device.

Flooded type evaporator : The liquid refrigerant is filled in the evaporator. The level of liquid refrigerant is maintained by a level control valve. Generally float valve is used. In this evaporator the refrigerant is circulated by a surge chamber.

Defrosting : Defrosting is the process of removing the frost accumulated on the surface of evaporator.

Necessity of defrosting in evaporator : Defrosting is necessary in low temperature application because excessive frost in the cooling coil will act as an insulation that may reduce the cooling efficiency.

Different types of evaporator

Natural convection type of evaporators : The evaporator may be classified as natural convection type and forced convection type. In the natural convection type, the fluid being cooled flows due to natural convection currents arising out of density difference caused by temperature difference. The refrigerant boils inside tubes and is located at top. The temperature of the fluid, which is cooled by the refrigerant, decreases and its density increases. The cooled fluid moves downwards due to its higher density and the warm fluid rises up to replace it.

In natural convection type evaporators and some others evaporators, the refrigerant is confined and boils inside the tubes while the fluid being chilled flows over the tubes. The direct expansion coil where the air is directly cooled in contact with the tubes cooled by refrigerant boiling inside.

Natural convection coils : Natural convection coils are mainly used in cold storages. Long lengths of bare or finned pipes are mounted near the ceiling or along the high side walls of the cold storages. The refrigerant from expansion valve is fed to these tubes. The liquid refrigerant evaporates inside the tubes and cools the air whose density increases the high-density cooled air flows downwards through the product which is kept in the cold storage for cooling. The air becomes warm by the time it reaches the floor. Some free area like a passage is provided for warm air to rise up. The same passage is used for loading and unloading the product into cold storage.

Natural convection coils do not occupy any floor space, require low maintenance cost, can operate for long periods without defrosting the ice formed on them and do not require any special skill to fabricate them. These coils are usually welded at site.

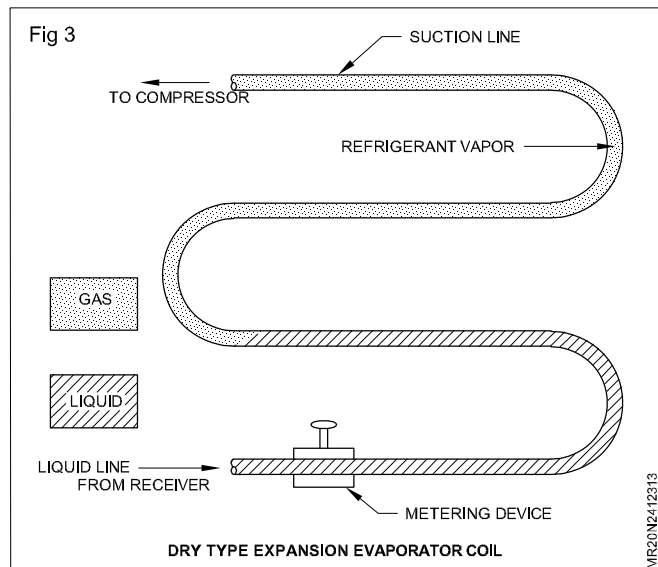
The disadvantage is that the natural convection heat transfer coefficient of natural convection coils is very small hence very long length of coil are required which may cause excessive refrigerant side pressure drops unless parallel paths are used. The large length of coils requires a large quantity of refrigerant compared to the forced convection coils. The large quantity of refrigerant increases the time required for defrosting, since before the defrosting can start all the liquid refrigerant has to be pumped out of the evaporator tubes. The pressure balancing also takes a long time if the system trips or is to be restarted after load shedding.

Natural convection coils are very useful when low air velocities and minimum dehumidification of the product is required. Household refrigerator, display cases, walk-in coolers, reach in refrigerators and obviously large cold storages are few of its applications. Sufficient space should be provided between the evaporators and the ceiling to permit air circulation over top of the coil. Baffles are provided to separate the warm air and cold air, ceiling mounted evaporators are used for rooms of width less than 2.5m for rooms with larger widths, two or more evaporator coils are used.

Servicing and maintenance of natural convection type evaporator.

Periodical cleaning and servicing is very much essential to improve heat transmission from outside to refrigerant liquid. Time to time defrosting will ensure an obstruction free evaporator surface and ultimately leads to better heat transfer. Use soft cloth or soft brush to clean the surface of natural convection evaporator.

Dry expansion type evaporators: In dry expansion method, the amount of liquid refrigerant feed into the evaporator is limited to that which can be completely vaporized, by the time it reaches the end of the evaporator. Only the vapour enters in the suction line to compressor inlet. The refrigerant flow control equipped with this evaporator feed is usually a thermostatic expansion valve, if not capillary tube is in small application. (Fig 3)



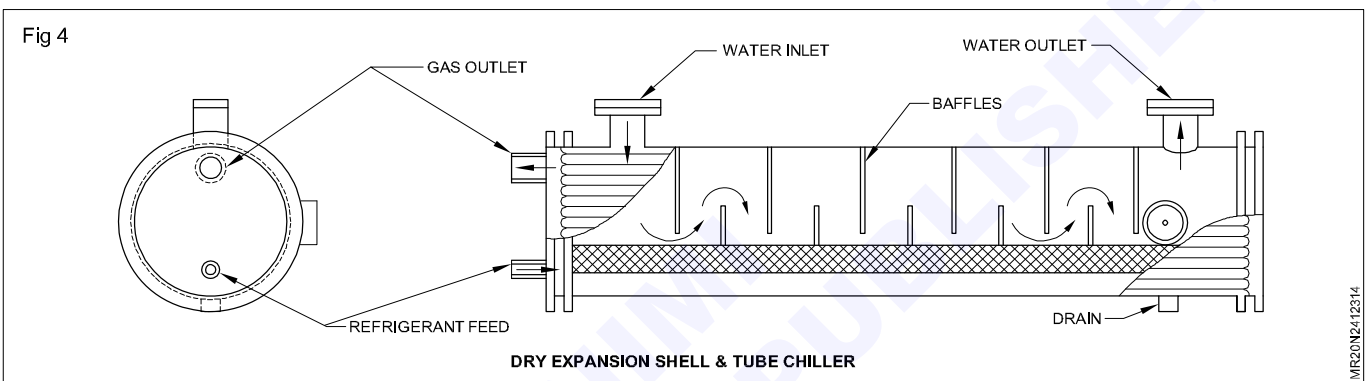
To ensure the complete vaporization of the refrigerant in the evaporator and thereby prevent the refrigerant remains in evaporator, hence to prevent the carry over of the liquid into suction line, and to the compressor. The refrigerant is permitted to become super heated approximately 10°F (-12°C) in the end of the evaporator.

With dry expansion feed, the resulting flash gas enters in evaporator along with the remaining liquid, that vaporizes progressively, as the refrigerant passes through the evaporator.

As it passes to the later portion of a dry expansion evaporator is nearly all in the vapour state and this portion of the evaporator will not perform as effective as the inlet portion of the evaporator, where the refrigerant is larger as liquid state. So the surface temperature of a dry expansion evaporator is always lowest near the refrigerant inlet and highest near the outlet.

The saturation temperature of the refrigerant also be lowest at the outlet, hence the drop in pressure by the refrigerant in flowing through the evaporator, compared to flooded type evaporator. The dry expansion evaporators are much simpler in the equipment which is smaller in design, much more compact, required less refrigerant and overall cost is less. Mainly oil carry over problem reduce. For these reasons dry expansion type is very popular. Since oil return from flooded type evaporator is sometimes difficult to accomplish.

Dry expansion shell and tube chillers: This is constructionally similar to the flooded type, but the liquid to be cooled is circulated outside of the tubes (in the shell) and the refrigerant gas passes inside the tubes. (Fig 4) A series of baffles ensure that the liquid is brought into contact with the maximum tube surface as it passes through the shell.



Construction and function: The liquid refrigerant is fed into an end cover and evaporates as it passes through the tubes, as it travels to the end of the tubes it completely vaporize and turn as a dry vapour before enters into compressor suction. The number and length of the refrigerant circuits depends on the tube length and on the arrangement of the baffling in the end plates or refrigerant heads which are bolted to the tube-sheets at the end of the chiller.

The baffles controls the liquid velocity in the shell to give more heat transfer effect.

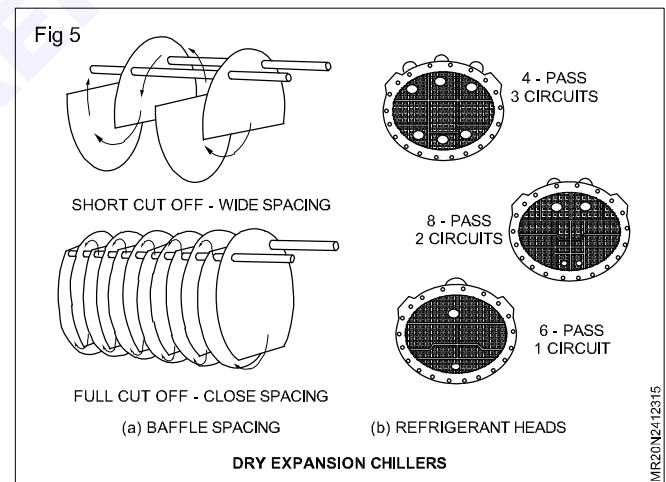
The refrigerant circuit arrangement for any one model chiller can be changed by changing the refrigerant heads. The arrangements of baffles fixed on tubes also vary as per design. (Fig 5).

In the fixed tube sheet design, the tube sheets are welded to the shell, hence the tube bundle is not removable. When the end plates are unbolted, the tubes become visible to clean.

Some chillers are designed with removable tube bundles. In this type the tube bundle can be removed as a unit and easy to do maintenance in tube side, or shell side. (Fig 6)

Maintenance of dry type chillers

- 1 If the liquid outlet temperature is above normal, there is a flow restriction due to sludge type deposits in the shell.



- 2 If the suction pressure is below normal a restriction in the heat transfer tube's outer area deposits. These kind of deposits can be cleared by acid circulation in the shell.
- 3 Oil formation on the inside of the tubes, the tubes can be flushed out with Nitrogen pressure.

Advantages in dry-type chillers:

The main advantages in using dry-type shell and tube chillers are:

- 1 Dry vapour is always returned to the compressor.
- 2 The vapour returns the oil in circulation to the compressor suction.
- 3 Ice formation cannot fracture of the tubes.

Direct and indirect expansion evaporator: In indirect expansion the evaporator is indirect contact with the material or space refrigerated. It may include any heat transfer vessel, such as pipe, coils, shell and tube coolers, finned coils, in which the primary refrigerant circulated and evaporated to cool the material or space in direct contact with heat transfer surface.

In indirect expansion the refrigerant is evaporated in the coil of the evaporator, which are in brine tank. The brine is called secondary refrigerant is circulated to the coils of the cold room to do cooling, instead of the coils with the refrigerant inside.

Any coil that places the refrigerant in direct contact with the heat transfer surface, that is absorbing heat from the substance to be cooled is direct expansion coil. Therefore a direct expansion coil may be either dry type or flooded type evaporators.

Brine chilling evaporators

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

- explain what are chilled water and brine system
- explain what is nitrate borax programme
- explain parts and its function of brine chillers
- explain the servicing of flooded type evaporators.

Chilled water and brine systems, Description of systems

Chilled water system and chilled brine systems are closed systems with very little water loss, and therefore, require very little makeup. Do not drain them unless necessary.

a chilled water systems (Fig 1)

Chilled water systems circulate water that may contain treatment chemicals. A typical chilled water system is illustrated.

b chilled brine systems

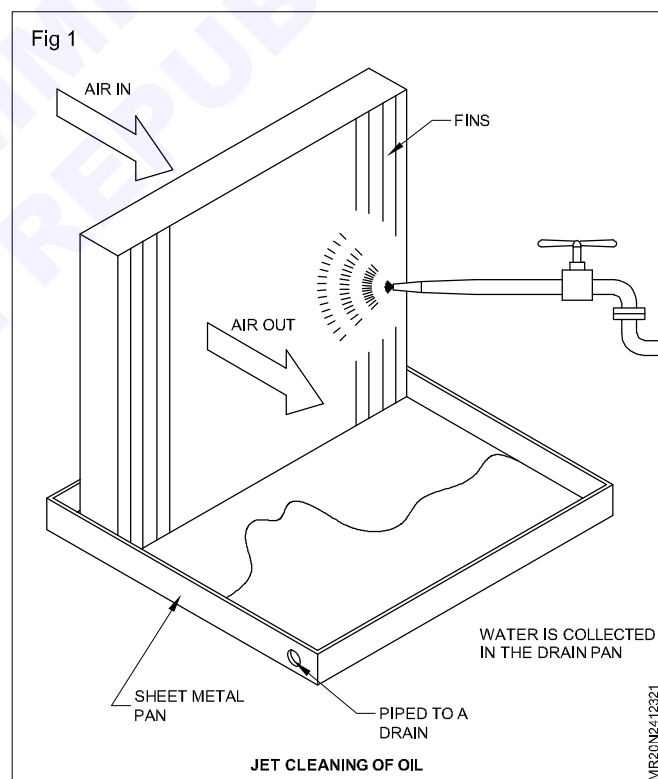
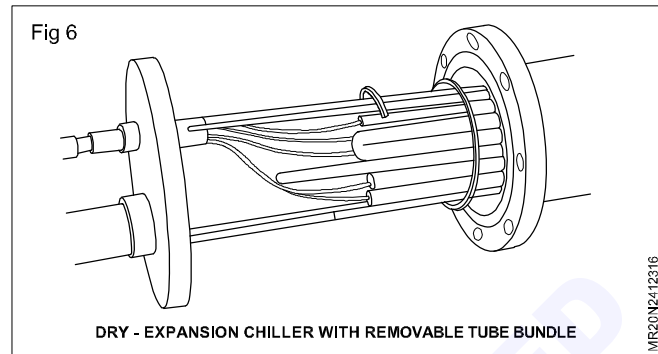
Chilled brine systems may involve calcium chloride brine, sodium chloride brine, sodium chloride and calcium - magnesium brine, or an ethylene glycol brine / treatment for corrosion control. Operating systems should be treated to inhibit corrosion. Softening of makeup water for these systems normally is not required because of the low quantity required. However, when hardness exceeds 250 ppm (as CaCO_3), treatment or blend the makeup to reduce the hardness to below 200 ppm as CaCO_3 .

a Nitrite- Borax program

Treat the initial fill for these systems (from potable water supply) with a nitrite -borax compound to a nitrite level of 1000 ppm (as NO_2). This will require about 17 to 18 pounds of nitrite borax blend per 1000 gallons of water in the system. The stock listed nitrite-borax powder form compound is a premixed blend containing approximately 68 percent sodium nitrite, 10 percent borax, 17 percent sodium carbonate (soda ash) and 5 percent corrosion inhibitor for copper. Treat the initial fill for pH and adjust to 9.0 using sodium carbonate (soda ash). Maintenance of the system is as follows:

Domestic & small evaporator coil used dry expansion coil & use capillary , A.E.V, T.E.V, EXV as throttling devices.

Dry coil means the entire refrigerant will be vaporised. In fact the refrigerant supplied by the metering device is as per the heat load demand in evaporator coil. So chances of flood back liquid to compressor is less.



- 1 Soften the makeup water if it has very high hardness (over 250 ppm in CaCO_3)
- 2 Add sodium nitrite -borax blend to maintain a nitrite level of 600 to 1000 ppm (as NO_2) in the system.
- 3 Add sodium carbonate to maintain a Ph range of 8.5 to 9.5.
- 4 Test monthly for Ph and nitrite levels.

It may be necessary to add a biocide that is compatible with the system pH to prevent bacterial attack of the nitrite. This program can be used in systems with ethylene glycol antifreeze. Molybdate-caustic soda program

This treatment can be used with systems containing copper alloys. The molybdate-caustic soda compound is a premixed blended liquid containing approximately 10 percent sodium molybdate, 3 percent caustic soda, and 3 percent copper corrosion inhibitor. Treat the initial fill with the sodium molybdate compound to a molybdate level of 125 ppm (as MoO₄) and adjust the pH to 8.5 with sodium hydroxide (caustic soda).

Soften the makeup water if it has very high hardness (over 250 ppm as CaCO₃).

Add the molybdate-caustic soda compound to maintain a molybdate level of 100 to 125 ppm (as MoO₄).

Add sodium hydroxide (caustic soda) to maintain a pH range of 8.0 to 9.0

This program can be used with ethylene glycol antifreeze.

Test monthly for proper pH and molybdate levels.

Determining leaks in the system. The presence of leaks in the system can be checked by testing the inhibitor concentration in the circulating fluid. Measure and record the inhibitor concentration once per month. When the inhibitor concentration has dropped to 98 percent of the original value, about 2 percent of the system water will have been lost. If the lapsed time for this 2 percent loss is less than 4 months, the system leakage is excessive and should be investigated and corrected.

Brine Chilling Evaporators

Description of Part	Function
Insulation	To prevent from sweating and energy loss combination temperature.
Drain	To drain the shell to remove contamination
Drain	To drain the brine from cooler tube side
Oil cooler gauge glass	To indicate the level of lubricant oil
Bypass valve	Manual operated flow control when float fails
Float regulating valve	Automatic level control to maintain refrigeration liquid in evaporator
Pressure gauge	To indicate the pressure
Outlet vapour to compressor suction	Permits the vapour to flow from evaporator to compressor suction
Service valve	For service use—vacuumizing the system
Safety valve	To safe guard the shell from bursting
Head A (end cover)	Seals the line from leaking out of the tubes and direct the flow.
Head B (end cover)	Seals the brine from leaking out of the tubes and directs the flow.
Brine inlet	To connect the brine to evaporator
Brine outlet	To connect the brine outlet evaporator
Liquid level	Liquid level in evaporator
Isolation valve	To isolate float

The parts of Brine and water chillers: Brine is used to reduce the freezing point of pure water. Pure water freezes at 0°C if salt is mixed in the water the freezing point of water will be lowered.

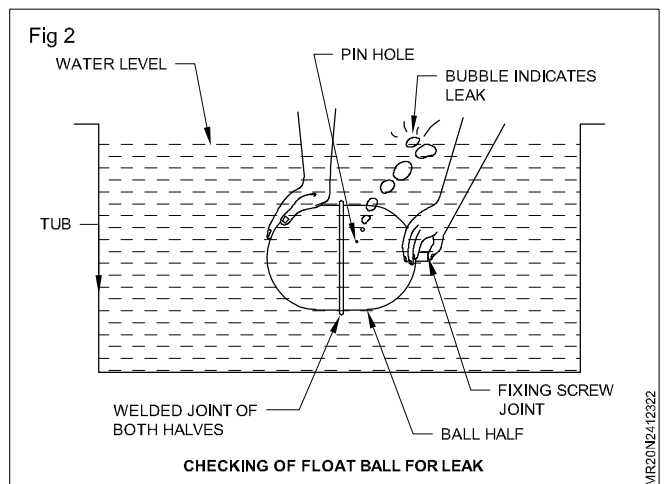
Float valve is a metering device maintains liquid level in evaporator

How to service floats: Unscrew the ball from the rod. Immerse the ball in a basin of water and check the ball for leak if there is a leak bubbles will be visible. (Fig 2)

If leak is observed the float is to be replaced. Do not arrest the leak by brazing. The float ball are vacuumized internally and the two half are joined together at the factory.

Remove valve pin check the pin and valve seat for pittings. If observed and its depth is not excess it has to be lapped in position.

Clean bleed off tube and all parts.



Assembly process for the float assembly: Immerse the assembly in a basin of water. Check physically that the ball is lifting and the valve is opening and allowing liquid flow outside. Drain all water from system allow to dry and then fix in the system. Clean the tubes and check for leaks and rectify.

Service the liquid level sight glass : Isolate the valve and remove the glass from position. Clean the glass with diluted hydrochloric acid. Rinse with fresh water. Dry and fix, replace the conical washer for the glass.

Leak check the glass when checking the evaporator tubes for leaks. Clean tubes as explained. The gasket prevents water from leaking out of the tube side end cover.

Cut gaskets : Place the old gasket on the new compressed asbestos fibre sheet. Mark the gasket with scribe and cut with chisel. Clean all edges with emery paper.

To check the quality of Brine : The commonly used brines are sodium chloride and calcium chloride.

The density of the brine should be such that the freezing point is from -12°C to -9°C below the temperature of which the brine is to be cooled in the brine cooler or ice tank. Then there will be no danger of the brine freezing. The brine temperature upon leaving the cooler should also be at -9°C below the temperature to be held in the coldest room. The freezing point of the brine depends on the strength of the solution or how much salt is dissolved in water.

The stronger the brine solution the higher the pumping cost so that the density to be maintained at the required temperature.

There are four essentials of a refrigerating brine : It must remain liquid, must not freeze at the lowest temperature to which the brine is subjected. Its corrosive effect when in contact with metals or other structures, materials must be at a minimum.

It should not undergo any serious change in character.

It should have a specific heat sufficiently high to permit economical operation without requiring excessively large quantity of brine.

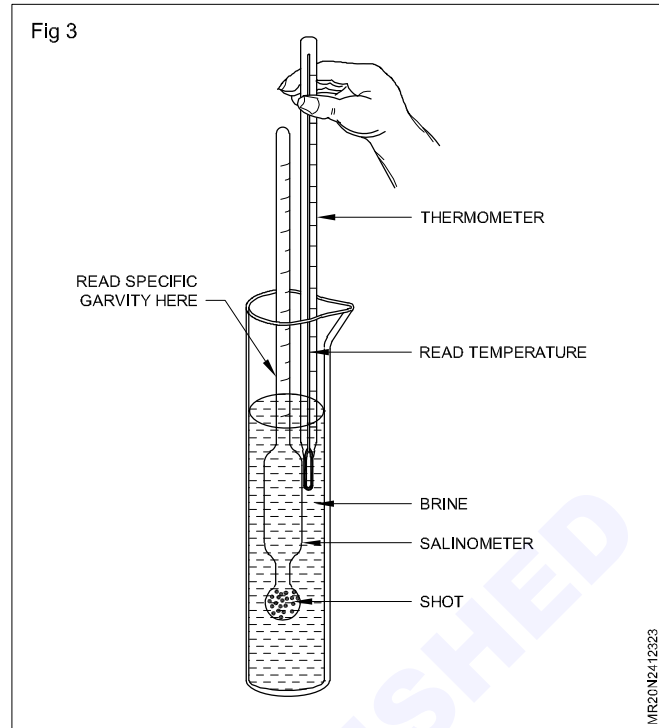
Brine pipes can be steel, common iron, seamless steel, pipes to be used.

Testing of brine specific gravity

Pour a sample of brine in a measuring jar. Float a hydrometer in the liquid, and read the scale where it coincides with the brine level. Insert a thermometer to determine the brine temperature, and refer the manufacturer takes for the exact density at the measured temperature. (Fig 3)

The pH of brine should be checked once a day with the use of Litmus paper. The strip of paper should be dipped in the brine and change in colour of the paper to be compared with the colour chart to know the pH.

The pH. should be at 7.0, above 7.0 indicates alkalinity, and below 7.0 indicates acidity. Action to be taken by operator as recommended by manufacturer to maintain at 7.0 pH.



Service the parts of water chilling evaporator

Pump down the system is explained.

Isolate water valves

Remove the end covers

Inspect and clean each tube as done for Brine cooler

Service float valves, safety valves and pressure gauge.

Pressurise the evaporator with system gas and test tubes leak.

If leaks observed rectify as explained in previous exercise.

Open water valves check for leaks.

Keep system under refrigerant pressure ready to start.

The water chilling evaporator chilled water system where refrigerant and water interaction takes place. The system is called a chilled water system. The refrigerant in the shell and the water in the tubes of a shell and tube evaporator (heat exchanger).

Refrigerant evaporates by picking up heat from the water which is in the tube side of the evaporator. This chilled water is then circulated to various water air heat exchangers are called Fan coil units or air handling units.

The shell and tube evaporator shells are made of high grade steel welded to heavy steel flanges. The length will vary according to the tonnage.

The shell and tube evaporator for water chilling.

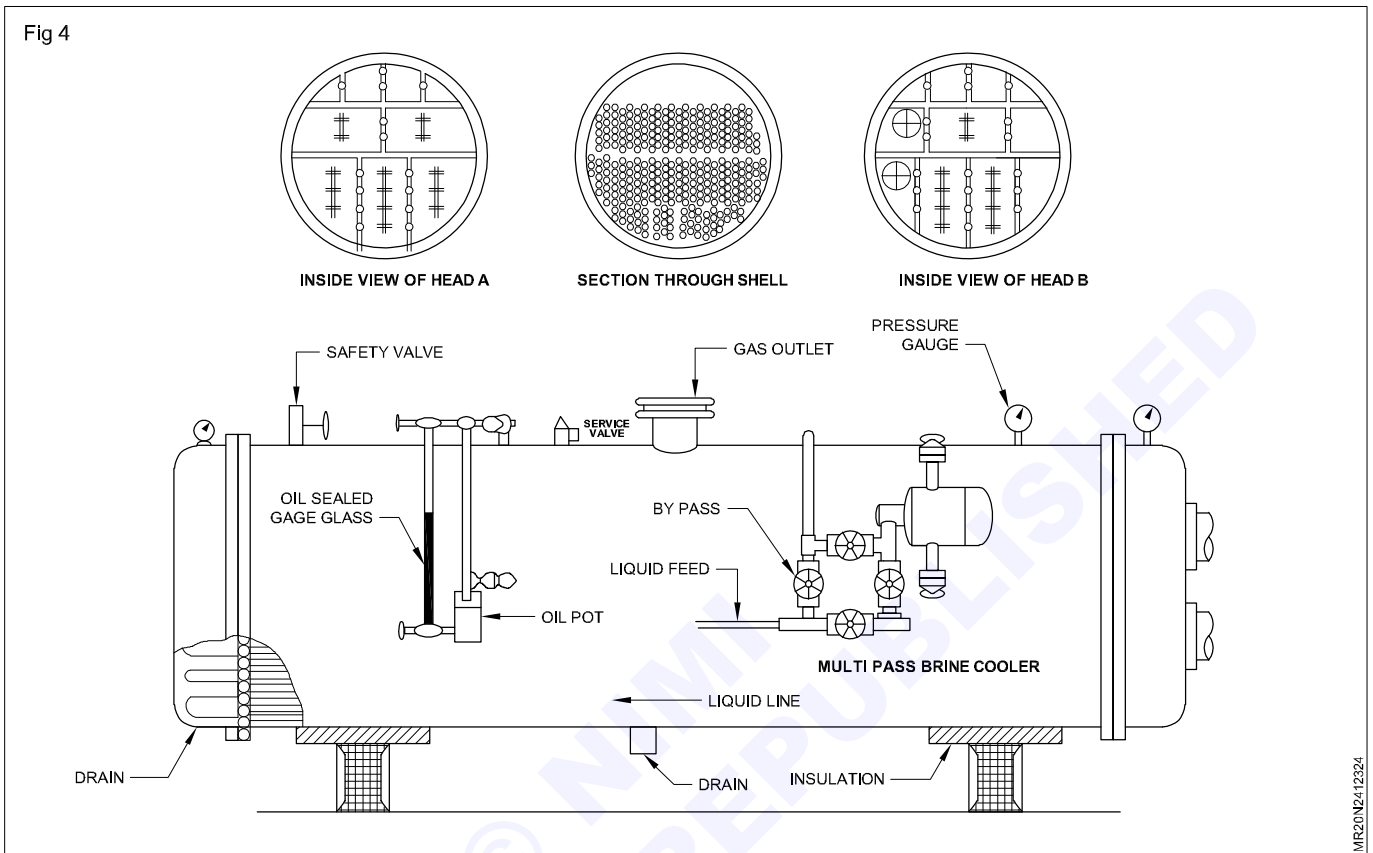
Tubes are made with copper with external fins around the tube through its full length, except where the tube is expanded to the tube sheet. Tube sheet are of steel which the ends of the copper tubes are expanded to prevent leaks and hold the tube

Service the flooded type evaporators

Advantages of the flooded evaporator : A flooded evaporator has some form of tank or header which keeps the inside evaporator surface full or flooded with liquid. A higher heat transfer rate per square foot of evaporator

surface is usually attained with flooded systems. But they require a large charge of liquid refrigerant to keep them full.

Typical industrial flooded evaporators fed with low side float valves are shown in Fig 4 such evaporators could be used for cooling either liquid or air.



Liquid or brine cooler similar to a horizontal shell and tube evaporator. But it provides several passes of the brine back and forth in these tubes. The refrigerant is in the shell. The heat flows from the brine through the tube walls to the refrigerant. The tubes give the surface necessary to transfer the heat. The top surface of the refrigerant is adequate to allow the bubbles formed by boiling, to break through to give proper vapour separation. The bubbles rising from the tubes induce a circulation of the liquid refrigerant up through the tube bundles and back down the sides of the evaporator. (Fig 5)

Fig 6 shows a similar evaporator designed for use in the brine tank of an ice plant. Here the brine only makes one pass through tubes. It is forced through by the action of an agitator in the brine.

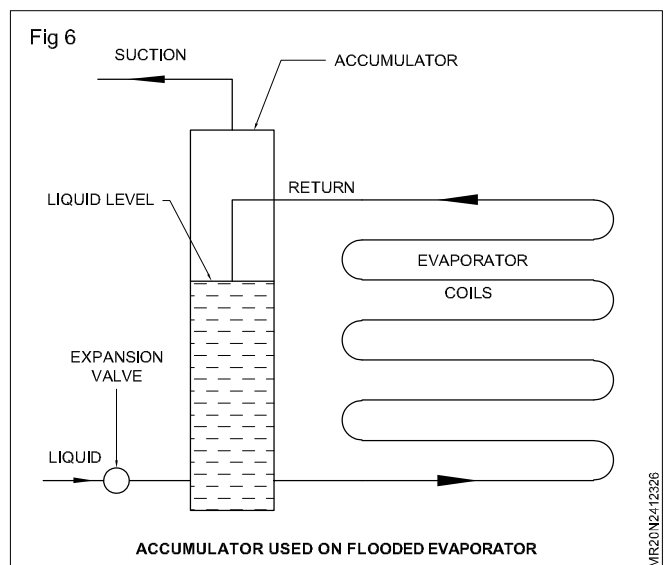
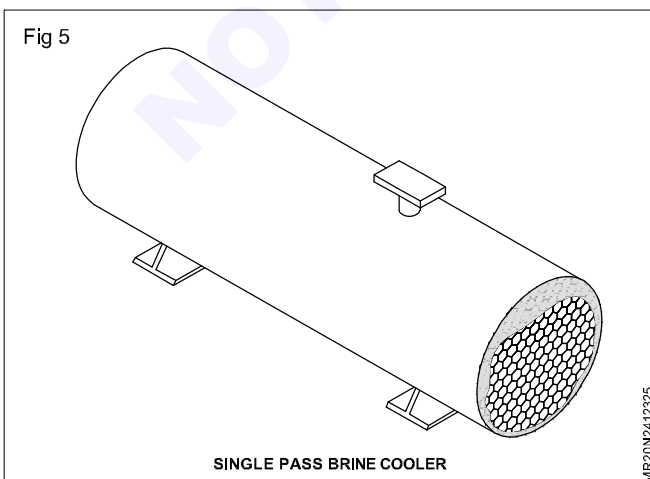
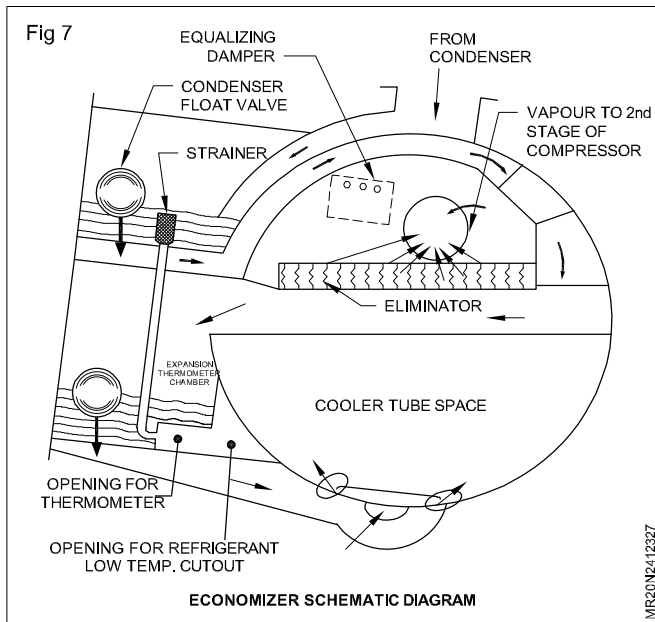


Fig 7 shows a method commonly used at one time and still found in many plants. An accumulator is made to keep the coil flooded and to separate the evaporator liquid from the vapour. These early forms were usually fed by a hand expansion valve, but more recently by low side float valves.



The best industrial evaporators of modern design combine an accumulator with headers or feeders which in turn are supplied with liquid from an accumulator. Return headers carry mixture of liquid and vapour back to the accumulator. In this design the mixture of liquid and vapour is lighter than liquid in the accumulator. This indicates a rapid flow through the tubes from the bottom to the top to give the circulation required for good heat transfer.

Yet the headers and tubes are short enough that this good top and is protected by the pick-up coil enclosure. The construction permits all high voltage connections and wiring to be made at a remote or non hazardous location.

Installation: This float chamber can be installed in any location where the ambient temperature of the liquid refrigerant in the evaporator is upto -40°C . It can be used on all refrigerants and non corrosive liquids which have a specific gravity of 0.5 or more and a maximum viscosity saybolt seconds under all conditions of operation. Capacity equalisation of liquid level in the float chamber is a function of the viscosity of the liquid. For fluids having a high viscosity the response of the unit will be slow. The level controller should not be used for water.

Testing before installation : Place the float upright and connect the electrical leads to the terminals marked pick-up coil on the electronic controller. Turn the level control dial to position 3 and the differential control dial to position 1. Connect the terminals marked line to a 230 volts 50 cycle A.C. and allow a minimum of 5 minutes for the unit to warm up. Insert any rod in the bottom connection of the float chamber and gently raise and lower the float ball observing the action of the Neon light. As the ball is raised to approximately the mid position of its travel. The Neon light should go out. When the ball is lowered approximately half

inch the Neon light should go "on", if you wish, by turning the control dials you may raise or lower the level or increase the differential. When installed in the systems to be controlled the 230 volts 50 cycle AC line supplying the electronic controller is protected with a 1.5 amp. fuse assuming load of standard solenoid coil. In case of higher loads the fuse rating should be suitably altered. The load circuit should be protected by a fuse seized in accordance with the connected load. It is not necessary to fuse the low voltage circuit to the pick up coil.

The level controller float chamber must always be mounted perpendicular and its location in relation to the chamber or evaporator must be such that the desired liquid level will fall within the high and low horizontal level marks provided on float chamber. Fig 10. The hand shut off valves are provided so that the float may be removed for cleaning without pumping down the system. The float chamber, accumulator and all liquid lines after the expansion valve should be insulated to reduce the boiling action of the liquid in the float chamber, so that the float ball could raise and lower smoothly. The solenoid coils should not be insulated along with the lines.

Servicing : To remove the float chamber from the system, close the hand valve on the bottom liquid connection, allowing the liquid refrigerant in the float chamber to evaporate or boil out then close the hand valve in the vent line, and disconnect all electrical connections and the liquid line vent pipes. To inspect or clean the float ball chamber remove the four cap screws, the coil housing assembly and the float chamber gasket. The float ball assembly can be removed and cleaned along with the inside of the float chamber.

In flooded evaporator or chiller capacity is more as the most of the coil flooded with refrigerant, naturally no starve in the evaporator.

Basically it is used in large system & liquid level is maintained by float control & refrigerant control by feed valve, LMC & other feeding devices. Thermal expansion & electronic expansion valve also used in this/system with low side float valve. (Fig 8&9)

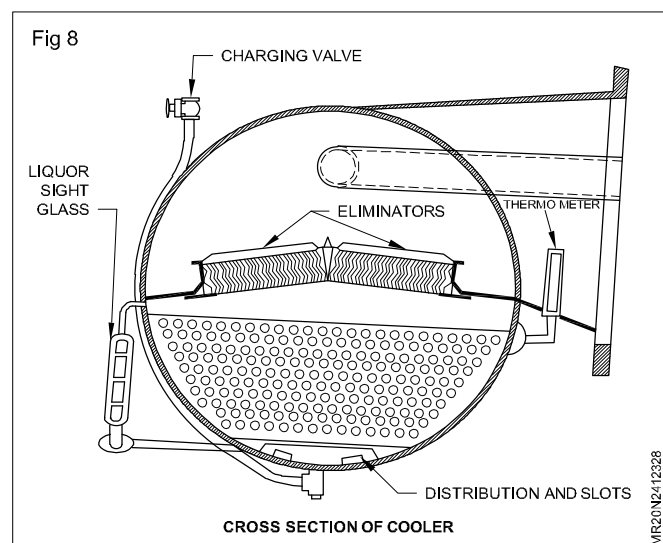
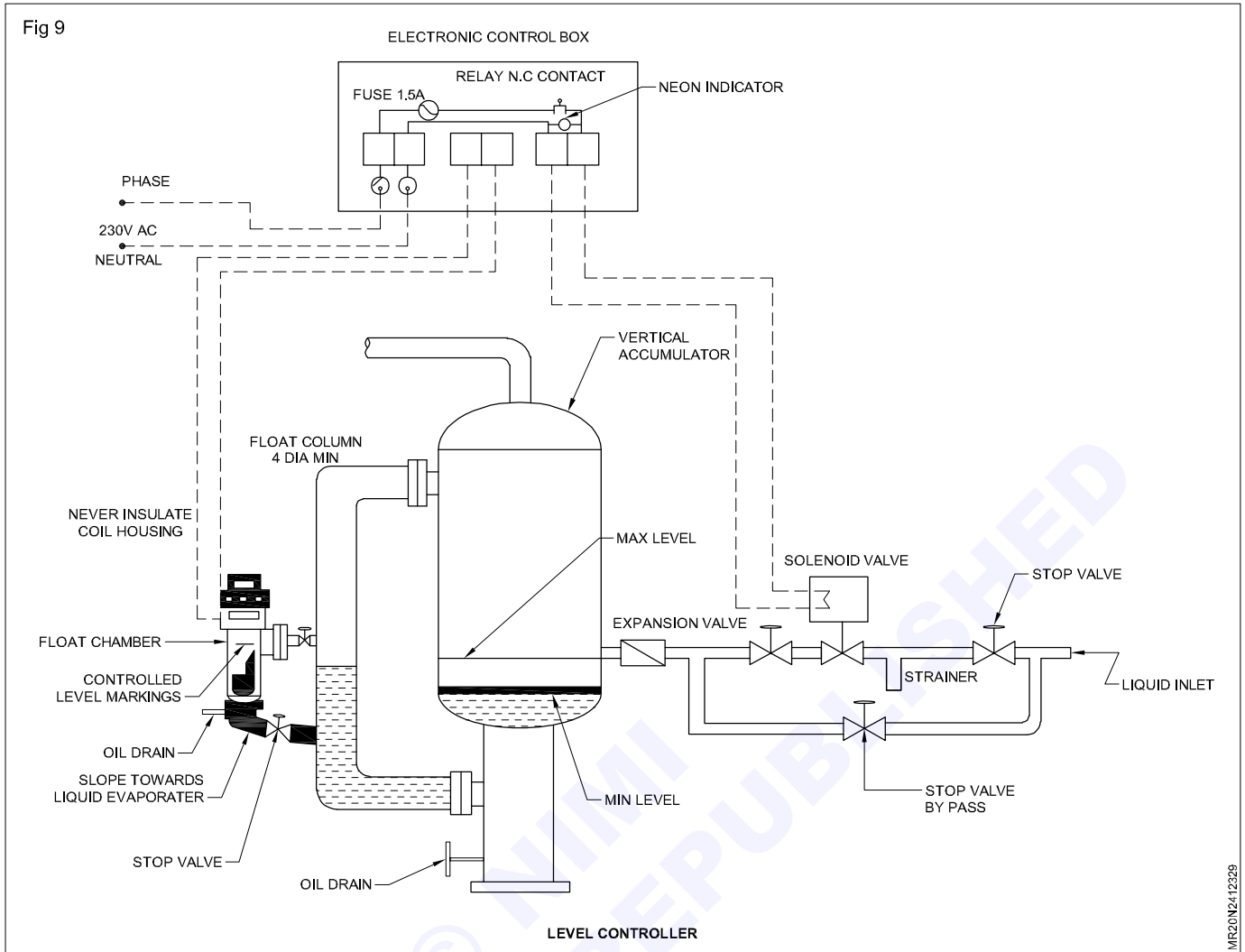


Fig 9



Defrosting methods

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

- defrosting
- explain defrosting method
- explain for removing oil from evaporator coil.

Defrosting : Defrosting is the process of removing the frost accumulated in the surface of evaporator.

Defrosting methods in evaporator : Defrosting is necessary in low temperature application because excessive frost in the cooling coil will act as an insulation that may reduce the cooling efficiency.

The following type of defrosting methods are

- Manual defrosting method
- Timer defrosting method
- Pressure defrosting method
- Temperature defrosting method
- Electric heater defrosting method
- Hot gas by pass defrosting method
- Reverse cycle defrosting method

Manual defrosting method : It is one of the simplest method of defrosting. Compressor is stopped until evaporator warms up enough to melt off the frost, after which the compressor is started up again manually.

Time defrosting method : In this method a defrost heater and timer is used. The timer shut off compressor every 4 or 6 hr operation and "ON" the heater coil. The heater is located near the evaporator coil. After 5 minutes or after defrosting again the timer switch "OFF" heater and "ON" the compressor motor.

Pressure defrosting method : This method depends on the rise of the low side refrigerant pressure as the coil temperature rises during defrost. The defrost is terminated by pressure actuated switch. The evaporator temperature indirectly control temperature of the refrigerant. The temperature of the evaporator is controlled by the saturation pressure of the refrigerant. This pressure corresponding to the required temperature of the evaporator.

Temperature defrost method : This method is same as pressure defrosting method. A remote bulb type thermostat is attached to the evaporator and depends on the temperature requirements of the system. This thermo state controls the cut in and cut out points at the compressor.

Electric heater defrosting method : A heating coil is fitted into the evaporator coil and used in large system. When defrosting required "OFF" the compressor and blower fan. Then "ON" the heating coil and frost will melt. After melt the frost "OFF" the heating coil and "ON" the compressor and blower.

Hot gas by pass defrosting method : This method is provided for removing the accumulated frost from the cooling surfaces. In this process, the hot gas discharged from the compressor is utilized as a source of heat to defrost the evaporator. Hot gas by pass line is installed between the compressor discharge and evaporator. The hot gas which is by passed, gives off some of its heat to the evaporator, this heat melts the frost and condenses into the liquid state.

Reverse cycle defrosting method : Another system defrosts evaporators by reversing the flow of refrigerant. This causes the evaporator to become the condenser and the condenser an evaporator. When the evaporator functions as a condenser, it melts the accumulated frost. This reversing is handled by installing a four-way valve. In operation on defrost, the four-way valve is turned either manually or automatically and hot gas from the compressor travels up the suction line. It heats the evaporator when gas condenses in it and by passes the refrigerant control by means of a check valve.

It passes through the receiver. As it leaves the receiver, a check valve by passes it through another refrigerant control into the condenser. The refrigerant evaporates in the condenser and is returned to the compressor in a vapour state.

The liquid receiver is designed to permit the reverse flow of vapour to travel over the reverse liquid in the receiver. It does not return the vapour to the condenser.

Evaporator servicing : Evaporators must be clean both inside and outside for good heat transfer. They must contain just enough liquid refrigerant at the proper vapour pressure to provide the required cooling. Air or water being cooled must flow in and out of the evaporators efficiently. The evaporator must be leak proof and of the proper size.

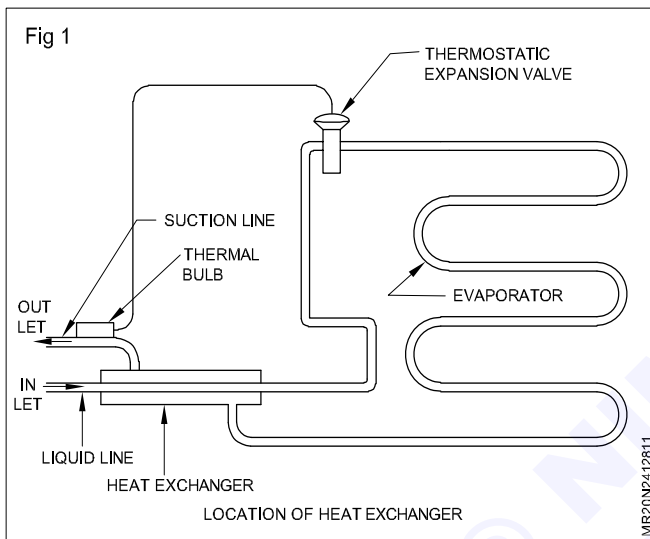
During operation of the refrigeration system some quantity of oil mixes with refrigerant and passes through the refrigerated tubing has lowest temperature compared with other tubings, these may be chance to clog this lubricating oil inside the tube walls of evaporator. This will effect the heat transfer capacity of the evaporator. During periodic service of evaporator, the oil trapped inside the evaporator tube walls can be flushed out using dry nitrogen. (pressure flushing method).

Liquid suction heat exchangers

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

- explain what is liquid suction heat exchanger (LSHE)
- explain what are the selection procedure of heat exchangers
- explain the advantages of heat exchanger and disadvantages of heat exchanger.

A liquid line and suction heat exchanger is used to transfer heat between liquid refrigerant leaving the condenser on the high pressure side of the system and refrigerant vapour leaving the evaporator on the low pressure side of the system. (Fig 1)



This heat transfer may be desirable for several reasons: To raise the vapour temperature to prevent frosting or condensation on the suction line. To evaporate any remaining liquid in the vapour stream to prevent possible compressor damage. To subcool the liquid to prevent flash gas in the liquid line. To increase system refrigerating capacity. In general methods, utilize a counter flow tube-in tube design is used to make this heat exchanger refrigerant vapour flows through the inner tube in a counter flow direction to the liquid refrigerant flowing in the annulus between the inner and outer tube. This counter flow parts provides the greatest temperature difference between the two refrigerant streams to yield option (maximum) heat transfer.

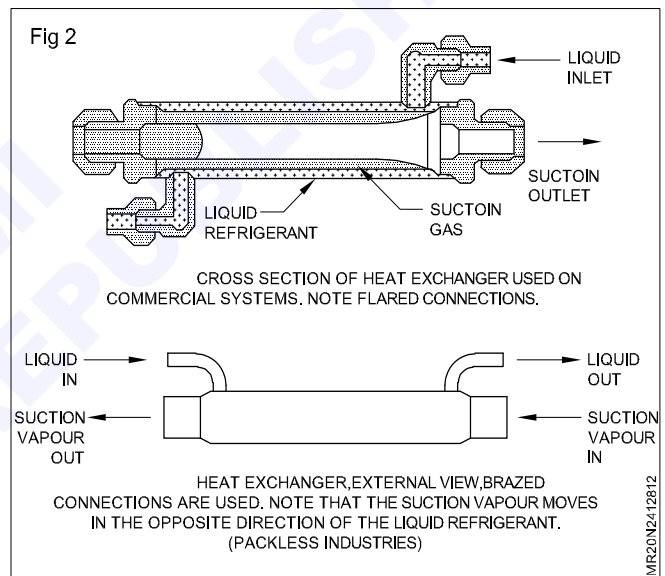
Design : A general heat exchanger design is to provide a 10°F liquid subcooling and 20° F suction gas superheat for R22 and R502. At this rating point, the condensing temperature is 110°F. (Fig 2)

Selection of heat exchanger : The heat exchanger selection is also having an important factor. The use of undesired models can cause system operation problems such as gas whistling and high suction side pressure drop. This also cause adverse effect on overall system performance.

In some applications the oversized refrigerant heat exchangers are used to attain additional liquid sub

cooling and suction gas superheat. This is an acceptable application as long as the temperature of the return gas to the compressor is less than 65°F to maintain proper compressor performance.

The selection of the refrigerant heat exchangers can also be based on matching of the system suction and liquid line sizes with the connection size of the heat exchanger, for standard low, medium and high temperature refrigeration systems.



Advantages of heat exchangers used in the refrigeration systems

- A Efficiency of the refrigeration system is increased (particularly at low temperature)
- B Prevent the outbreak of sub cooled liquid coming from the condenser in the inlet of expansion valve.
- C Ensures the suction inlet gas dry. Thus it prevents damage noise and inefficiency caused by liquid refrigerant
- D Provides sub cooling outside the condenser
- E Allows use of full evaporator surface for cooling

Location of Heat exchanger : The location of the heat exchanger depends on the intended use and allocation of equipment. If its purpose is to provide liquid sub cooling it is installed as close to the condenser. If it is used for removing the surplus of the liquid in the suction line the heat exchanger is installed close to the evaporator.

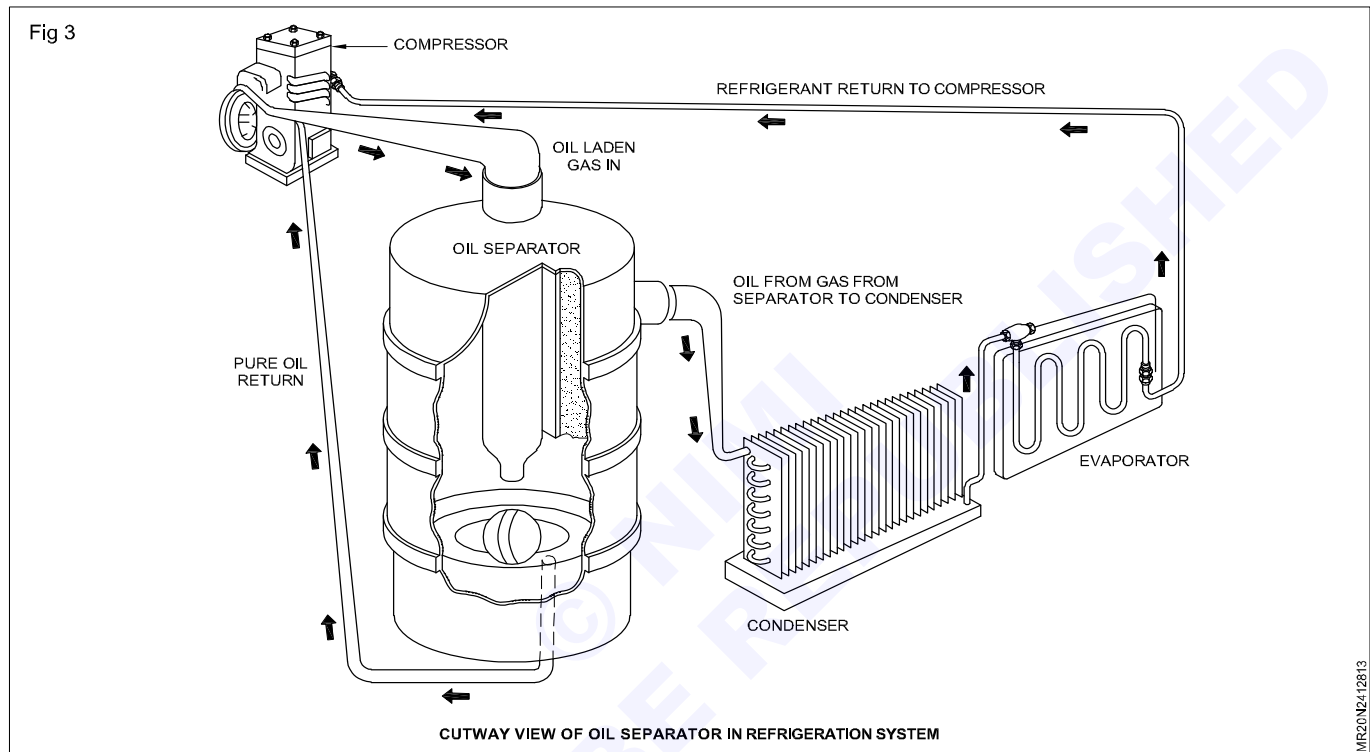
Disadvantage: The main disadvantage of heat exchanger is that they tend to increase the suction temperature which increases power consumption of compressor.

Another one is that the upper suction temperature limits for safe operation of the compressor should be met or the compressor may damage them. Liquid intake inter changer pipe lines increases the complexity of installation of the system.

Oil separator (Fig 3&4)

Oil separator is a device used to separate oil from refrigerant gas, returning the oil to the compressor, and allow the oil free refrigerant to travel in the system.

The term viscosity refers to the resistance of oil flow, it is designated by a numeral. A heavier oil has a higher number, the lighter oil has a lower number. The oil laden vapour gas enters the oil separator its velocity is reduced and hits the baffle plate. The oil being of higher density. Drops down to the reservoir. The density of the gas is being low it travels upward to the refrigerant system. In the reservoir the dripped oil is accumulated and the level raises the float, the valve opens, since the pressure in the oil separator is greater than in the compressor crank case, it enters in the crank case and maintain the oil level. These type of oil separator is known as high side oil separator since it is located in the discharge line of the system.



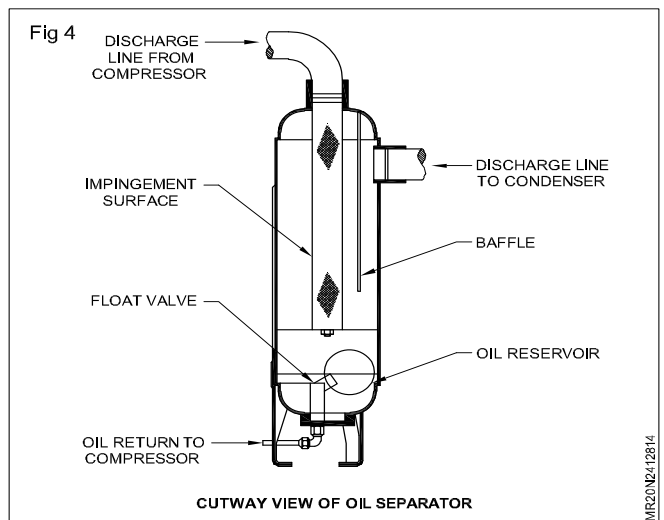
Refer table for knowing the selection of oil for different temperatures.

Table 1

Only oil recommended by manufacturers of the equipment should be used. When the manufacturers recommendation cannot be found, the viscosity of oil is indicated below.

Only oil recommended by manufacturers of the equipment should be used. When the manufacturers recommendation cannot be found, the viscosity of oil is indicated below.

Refrigerant oil should be selected according to compressor temperature, evaporator temperature and kind of refrigerant used



Service condition	Refrigerant	Viscosity
Compressor Temperature		
Normal	All	150 150/additives
High	Halogen	150/additives
	Ammonia	300 300/additives
Evaporator Temperature		
Above 0°F Halogen	Halogen	150 150/ additives
	Ammonia	300
0°F to 40°F	Halogen	150 150/ additives
	Ammonia	150 150/ additives
below 40°F	Halogen	150,150/ additives
	Ammonia	150,150 additives
Automotive compressors	Halogen	500

Accumulator

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

- explain the construction and working of accumulator.

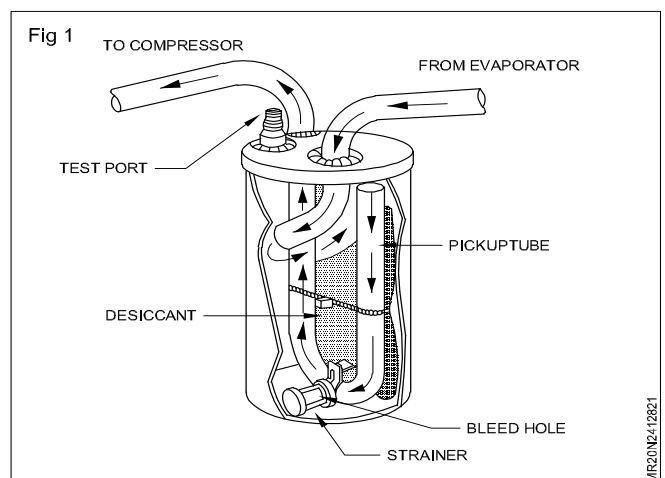
The accumulator is a safety device. It prevents liquid refrigerant from flowing into the suction line and into the compressor. Liquid refrigerant, flowing into the compressor, may cause considerable knocking and damage to the compressor.

The accumulator is connected in between the evaporator and the compressor of the refrigeration system. The primary function of the accumulator is to catch and hold any liquid refrigerant that didn't vaporise off in the evaporator. Liquid refrigerant getting to the compressor can damage the pistons or scrolls. The oil out of the compressor crank case. This loss of oil will prevent proper lubrication to the compressor, and can damage compressor.

Function of accumulator (Fig 5)

The suction gas leaving the evaporator enters the accumulator at the top and passes through a baffle or screen. Any liquid present collects on the screen and falls to the bottom of the accumulator. Inside the accumulator there is a 'U' shaped tube that will allow only the refrigerant vapour to exit and enter to the compressor. A small orifice in the bottom of the 'U' tube will allow any oil that collected in the accumulator to exit and return to

the compressor through the section line. Accumulator failures may happen on a properly maintained system. A plugged orifice in the 'U' tube would be the most likely problem. This plugged orifice would prevent oil from returning to the compressor. Proper accumulator sizing is important when re-piping.



Water cooler

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

- know the general details of water coolers
- types of water cooler
- functions of instantaneous/pressure type water coolers and storage type water cooler
- explain the wiring circuit and functions of electrical parts.

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

The temperature of water should be around 45°F-50°F (drinking level). Water coolers were used/provided according to the requirement of people using it. Regarding this a separate table is given in this lesson.

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:

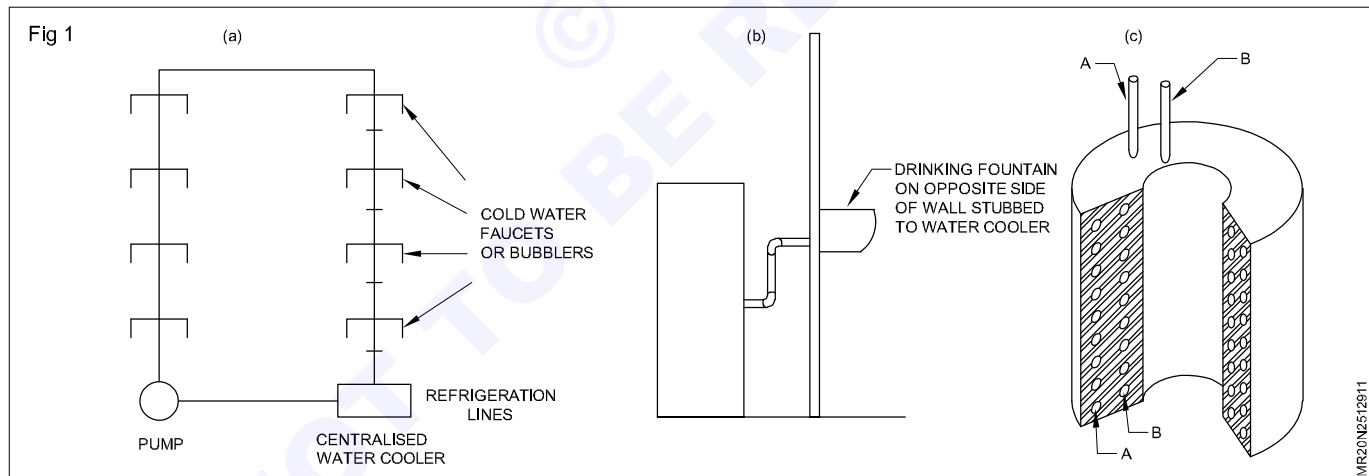
- Instantaneous type water cooler/pressure type water cooler.
- Storage type water cooler

Function of Instantaneous type water cooler with Bubbler model

Instantaneous type water cooler is the type which cools water at a faster rate when compared to storage type, It is remote type cooler because the refrigerant lines are (Fig 1A) piped to it from remote condensing unit. It hold a minimum quantity of water at a time depends on adequate surface and rapid refrigerant evaporation to chill the water as needed.

Unit may be fed with expansion valves for better performance. Now-a-days units comes with the capillary tubes also. Instantaneous type may be used with self contained. (Fig1B). In some unit bubblers used (connected) in cooler. This makes it possible to supply at two points with one unit. (Fig 1C)

Bubblers used in only short distance from the cooler to prevent exercise use of both water and refrigerator. Naturally bubblers should be placed at that point where the demand is less.



Where cold water is required at many different place, a circulating water system is used (Fig 2). The refrigeration losses are greater with cold water flowing through the pipes at all times. Pipe sizes should be maintained according to speed of flow of water into that and heat load for 5°F of temperature raise.

Function of a instantaneous type water cooler/ pressure type water cooler (Fig 3)

In instantaneous type unit water passed to the tank through the pre-cooler jacket surrounded by the drain line (which is cool when the water drains). So there itself a drop in temperature occurs. The water (outlet) leaves for

cooling chamber at the bottom and is connected to the bubbler or faucet.

The waste water flows to the drain tube through a drain fixed under pre-cooler. The cooling chamber is well insulated (by glass wool/Puf type).

Condensing unit fitted on the bottom of the unit where a fan motor with blades provided for condensation while the cooling chamber below the top of water cooler.

The water cooler body had been designed in such a way that its one or other sides can be easy to remove for service.

In the instantaneous type water cooler water is flow up when the bubbler works (when it is pressed at the top air gap in line makes way to pressurise the cold water to pass.)

Instantaneous water coolers are come in lower capacities mostly (maximum of 150 lts. can be possible). This type has been fitted with sealed compressor mostly pre-cooler type will be used to reduce the water (inlet) temperature before entering the evaporator tank.

Cooling capacity	Power consumption KW/PH	Person's served per hour
40 lts.	0.46	200
60 lts.	0.67	300
150 lts.	1.45	800

General details of the pressure type water coolers are given below.

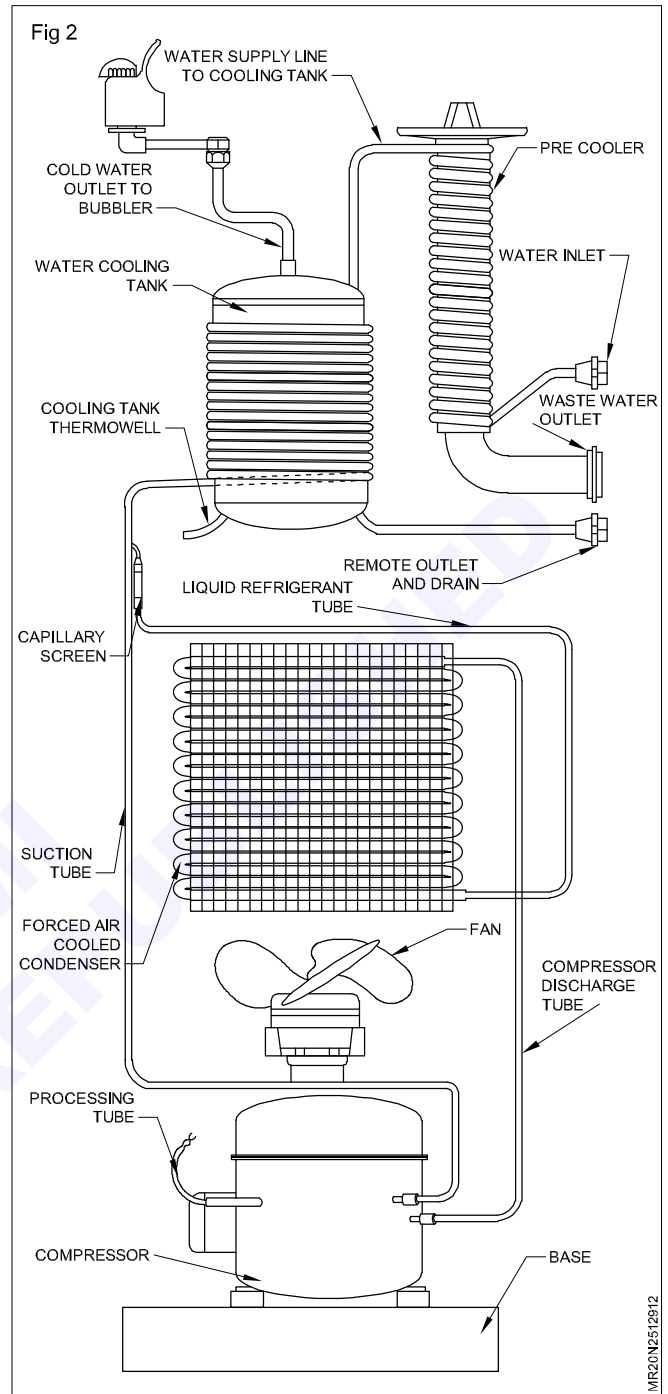
Functions of all parts and specifications

Compressor: The main function of compressor is to draw low pressure low temperature refrigerant and make it high pressure high temperature refrigerant vapour by compression.

Condenser: It is used to get circulate the high pressure/high temperature vapour through its pipe while the vapour travels because of air passing its fins provided by fan motor the temperature drop occurs and simultaneously the high pressure vapour turns to liquid state at the outlet of condenser which is called as condensation.

Refrigerant lines: The copper lines of 1/4" size and 3/8" or 1/2" sized were used to connect the compressor-condenser-strainer- evaporator coil and to the suction line of compressor (return) for passing the refrigerants in different status.

Capillary tube: It is used to pass the refrigerant in liquid state with low pressure and when comes out of it at the evaporator entrance the change of state occurs which is called as evaporation. Where the cold refrigerant flows throughout the evaporator. The pressure of the refrigerant is also decreasing at the outlet of capillary tube.



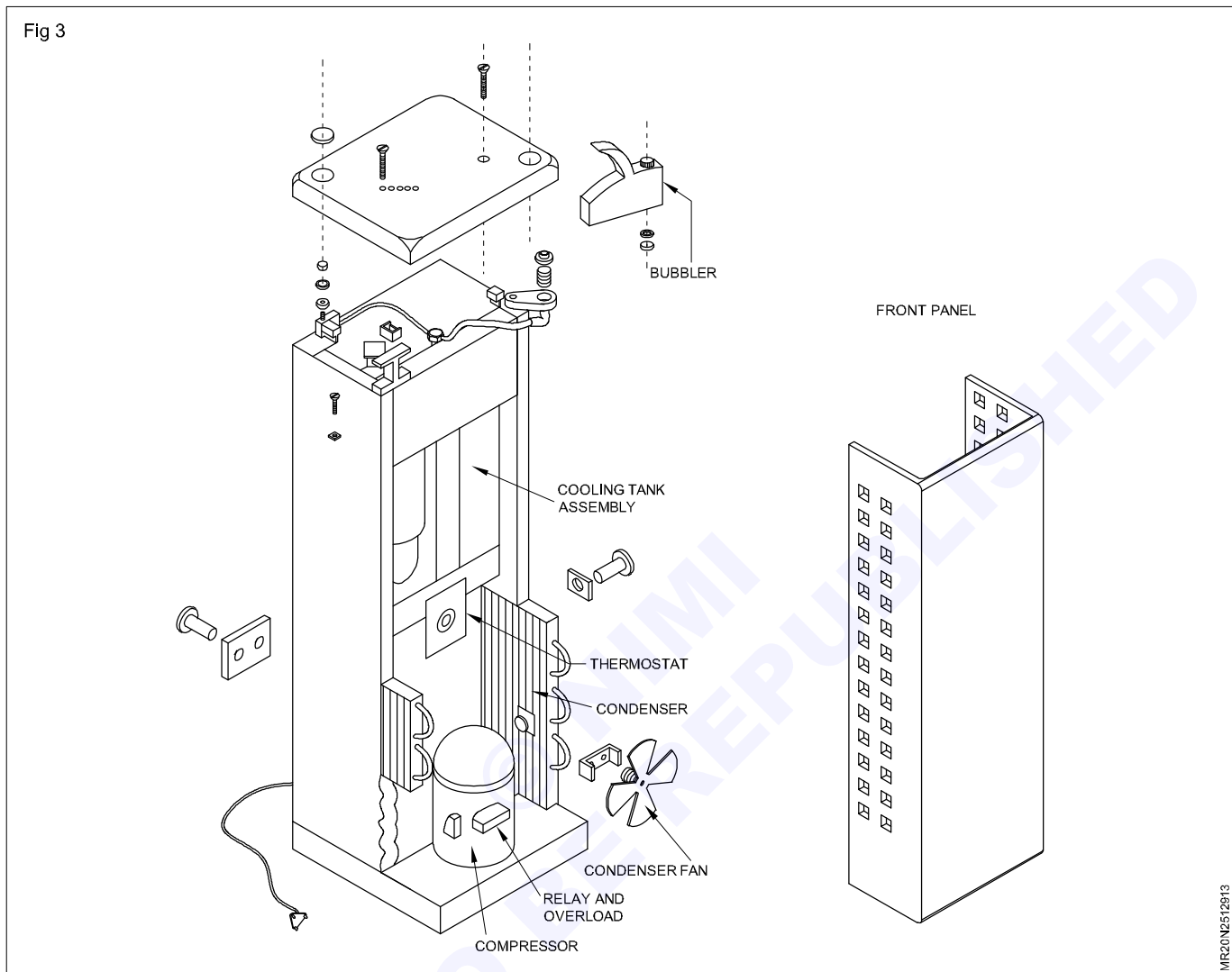
Drinking water table's given below

Usage	Temperature °F	Total water used and wasted
Office building-Employees	50	1/8 gal. Per hr. per person
Office building-transients	50	1/2 gal. Per 250 persons per day
Light manufacturing	50-55	1/5 gal. per hr. per person
Heavy manufacturing	50-55	1/4 gal. per hr. per person
Restaurants	45-50	1/10 gal. Per hr. per person
Cafeteria	45-50	1/12 gal. Per hr. per person
Hotel	50	1/2 gal. Per hr. per person
Theater	50	1 gal. Per hr. per 75 seats
Stores	50	1 gal. Per hr. per 100 customers
Schools	50-55	1/8 gal. Per hr. per student
Hospitals	45-50	1/12 gal. Per day per bed

Drier/Strainer : This is fixed in between the condenser outlet and capillary inlet used as drying agent purifies the refrigerant and eliminate moisture.

Evaporator/cooling chamber - Storage type : In this type Evaporator tank is soldered with cooling coil outside the tank (touching the body with lead soldering). Normally

2/3 height can be covered. Also minimum of some distance will be maintained at the start of the coil from the bottom of the tank capacity of the water tank is 80 lts. 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 fitted 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 4 & Fig 5)

- 1 Excess water drain (overflow)
- 2 Water inlet
- 3 Float ball (assembly)
- 4 Drain hose
- 5 S.S. tank
- 6 Cold water outlet
- 7 Insulation
- 8 Drain plug (bottom)

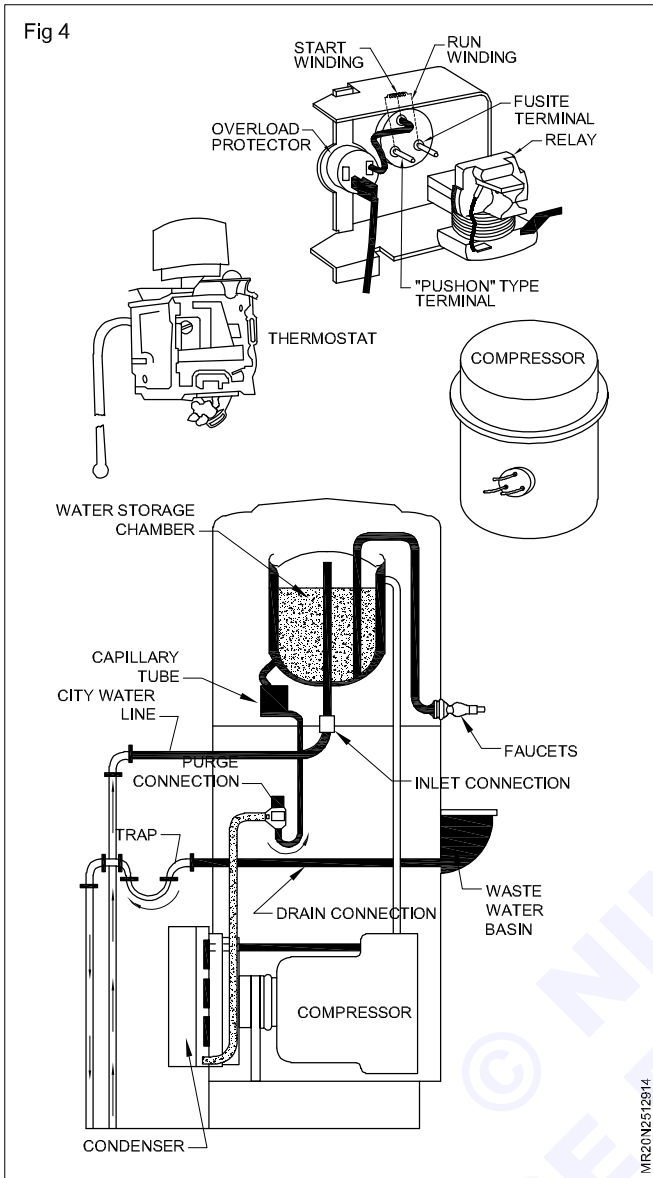
Condenser fan motor : Fan motor (with rated capacity) used (with blades) to circulate air over the fins of condenser to take out the heat of the vapours passing

through the coil and makes the change of state from vapour to liquid at the outlet. Fan motor should be equipped well. There will be no slackness in the bolts with the base.

Thermostat : All the water coolers are provided with this to control/maintain the temperature of the unit. If it malfunctions, chance of frosting of water happens which disturb flow of water at outlet (cold water tap).

In the instantaneous type if frosting happens due to malfunctions of thermostat leads the stoppage of water at the water draining area (because the water inside the tube gets frosted and stops the flow). This will be applicable for bubbler (push) type.

Water connection for cooler : In the water coolers, water is the main sources of supply water to the tank P.V.C. pipes/G.I. pipes are used with necessary bends/tee connection/U bends/elbow connections duly connected/tightened for this purpose.

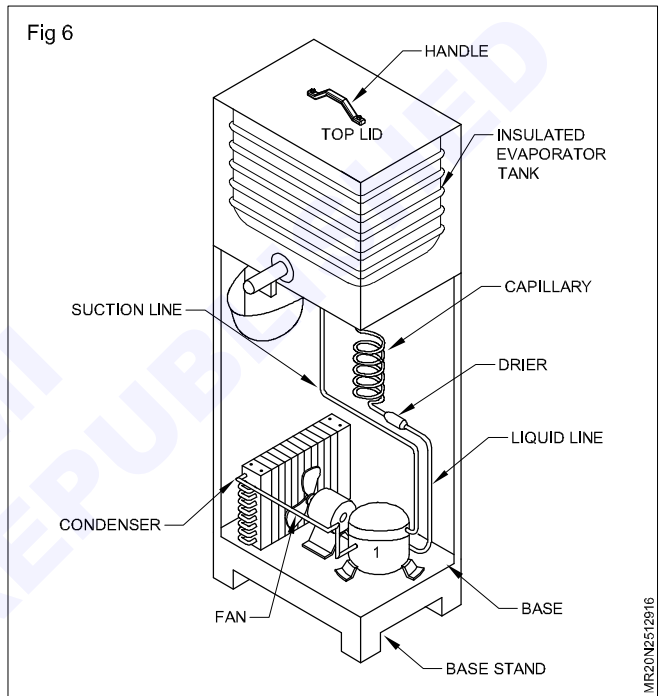


Taps will be provided at the cold water outlet in various types such as push type, screw type, thread type etc. In some unit hose will be used to connect tap and water outlet (chiller tank).

Float assembly are used in storage type water coolers to maintain the capacity/water level at the tank to prevent excess water (at storage tank) come out through over flow line.

Basically 1/2", 3/4" sized pipes/PVC/G/I. used for connection in the water lines. Mostly water lines are connected from overhead tank.

Cross section of storage type water cooler is given in (Fig 6)



Various models of storage/instantaneous/pressure type units (Fig 7)

The capacity/specification of compressor, condenser, fan motor, evaporator capillary and electrical details are given below for few capacities only.

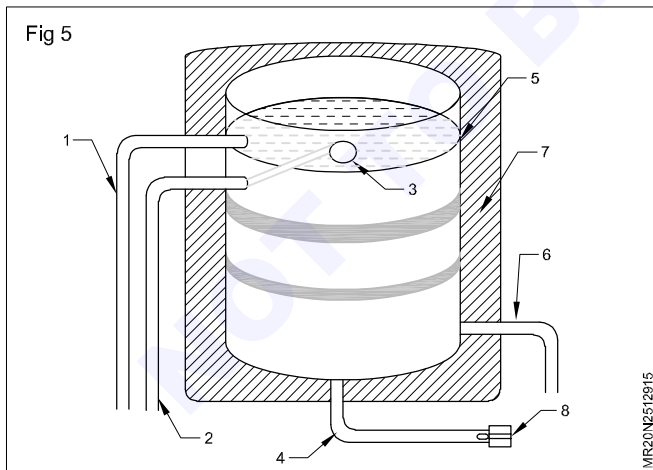
Wiring circuit of water cooler and function of each electrical parts (Fig 9)

Fan motor : Normally water coolers fitted force draft with air cooled (finned) condenser. For doing condensation, fan motor is placed behind the condenser in the base with blades fitted on the shaft.

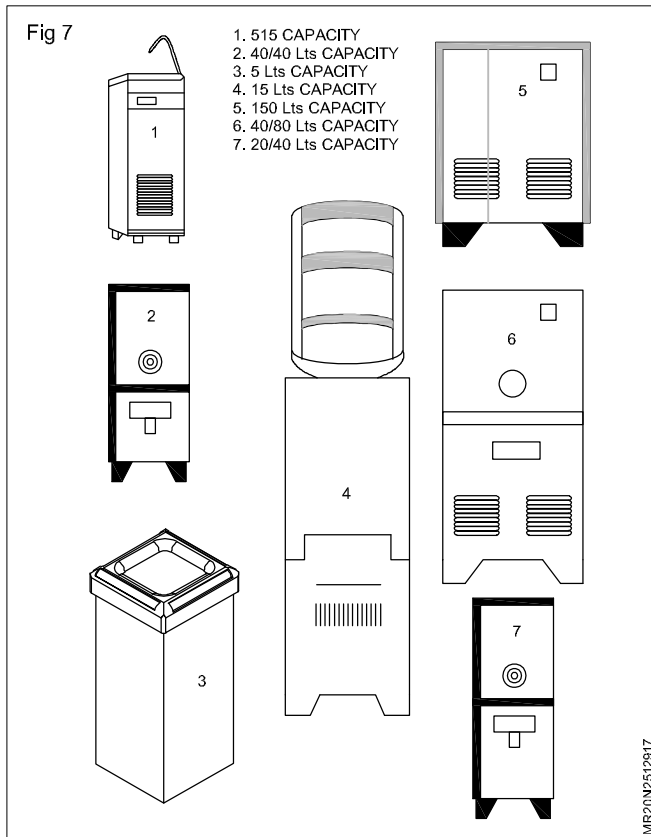
Fan motors having single speeded, this is connected to thermostat line in series, when compressor stops fan motor also stop functioning.

The capacity of the fan motor varies with the condenser capacity of the water cooler (ranges=1/32HP to1/3HP) also the blades varies in designs.

If fan motor fails, condensation problem arise and correspondingly the refrigeration effect changes. It leads to no cooling



All connection will be tight enough to prevent water leak, P.V.C. pipes will be well fitted with adhesives. Normally inlet connections will be provided with filters to prevent dirt entering to the tank. Also drain lines are provided with basin at the water tap area.



Some fan motor has comes off without a capacitor (only lower capacity). Higher capacity fan motor used/connected with capacitor ranging 2 mfd. to 6 mfd.

Hence fan motor plays an important role in the water cooler units so it has to be service at relevant interval for trouble free functioning of water cooler.

Overload Protector: This part is connected to compressor in series. 2 way Overload protector is used for water cooler. The main function of this is to safeguard the compressor to the following reasons.

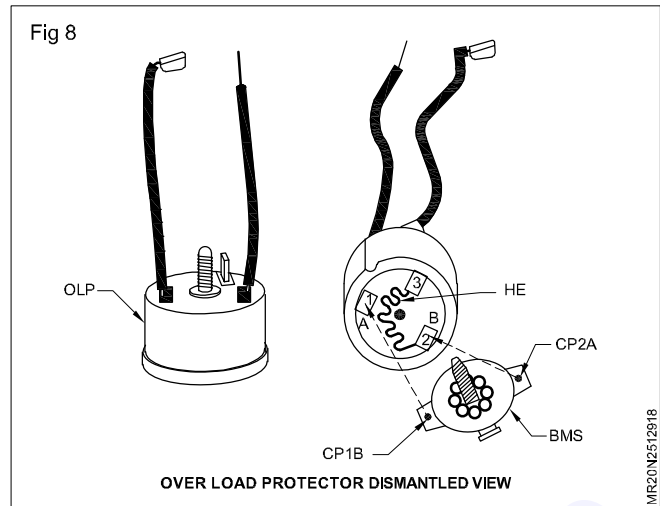
- 1 Low voltage / high current
- 2 Overheating of compressor body
- 3 Failure of relay

Internal overload has heating elements and bimetal strips. When there is a low voltage, the heating element heats up and disconnect the supply at other end. Thereby compressor stops. (Fig 8)

Compressor gets overheated due to weak winding or no oil. Heat on body makes bimetal trips its terminal and disconnects power supply to compressor.

Thermostat : Functions as an automatic control to maintain temperature of the cooler.

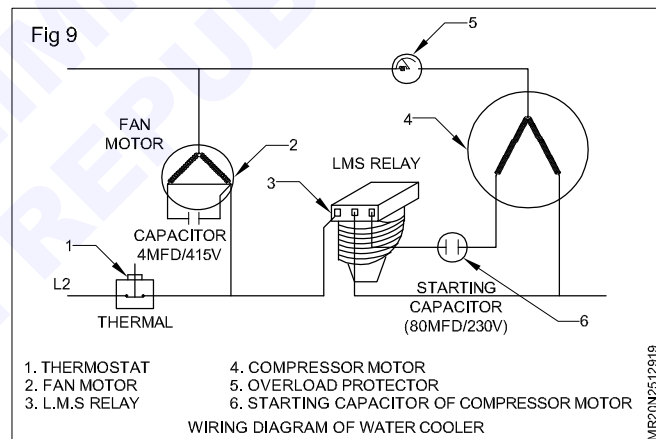
When predetermined temperature reaches at the water cooler a sensor connected to thermostat act and disconnect the leads at thermostat, thereby compressor shut off (electrically). (Since thermostat is connected to compressor in series). As and when temperature raises in the water cooler automatically sensor acts and makes contact at the terminal thereby compressor line get connected and compressor starts working.



The temperature difference given between cut out and cut in will be between 3°C to 5°C. The cut off range (adjustable) will be between 7°C and 22°C.

High temperature thermostats has its capillary with sensor lesser in length when compares to low temperature thermostat.

Relay (Fig 9) : Relay is used protect compressor winding. Also gives initial power to starting winding at the compressor needed and cuts off power supply at running.



Types of relays : According to the capacity and wiring is varies. Normally smaller capacity water coolers connected with current coil relay (or) pin type relay. These relays were connected with phase line of the supply. Pictorial description already given.

The higher capacity water coolers get connected with potential relay where C.S.R. type circuit. When this relay used both running and starting capacitors used in the circuit. The function of this relay is already given in the earlier exercises.

Capacitors : Capacitors used in (alternating current) A.C. supply basically changes single phase electrical flow to two phase electrical flow. The capacitor connected will be usable for both the winding of the compressor if the capacitor used in the starting capacitor.

Starting Capacitor : Only on certain unit/capacity stating capacitor being used for few seconds at a time in the starting winding.

If the starting winding used often or compressor started often the capacitor it loose its life.

Running capacitor : This is used with C.S.R. circuit with potential relay. Running capacitor is used to maintain

required power factor. Never use the improper sized micro fared capacitor to the supply especially to the starting winding (S.C.). Always test the capacitor before fixing. Capacitor terminals should be connected properly. If loose connection it may lead to capacitor burst.

Height x Width x breath in mm	1135 x 310 x 310	1285 x 430 x 440	1285 x 430 x 525	1325 x 430 x 440		1610 x 610 x 610
Capacity	15	20	40	60	100	150
Compressor	AE 3412A	AE3415M	AE4440M CAJ34	CAJ2512	AJ11E	AHR13 AH5516E
Condenser	9'x9'x2 row x 3/8" OD	9' x 9' x 2 x 3/8" OD	11' x 10' x 3 3/8"OD	13'x 12' x 3 3/8"OD	14'x14'x3 x 3/8" OD	22'x17'x2 x 3/8"OD
Condenser fan motor	1/83 HP 1350 RPM	1/83 HP 1350 RPM	1/36 HP 1350RPM	1/20 HP 1350RPM	1/20 HP 1350RPM	1/12 HP 930 RPM
Condenser Fan blade	9" dia	9" dia	10" dia	13" dia	13" dia	16" dia
Evaporator tube	26' x 5/16" OD	30" x 5/6" OD	50' x 3/8" OD	70' x 3/8" OD	80' x 1/2" OD	(65' + 65') x 3/8" OD
Capillary	.042" x 16' x 1	.050" x 10' x 1 no.	.050" x 5' x 1 no.	.050" x 5' x 2 nos.	.055" x 46" x 2 nos.	.055" x 32" x 2 nos.

Visible cooler and Bottle cooler

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

- explain the type of bottle cooler
- explain visible cooler and its type and functions
- explain the service procedure of bottle cooler and visible cooler.

Bottle cooler

Types of bottle coolers

Bottle coolers may be divided into two types

- 1 Domestic type and other
- 2 Commercial type

Domestic type: Domestic type of bottle coolers are also classified as direct expansion type bottle coolers.

The direct expansion type bottle coolers are used in petty shops, offices and small commercial establishments.

Direct expansion type bottle coolers are one in which the cooling coil or evaporator coil is wind around the storage tank. The winding of coil in other type of bottle coolers are inside the storage tank.

Evaporator coil winding outside storage tank: (Fig 1)

In this type of bottle cooler, insulation in between the storage and cabinet should not have crack or joint, thereby allowing moisture to leak inside the cracks and gets deposited over the storage tank in the form of ice at low temperature, thus reducing the efficiency of the insulation, or even spoil the insulation. During servicing, cleaning evaporator is difficult, but cleaning cooling compartment is very easy with this type of construction.

Evaporator coil winding inside storage tank: In this type the migration of moisture outside storage tank is limited, thereby efficiency of bottle cooler is increased. But cleaning/servicing of cooling coil is very difficult.

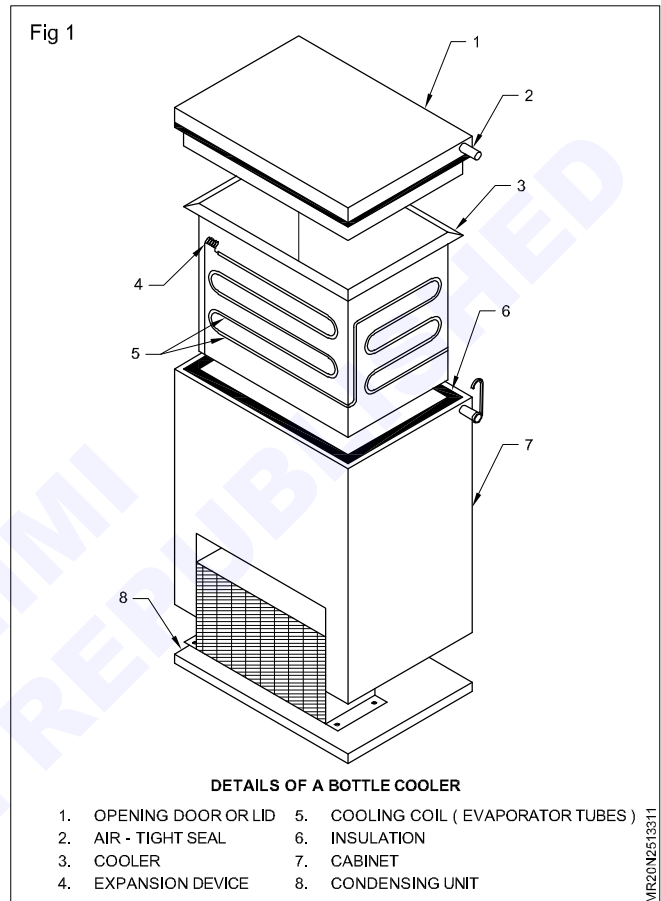
Also cooling space is decreased by the space occupancy of cooling coil.

Direct expansion type bottle cooler comes in two types:

- 1 Horizontal type
- 2 Vertical type

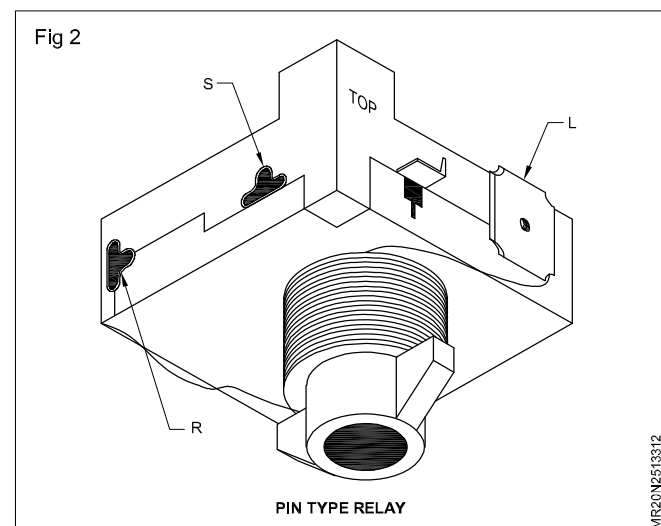
Horizontal type bottle coolers: Employs natural convection of air inside storage cooling compartment. The advantage of this type of bottle coolers is during opening door the heat loss is minimum, due to the flow of air inside storage compartment is natural and not forced driven. This type of bottle cooler is used in offices, service stations and markets.

Vertical type bottle coolers: Employs mostly forced air type cooling. In this type bottles are arranged in different way and opening of door is very small. In this type of bottle-cooler pre cool storage space created and by this method circulation of cooling of bottles are even, not allowing left out of uncooled bottle, the rotation of stock is even and

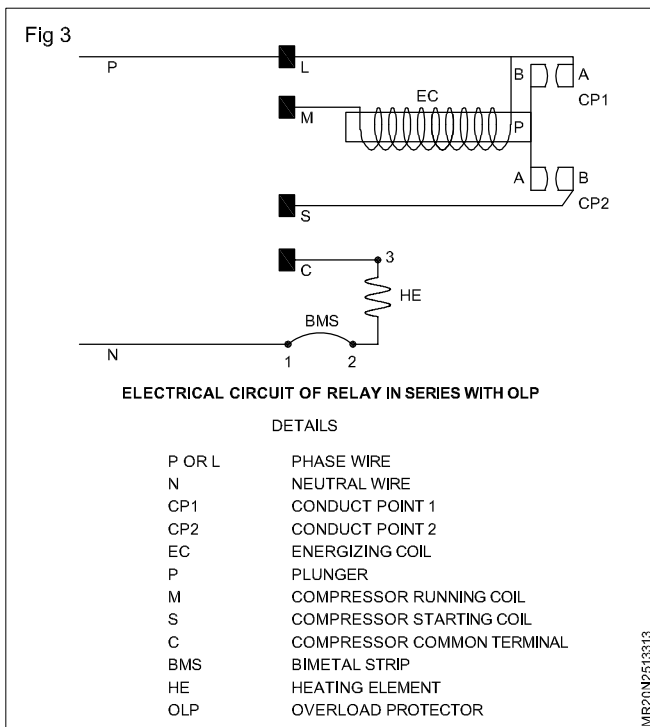


stable due to long space is available inside the cooling compartment.

The relay which is used in bottle cooler are shown in (Fig 2)

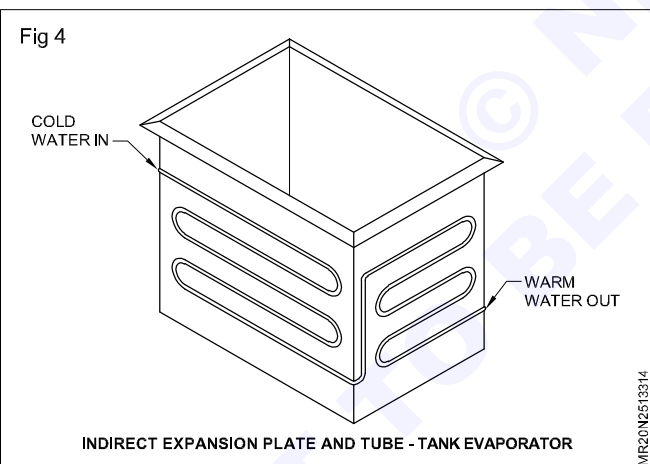


The electrical circuit of relay and the details are in (Fig 3)



Commercial type : In this type of bottle cooler indirect cooled evaporators are used.

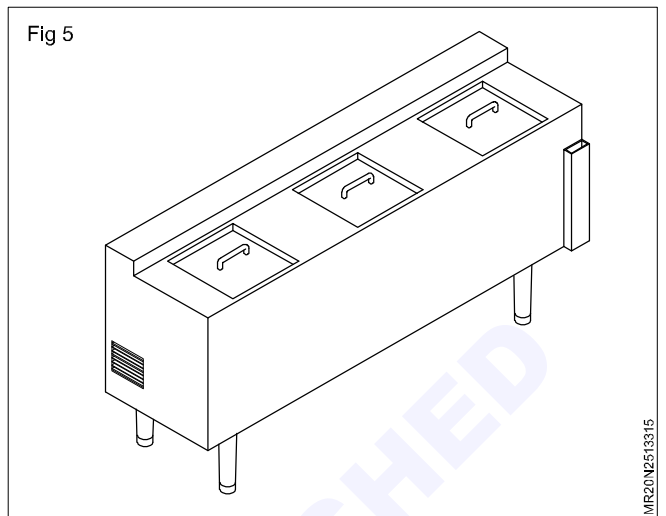
A line carrying cold water from the cold water tank winding around the storage cabinet and thus the cooling temperature is achieved inside storage compartment. (Fig 4)



Preservation of beverage stored in bottle cooler: Bottle cooler serves to store various types of beverage fresh, by lowering the temperature of bottle coolers. The beverage stored in the form of milk, dairy products, fruit juices, drinking water and cool drinks, retain their original taste and flavour and also nutrient value of the food does not get disturbed. The life of beverage stored in bottle last 3 to 6 months.

In European countries in winter, there is a heavy snow fall. There is scarcity of milk and the cultivation of fruits is limited. To overcome above difficulties and to make immediate available required food and fruits concentration stored in bottle, besides milk even in off season you get the required fruit juices and milk product having genuine nutrient value at affordable prices. The need for preservation of beverage is required.

Evaluate indirect expansion bottle coolers : Indirect expansion bottle coolers are used for commercial type of plants (i.e.) milk vending, bottled drink plants, fruit juices, where production of above products are done in large scale. (Fig 5)



Indirect expansion cooling of bottle coolers can be termed as secondary cooling. Here the cooling coil does not in direct contact with storage tank. Instead refrigeration cycle cools the necessary water at desired temperature in large water tank and in turn cold water is passed through the storage area of bottle coolers.

Indirect expansion bottle coolers are as such commercial type and plants holding goods for sale in retail store like milk vending or storing bottles and beverage cooling. The refrigerated compartment may be a cabinet, it may be self contained or the mechanical equipment may be in a basement or other convenient place.

Visible cooler - Types, functions and applications.

“Visible cooler” is a type of refrigerated cabinet that displays merchandise as well as cools it. Visible coolers are designed to be attractive and provide lighting for the merchandise inside. They are also called self-service cases and reach-in-cases.

Visible coolers are commonly used to keep cool the food products such as beverages (bottled), bakeries, chocolates, milk etc.

Application

Visible coolers are widely used in commercial establishments like retail/bakery shops, super (food) markets, canteens/restaurants.

These coolers are maintaining the temperature range between (normally) '0' to 10°C inside.

Types/Models

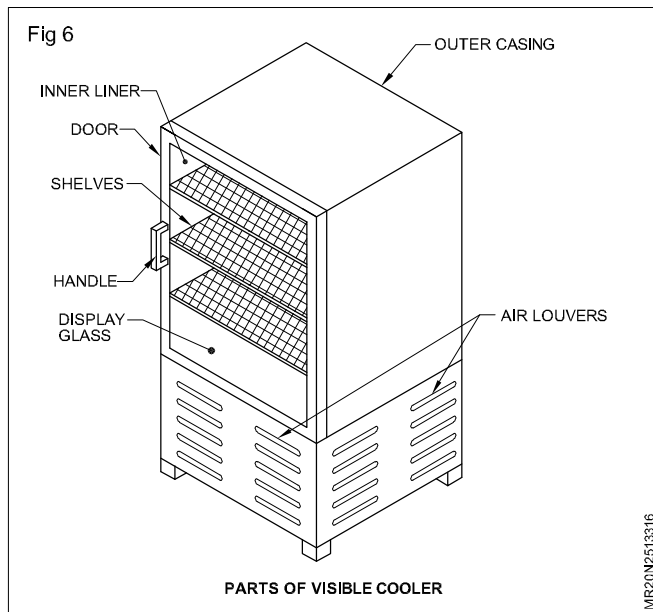
Visible coolers employs the ‘Evaporator’ of refrigeration system may be either forced convection type or natural convection type.

Capacity of these coolers begins from 90 litres to the maximum 300 litres and above.

The minimum capacity (90 lts.) cooler has natural convection plate type evaporator and is used to store chocolates, dairy products, etc.

Specifications/features (Fig 6)

Outer casing: It is made of galvanised steel with backed-on paint finish for durability.



Inner liner: Normally it is made of stainless steel for long life and easy maintenance. Plastic (food grade/ABS) liners are also used for economical purpose.

Glass door: 2 or 3 pane type, space between the layers may be vacuumised to eliminate heat transfer by convection. Outer pane may be toughened for safety.

Shelves: Adjustable type to accommodate all sizes of bottles and cans.

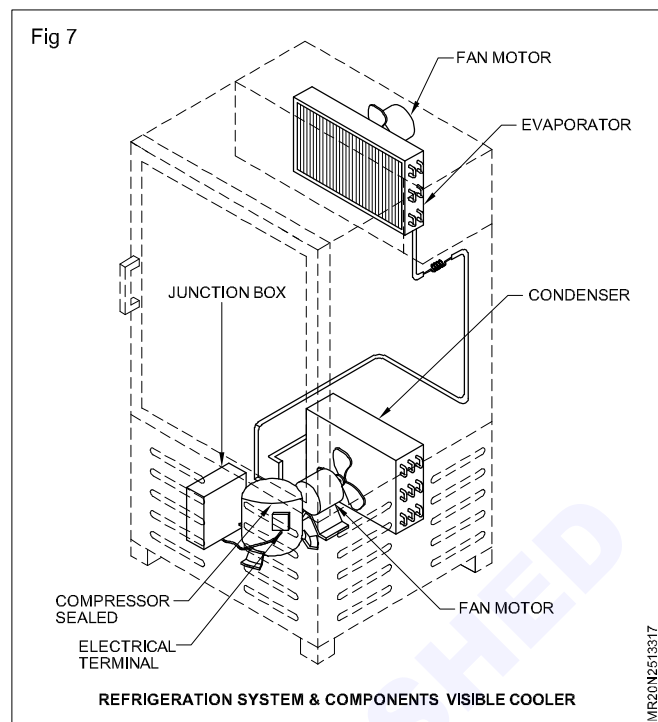
Insulation: High density, CFC free, rigid polyurethane foam, which has low thermal conductivity.

Function of Unit: (Fig 7)

The cooler employs a vapour compression refrigeration system for achieving the cooling effect which is normally used in water coolers, bottle coolers etc. The compressor will be hermetically sealed, reciprocating type compatible to medium/low temperature applications (evaporating temperature between 5°C to -5°C) with HFC-134A as refrigerant. The condenser may be air cooled either natural convection (90 lts. capacity) type or forced convection type (above 165 lts.) Similarly the evaporator will be finned forced convection type for high capacity models (above 90lts).

The operating power supply will be single phase, 230V, 50 hertz, A/C supply.

The electrical components are as same as used in water coolers, bottle coolers with additional components such as tube light/fluorescent lamp (fitted inside of the cabinet) and evaporator fan motor. Some coolers are fixed with heaters for defrosting evaporator.



The electrical accessories such as starting relay, overload protector (OLP) are as same as used in water coolers except the thermostat which is used here, bottle coolers type.

Normally the evaporator coil with fan motor located at topside circulates cold air. Fan is directly connected to the power supply lines to operate even after the thermostat opens the contact.

Periodic servicing of bottle cooler / visi cooler

Adopt healthy practice of maintaining bottle-cooler periodically every bi-monthly turn off the unit from power and clean internal parts by using neutral detergents and external enamelled sheet metal body with warm water and dry out immediately after cleaning out all the dirt and dust from external body.

For Internal body, after cleaning with neutral detergents rinse the internal body with enormous water and dry it immediately, you can use a drop of vinegar will eradicate foul smell from Inside the body of bottle-cooler

Everyday using dry cloth can clean the external body of bottle-cooler and dusting the inner condensing unit with the same dry cloth. And so used cloth can be cleaned with detergent daily and can be reused daily. Check that the equipment free from noise and vibration.

Every week check the running amperages of compressor and if necessary condenser fan motor. Also Inspect condenser and make sure it is free from air flow obstruction.

Monthly shutdown the unit and remove all the food load stored and shift to similar unit in running condition. Now all the ice formation if any to drain away, by opening drain hole and as said earlier use excess water to clean internal surface and dry it out. The internal cooling compartment metallic section is corrosion proof, but take care not to use heavy detergent as it may corrode the surface instantly.

Quarterly clean finned condenser for dirt and dust (freedom from blockage) Also lubricate fan /motor bearings as necessary check.

Yearly, shut down the unit, examine compressor and discharge and suction line for oil trace of gas leaks, without damaging compressor, condenser and by removing Fan Motor and Fan blade, clean and repaint the condensing unit. Check all operating and safety controls for correct setting and operation.

Make a habit of mounting of components properly, such as mounting of relays with top side up. Always insulate open terminals. Components should be mounted away from water.

Make a routine habit of maintaining electrical components, every time you attend for service maintenance

- Check all accessories for proper working
- Replace defective component before they go dead.

If compressor cycles on overload protector, do not short-cut to solve problem by splash water on condenser to make cool.

Don't give extra pressure when relay clip being fixed and so as the compressor terminals. When changing compressor do not forget to change components of compressor make.

HFC-134a and Hydrocarbon (HC) refrigerants and their retrofitting procedure for coolers

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

- explain about HC refrigerant and its retrofitting procedure for visible & bottle cooler
- explain about HFC-134a refrigerant and its retrofitting procedure for visible & bottle cooler.

Hydrocarbon (HC) refrigerants: Hydrocarbons have been used alternately as refrigerants in refrigeration system. Their use has been increased in the past 10 years and now being used in place of R-12 (CFC group) for medium and low temperature applications such as bottle coolers, refrigerator/Deep freezers etc, Hydrocarbons are absolutely environment friendly refrigerants due to their nil effect on Ozone layer and global warming.

There are 2 kinds of Hydrocarbons commonly used in refrigeration systems, which are

- Isobutane (R-600a)
- Propane / Isobutane blend (HC blend)

R 600a is widely used in domestic refrigerators. Its refrigerating capacity is about 60% at that of R-12. Compressors used with R 600a must have a much higher displacement, but have the same size motor for R-12 appliances : Therefore a new model with as different displacement/motor combination is need. It (R 600a) is NEVER used for conversion/retrofitting of existing CFC-12 or HFC-134 a refrigeration systems.

Hydrocarbon blend has very similar properties to CFC-12, it gives the same capacity and operates at similar-pressures. These are very good refrigerants with different characteristics to CFCS and HFCS with their relative values :

- High latent heat value than CFC & HFC's
- Low liquid density than CFC & HFC's

CAUTION:1 Hydrocarbon refrigerants are flammable when mixed with air and ignited. 2 Necessary safety precautions to be taken by using non-sparking (sealed) electrical components such as door switch, lamp holder, thermostat, Relay, OLP etc.,

Assessment of necessary electrical component changes

Since the Hydrocarbons are flammable type (at particular conditions), it is required proper care must be taken on electrical devices as they may produce sparks at some unsafe conditions. Unsafe devices are those which spark when they operate. Where such devices are attached to or close to the refrigeration circuit, they could ignite leaking Hydrocarbon refrigerant. The electrical devices which is required to examine are usually the compressor relay, compressor overload protector, thermostat, door switch, on / off switch and light.

These devices must be:

Replaced with sealed or solid state types (that do not spark)

or

Enclosed in a sealed box

or

Moved away from the refrigeration circuit to safe place

(Top side) where leaked refrigerant cannot reach. (Density of Hydrocarbon is more than air)

If the compressor requires replacement, special Hydrocarbon blend compressors will be supplied by the manufacturers with safe relay (PTC type) and over load protector (sealed)

The fan motors and capacitors used in appliances are not ignition sources.

Charge the HC refrigerant in liquid form only.

Charge only 40 % of HC refrigerant that is usually charged with CFC-12 refrigerant (approximately 180gm CFC refrigerant 40% of HC refrigerant = 72gms)

(Refer 1st sem theory lessons for more in per motion regarding retrofitting)

Retrofitting of CFC filled bottle cooler with the HFC 134a refrigerant (Fig 1)

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.

Change with new compressor which has polyester oil lubricant and displacement of the compressor slightly large. 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.

Wiring circuit of bottle cooler & visible cooler

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

- describe detail of electrical circuit of bottle cooler and visible cooler
- elaborate function of electrical components of bottle & visible cooler.

Detail of electrical circuit of bottle cooler and visible cooler: A/C single phase wiring is used in bottle cooler. Main incoming line are stabilized with a stabilizer from which phase and neutral wires are tapped. The earth from supply grounded to bottle cooler. The phase wire is connected to L_1 of the relay and OLP, compressor's

Here new filter drier is used (molecular sieve type) which has greater moisture absorbing potential and molecular sieve filter driers 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.

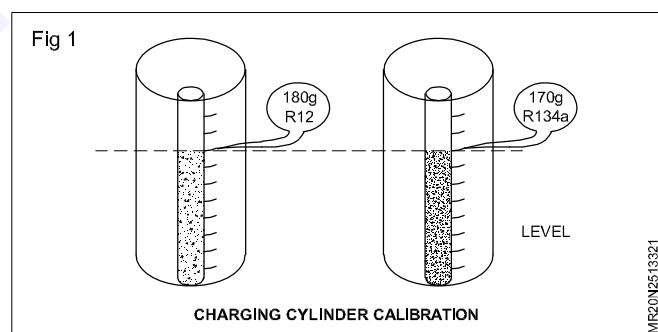
Connect HFC 134a gas cylinder to the system with manifold valve purge air from all the hoses connected by opening HFC 134a gas partially. Now charge the system with HFC 134a and weigh the amount of gas charged by using electronic weighing machine.

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).

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.



common and Line 2 (L_2) dummy point is connected by neutral line. When the relay is energized by the current drawn by the running winding, connects the starting winding by closing the contact of it. And since the compressor current drawn is reduced and flux increased and the compressor gets speed. After compressor getting

speed the closed contacts of the relay get opened which cuts the starting winding from the circuit and running winding kept stable in constant run. A thermostat also connected in series of the circuit (switch off compressor when the sufficient temperature attained and switch on when cabinet temperature raises and call for compressor to switch on).

A fan motor is kept in series with thermostat for condenser coil for better cooling efficiency. And in another type of bottle cooler. a fan motor for cooling coil is also provided which boosts the cooling efficiency, by providing even and uniform temperature to all the areas of cabinet of bottle cooler. This is possible as the evaporator and fan assembly are generally located near the centre of cabinet. Because the cold air blown over the top layer of the bottles in the cooler to lower layer of the bottles to the bottom of the cooler. The air drawn by this recirculated through the evaporator coil with fan assembly. The fan motor of the cooling coil does not cycles with the refrigerating machine but operates continuously as soon as the bottle cooler is connected to power supply.

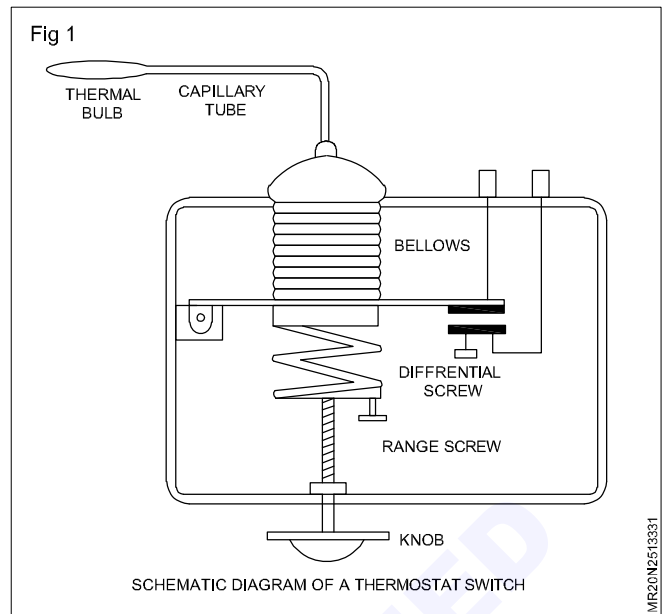
Function of electric components :

Relays : Current magnetic relays are used for low torque, smaller horse power application such as domestic refrigerator and semi commercial units such as water/ bottle cooler, ice candy/cone machine and deep freezers etc. These relay uses electric characteristic of the motor for operation. The running winding consumes more current when the rotor turning slowly that it does when it reaches full speed. When the rotor picks up full speed the magnetic field builds up and collapse in the motor. Producing a bucking or counter electromotive force or voltage in the running winding.

The current magnetic relay is identical in function to solenoid valve. When the motor control (i.e. thermostat) contact closes and high current flows in running winding. The magnetic current relay coil is totally magnetized, it overcomes spring pressure and closes the contact there by closing the starting winding circuit and motor speed up of the 3/4 of rated speed. In this process amperes drawn by running winding decreases which decreases the magnetic current relays which in enough lower the spring pressure to open the point. Current magnetic relays can also be called as ampere relays.

Overload protector : All starting relays have some type of overload protection. It incorporates a bimetal disc and a resistance heater and gets overloaded as it heats up bimetal disc through resistance heater. The bimetal disc when gets heated up bends and opens the contact of the motor, stopping the motor. It will reset after 2 to 3 minutes when the bimetal disc cools down.

Thermostat : It is a switch which controls the temperature of the refrigerated space by breaking or closing the electric current to the compressor motor. The running time of compressor is increased or decreased according to temperature in refrigerated space requirement by adjusting knob (range screw and temperature differential screw). The parts of thermostat are as follows. (Fig 1)



- Sensing bulb
- Capillary tube
- Bellows
- Electrical contacts
- Range screws (settings)
- Temperature differential screw (knob)

The electrical contacts or contact points have link with adjusting knob. The thermal bulb or sensor bulb is connected to bellows by an capillary tube filled with volatile liquid. The bulb is clamped to the last coil of the evaporator. The contact points are connected in series with the compressor. When the temperature of the evaporator rises, rising the temperature of the bulb clamped, increased the pressure of volatile liquid causes the bellows to expand. This instigate the contact point which completes electrical circuit and starts the compressor. And vice-versa if the temperature of the evaporator decreases, decreasing the bulb temperature, decreases the pressure of volatile liquid causing bellow to contact sufficiently to open the electrical circuit and stops the compressor.

In this way automatic working of refrigerated space with desired temperature is achieved.

The range screw used to change temperature range by cut out setting changing of thermostat.

The temperature differential screw used to increase or decrease temperature difference between cut in and cut out points.

Fan motor: Single phase inductor motors shaded pole motors are used for condensing unit and in force drafted cooling coils of the bottle coolers. These motors are direct driven, low cost comes in fractional horse power from 1/100 to 1/4 HP. These motor use very small starting torque . These type of fan motor have limited enclosures allowing the ventilation air to pass through to cool down the winding coils. These type of motors are called drip proof. Even though a drop or two of water falling above the motor, will

not affect the motor performance. These type of motor are used in indoors and outdoors where the motor are not subject to rain.

Wiring design: Any refrigerating/air conditioning appliance has the compressor which is based on the capacity of the unit/appliance and the design parameters like evaporating temperature and condensing temperature of the refrigerant. Likewise, the wiring circuit also.

Low Back Pressure (LBP) compressors which are suitable for refrigerator and deep freezer applications, may require RSIR type of wiring for small capacities. CSIR type of wiring may require for large capacities. But the compressor which is suitable for visible cooler application is coming under medium back pressure (MBP)/commercial back pressure (CBP) range. In this range the compressors are operating by the evaporating temperature between -18°C to 10°C with RSIR/CSIR/CSR wirings according to its capacity (2 crates to 10 crates of bottled beverage load).

Accessories : There are four major accessories which are required to run the compressor, they are starting capacitor, running capacitor, overload protector (OLP) and starting relay. But the accessories required by the compressor is based on the wiring circuit. RSIR wiring will require relay and OLP only. Both these accessories are available in the form of relay package assembly (RPA) - plug on type. (Fig 2).

CSIR wiring has no running capacitor and works with relay OLP assembly and start capacitor only. But CSR wiring will require the complete accessories.

The accessories details of the compressors which are used for visible cooler application are tabulated in Table 1.

System Operation: Normally low capacity visi coolers (upto 2 crates, 90 lbs internal volume) equipped with plate type evaporator and sealed compressor with RSIR wiring. Medium capacity coolers (upto 4 crates, 220 lbs internal volume) are made with forced convection evaporator, air cooled condenser. Natural convection type, sealed compressor with CSIR wiring, large capacity coolers (upto 10 crates, 330 lbs. internal volume) equipped with Forced convection evaporator and condenser, sealed compressor with CSR wiring.

The coolers of all capacities will have the internal light (tube light/CFL lamp) one, two, or three numbers according to the capacity. The wiring is designed, to glow the internal light whenever door gets opened as it connected through the door switch. The phase line from the 3 pin plug is taken into 2 branches, one goes to cabinet light, another goes to compressor through the thermostat. The compressor and fan motor(s) are controlled by the thermostat when the desired temperature is reached.

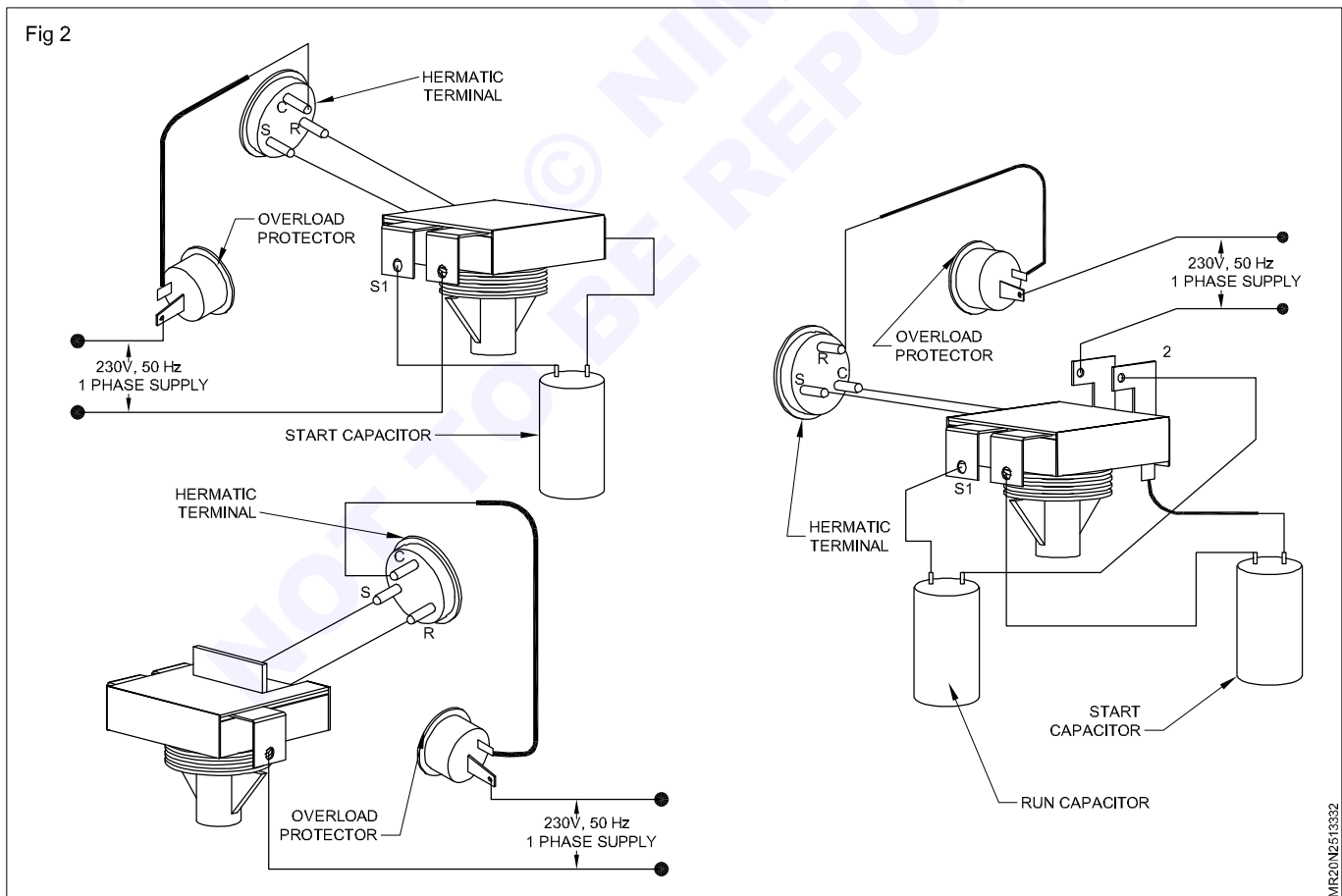


Table 1

Accessories details for different model compressors

Compressor model	Application	Cooling capacity
MLA 9384 YCG	Chest cooler	2 crate
MLA 9410 YCG	Visi cooler	2 crate
	Chest cooler	4 crate
MLA 9414 YCG	Visi cooler	4 crate
MLA 9424 YCG	Visi cooler	7 crate
	Chest cooler	10 crate

Various compressor module & Parameters

Compressor Model		CBP compressors	MLA 9384 YCG	MLA 9410 YCG	MLA 9414 YCG	MLA 9424 YCG
Circuit			RSIR	RSIR/CSIR	CSIR	CSIR
Frequency	Hz		50	50	50	50
Rated voltage	Volts		230	230	230	230
Current	FLA Amps		1.0	1.3	1.2	2.3
Power	Watts		156	182	240	364
Energy Efficiency	K.Cal/W-hr		1.13	1.2	126	1.38
Ratio	Bu/W-hr		4.5	4.8	5	5.5
LRA	Amps		10	10.5	13	14
Voltage Range	Volts		170-260	170-260	170-260	170-260
Relay			Plug on	Plug on	Plug on	Plug on
OLP			External	External	External	External
Start capacitor	Mfd		-	40/60	40/60	40/60
Run capacitor	Mfd		-	-	-	8
Oil quantity	CC.		300	300	300	250
Weight including oil	Kg.		9.8	98	11.8	112
Compressor cooling			7.0CMM	7.0CMM	8.0CMM	8.0CMM

Deep freezer - types, functions, service and maintenance

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

- explain the function of deep freezer
- differential various types of deep freezer
- understand food preservation
- understand service maintenance and troubleshooting procedure of deep freezer.

Introduction

Deep freezers are the refrigerated cabinets, which are used to store the perishable food products (meat products, dairy products..) at the required temperature levels. (-10°C to -30°C)

Specification of parts (Fig 1)

The outer body is fabricated by GI sheet and covered with powder coated paint finish for durability (long life).

The inner liner either made out of stucco aluminium (rust free) or stainless steel (food grade).

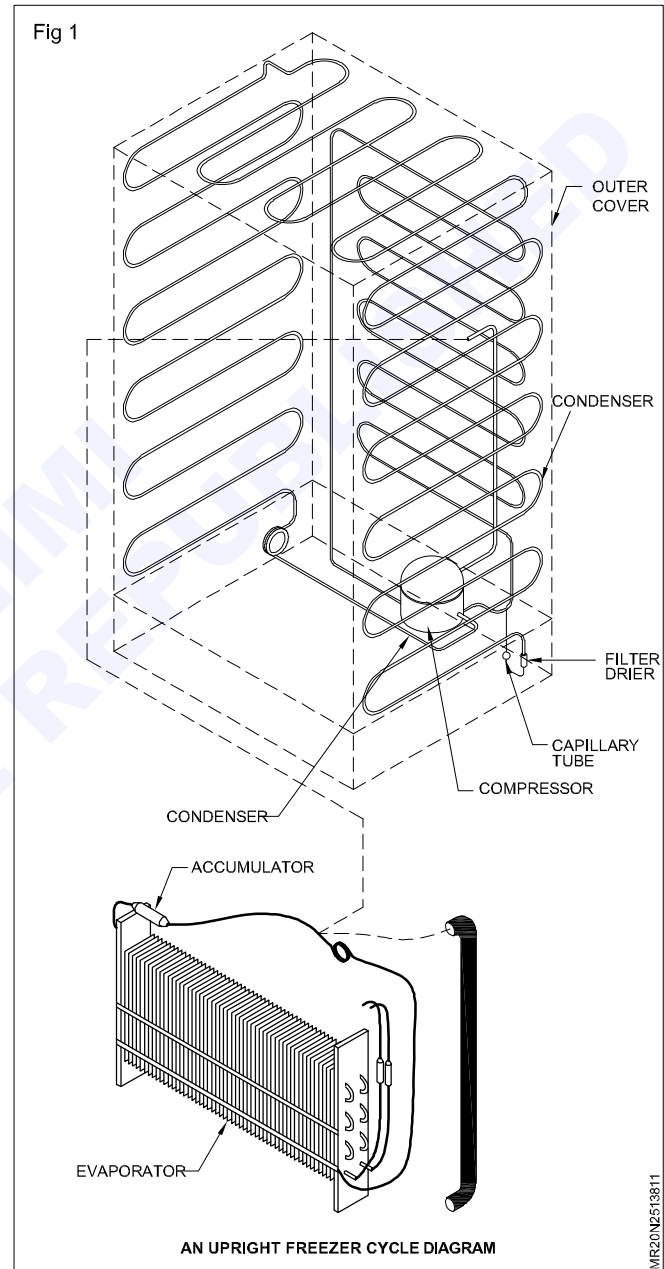
The insulation will be high density, polyurethane foam is injected by using high pressure injection machine of thickness 50mm.

Function of deep freezer: The evaporator is very closely surrounds the inner liner. During the unit operation refrigerant flows through capillary tube to evaporator. As the evaporator tube is attached to cabinets' inside lining, when the refrigerant flows through evaporator coil, the entire cabinet surface gets cooled. And all the refrigerant gets evaporated to vapour by the time it passes through evaporator tubes. Any left out liquid refrigerant flows into accumulator placed at the end of evaporator coil.

The accumulator outlet connected to suction line into compressor. The vapour goes to compressor to form high side pressure. High temperature vapour from the discharge side of the compressor flows through pre-cooler starting at top back of the cabinet. The pre-cooler zig zags across the back of cabinet to the down of compressor forming a loop (the loop in the bottom of compressor is immersed in oil). Here partial cooled refrigerant picks some heat from the oil besides lowering oil temperature in compressor. From here the high pressure vapour reaches top end of cabinet from where it zig zag across ends in front of cabinet and returns to filter drier completing high side circuit.

Differentiate various types of deep freezers: The commercial deep freezers are classified a chest type freezers, upright freezers, reach in refrigerators, display cases.

The advantage of chest type freezers is very cold air in chest type freezer does not spill out each time the lid is opened. This controls considerable amount of moisture entering the cabinet. Air changes are less when the cabinet is opened. Hence most chest type freezers have manual defrost (needed four times a month).



Upright freezer makes frozen food storage easy. Frost free and auto defrost mechanism in these freezer is very good. The construction and system function is similar to chest type freezer, except the insulation is heavier and there is a different in motor controls. The auto defrost cycle is activated every 12 hours. In frost free models a fan circulate air through evaporator then through the food section. The evaporator located behind the baffle.

Reach in refrigerator has single or multidoor. A blower coil is usually installed in the top or on the rear inside of the cabinet so the flows to and from the coil is unrestricted. Reach in refrigerator are self-contained which requires drain lines only to be installed. The glass door permits effective display when desirable. Reach in refrigerator or cabinet serves as food storage, bottle beverage storage and dairy food storage. The temperature in this unit does not exceeds -5°C .

Understand food preservation

Refrigeration process is final phase to preserve foods. So it is better to understand good refrigeration process and how to control it to get best results.

Short time preservation of food for domestic and industrial is not critical. Long time preservation need to be understood. Some products cannot be kept over a week, others can be kept for months or for years with proper freezing.

All types of foods such as plants or animals foods contain three major molecular components, carbohydrates, proteins and fats. These chemical compounds provide vitamins, minerals required by human beings.

The destruction above ingredients can cause food spoilage such as bad odours, bad taste, uncommon colour.

Methods of food preservation: Done by two methods

- 1 Eliminating organism from the food products
- 2 Retarding the action of destruction to a permissible level.

Fruits and vegetables remain alive even after harvesting and used as food later and in the meantime it is stored during their growth. This living activity can be retarded by low temperature application which retards enzymic activity.

Animal products decompose easily. They are naturally attacked first by natural enzymes. These effects can be controlled by low temperature which arrest natural activity of enzymes.

The temperature for preservation is between -15°C to -25°C for long term freezing. By way of quick freezing cold air is brought out by forced circulation for freezing the food in storage.

Humidity plays an important role in spoilage of food. It shrinks the food, evaporates water from the food. To avoid this high relative humidity of 90% in the air is preferred. But this high R.H. is not preferable with all foods, it creates favourable atmosphere for growth of bacteria.

Importance of servicing deep freezer

Deep freezers are classified into three types

- Chest type deep freezers
- Upright freezers
- Display deep freezers

Deep freezers in the long run usage are subject to decrease in its performance. Hence it needs periodic servicing.

Storage life and temperature for food kept in freezer

Sl. No	Food	Maximum temperature	Storage life
1	Vegetables (except leaf vegetables)	0°F (-17.8°C)	1 year or more
2	Fruits	10°F (-12.2°C)	4 months
3	Meats Beef Lamb	0°F (-17.8°C) 10°F (-12.2°C) 0°F (-17.8°C) 10°F (-12.2°C)	1 year or more 4 months 10 months 4 months
4	Fish	0°F (-17.8°C)	4 months
5	Poultry	0°F (-17.8°C) 10°F (-12.2°C)	10 months 4 months
6	Dairy products	0°F (-17.8°C) -210°F (-12.2°C)	1 year 3 months

External body servicing : During the usage of deep freezers in long run and the different types of foods stored and when shifting food items for usage, food stored tends to spill over the external body of deep freezers, and as frozen food melts to give droplets of water which when dries out over the enamel painted body of deep freezers, changes the colour of paint, also when frequent opening and closing the door/lid of the deep freezers tents and damages the external body of deep freezers.

Also due to radiation from external lights will diminish the paint enamel colour of deep freezer's external body and change in colour will allow radiation heat to penetrate inside the deep freezers, bring about temperature rise, thereby retarding the efficiency of the deep freezer.

Internal body of deep freezer servicing: Due to frequent opening of deep freezer doors/lid, the atmospheric hot air carrying moisture get settled inside deep freezers compartment as small ice - pellets and through the other food preserved inside deep freezer give away a fractional 1% to 2% of moisture to form ice pellets. Also if fruits are stored in house hold deep freezers without moisture proof packing, gives away its water content in fruits as moisture which gets accumulated as frost inside freezer compartment. Thereby different foods preserved has different molecular component structure, when mixed in the form of ice crystals brings chemical reaction and food degrading and inner surface patches of fungus formation and colour change inside deep freezer compartments. To overcome the foul smell and to remove other dirt collected inside the deep freezer compartment from the environment. It is necessary to service deep freezer periodically.

Servicing the system : The compressor and condenser with fan motor which is fixed in front bottom right side of deep freezer in chest type deep freezers, where a lot of dust and dirt gets accumulated, when the unit is running for months together. Also with rats and other flies gets trapped inside this compartment, we get foul and dirty smells and also the performance of deep freezers gets affected. To overcome above difficulties, we should periodically clean the compressor, clean the condenser

fins, check the blade fixing, fan motor oil and repaint the fan motor base, besides checking the electrical circuit.

Servicing of electrical components

Thermostat: Thermostat is a switch which controls the temperature of deep freezer by making or breaking the electrical circuit of compressor motor.

Automatic defrost timer: Thermostat is a temperature standard control serving as 'ON' and 'OFF' switch for the compressor according to required temperature maintains in freezer compartment.

The compressor is controlled by temperature control switch during both the defrost and refrigeration cycle. The defrost control switch be in defrost position during the thermostat cutoff position (when the compressor is OFF).

The defrost cycle will not start until the temperature control switch closes and starts the compressor. The switch arm is moved to the defrost position by an electrical clock. The switch arm is returned to the normal position by a power element which is responsive to changes in temperature.

Identify parts and controls with function and specification in deep freezer

How to service chest freezer lid: Remove cover of the hinges. Mark position of hinge adjustment, check the counter balance spring for its action and rectify if you find any defects. Service the spring and screws with proper lubricant. Put back the hinge cover and set and align lid with the chest type freezer body for even seating. Now check the function of lid by opening and closing the lid of chest type freezer. Refer (Fig 2) Lid hinge for chest type freezer.

Preventive maintenance and troubleshooting of deep freezer: Basic steps to troubleshoot a deep freezer

When attempting a improper function of deep freezer go into all sort of details. Avoid distance trouble shooting have a positive approach, tackle problem one by one, look for simple point, take prompt action.

Also, to keep deep freezer from trouble free performance. All mechanical equipment like deep freezers needs strict maintenance. In today' context of energy crisis and material shortage, proper and timely preventive service can result in as considerable amount of saving in power and material. Good maintenance and service is possible if the unit is properly installed and commissioned.

Failures

Some failures occurs in a plant that seems to be small and have no significance can be come serious trouble. This will result heavy expenditure, wastage of precious time and lots of extra work. Usually at a most in convenient time. So periodical checking and servicing helps in anticipating trouble and taking correct action.

The best advice to trouble shoot is to patiently listen to customer (layman) queries and get the lead of the problem successful troubleshoot.

Knowledge of basic fundamental, equipment and capacity to think and analyse. A majority of the problem are usually due to minor defects which when tackled in a calm and collected way can be solved and rectified easily.

Causes for the defects 'Unit trips'

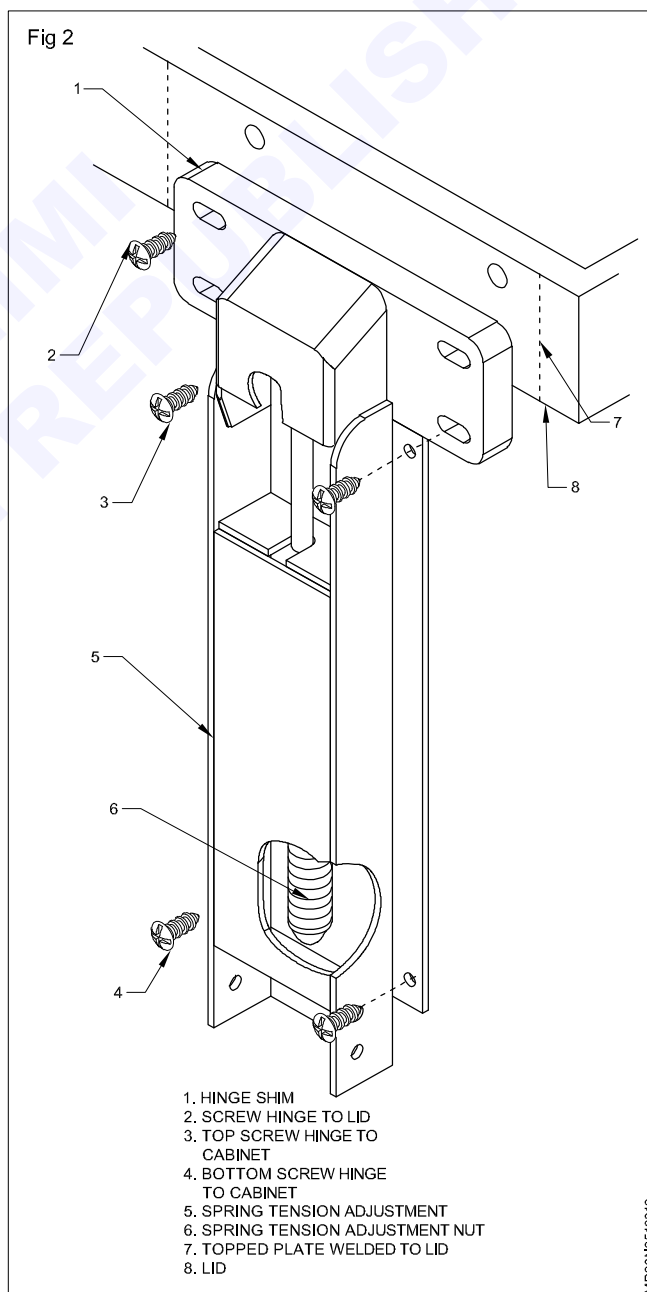
The trouble shoot for defects 'Unit Trips' are of two types

- unit trips when trying to start
- unit trips after it gets started

Unit trips when trying to start

Unit tripping when trying to start can be due to errant main supply caused by uneven voltage and Loose wiring, extremely long extension chord, several appliances on same circuit and undersized cable can bring about a deep freezer to trip when trying to start.

A relay coil burnt or a weak bimetal disc of an overload protector or a weak starting capacitor can make compressor to trip.



Unit trips after it gets started

There are various causes/sub-causes that can bring about unit to trip after the unit get started. But a limited and selected cause are listed below. High discharge temperature can be due to (contaminant) or non-condensable gas in the system, condenser hot air short cycling can make the deep freezer to trips after the unit gets started.

Likewise if the evaporator gets enormous amount of warm or hot food load more frequently will call the unit to trip now and then as the evaporator will not obtain the required temperature.

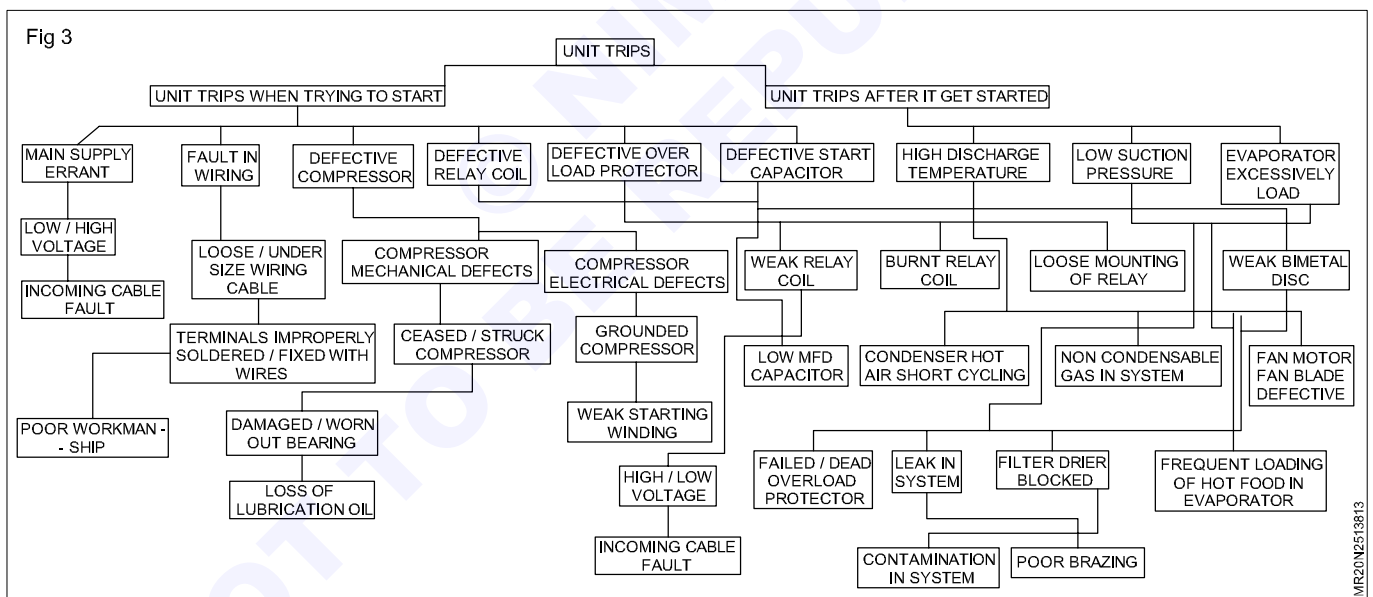
Due to leak in the system and if due to contamination drier filter get blocked and brings low suction pressure and the unit trips.

Preventive steps to rectify the defect 'Unit trips' (Fig 3)

Periodical checking of the system for refrigerant leaks. In addition to the refrigerants being very costly a system running short of the refrigerant can get affected due to excessive cylinder head temperature. In hermetically sealed units, this can also result in compressor motor burnt out and system contamination. Checking operation of safety and operating controls periodically. It is imperative to verify that all safety controls are functioning properly that all safety controls are functioning properly to protect the equipment against abnormal working conditions.

If there is any fault in the incoming cable due to poor workmanship can cause electrical breakdown which can lead to unit trips, when it tries to start. Electrical breakdown is the cause for poor electrical connections. When current passes through a electrical wires which is improperly connected to circuit will melt the insulation of the wires, these problem given way to short circuiting the electrical system. Also replace wire which has damaged brittle insulation. Brittle insulated wire will crack when bent. Also make good solder metal terminals at end of stranded wire.

Adherence to an effective planned schedule to keep the heat transfer surface such as condenser free from dust, corrosion etc. This is because refrigeration being a heat transfer equipment, even a small amount of fouling of the heat transfer surfaces can reduce its and complete system capacity and increase power consumption. Lubricate moving parts at right time with quality lubricants with right and required amount no less or no more (extra) Vibration has to be checked periodically because vibration is one major factor contributing to refrigerant leaks. Also seasonal periodical overhaul of components is must. Maintenance of a proper record sheet with reading of Deep freezer. A fully recorded record sheet helps in trouble shooting a fault. It is also a tool for planning and scheduling maintenance work to avoid emergency repairs and save time.



Analyse the causes for 'Poor cooling'

A compressor which is not pumping adequately will produce very little cooling effect. The evaporator will not get sufficient temperature to get cut-off temperature of thermostat, even with, continuous running of compressor. Check operating pressures. If the high side pressure is low and low side is high, a defective compressor is confirmed and must be replaced. In correct refrigerant charge is also indication of 'poor cooling' A system undercharged or if there is a gradual leak of refrigerant, that can be noticed at last few coil of evaporator free from frost. The system will run continuously as the temperature control does not make cut out due to evaporator does not

reaches the required cooling temperature. The head pressure will be lower than normal when the system has stabilized.

In over charged system, there is a extension of frost to the outlet of Evaporator leading to suction line, and better explained in problem tree. If the over charge is great enough, the control contact may not get cold enough to cut out the compressor, resulting in long period of operation. Restriction in evaporator is also the cause of poor cooling It happens by minute particles (contaminant) or moisture get trapped (may freeze or lodged in the evaporator or kinked tubing

The evaporator will have little or no frost formation and compressor will run continuously. Moisture in system will usually freeze at the outlet of the capillary tube where it joins evaporator tubing, but the remaining evaporator tubing will be free from frost.

Due to leaky door (door gasket not evenly seated or closed) or by frequent opening of door/lid of the deep freezer or by highly moist Environment, excess frosting get coated over evaporator and this coating acts as Insulation between cooling coil and cooling compartment thus making poor cooling.

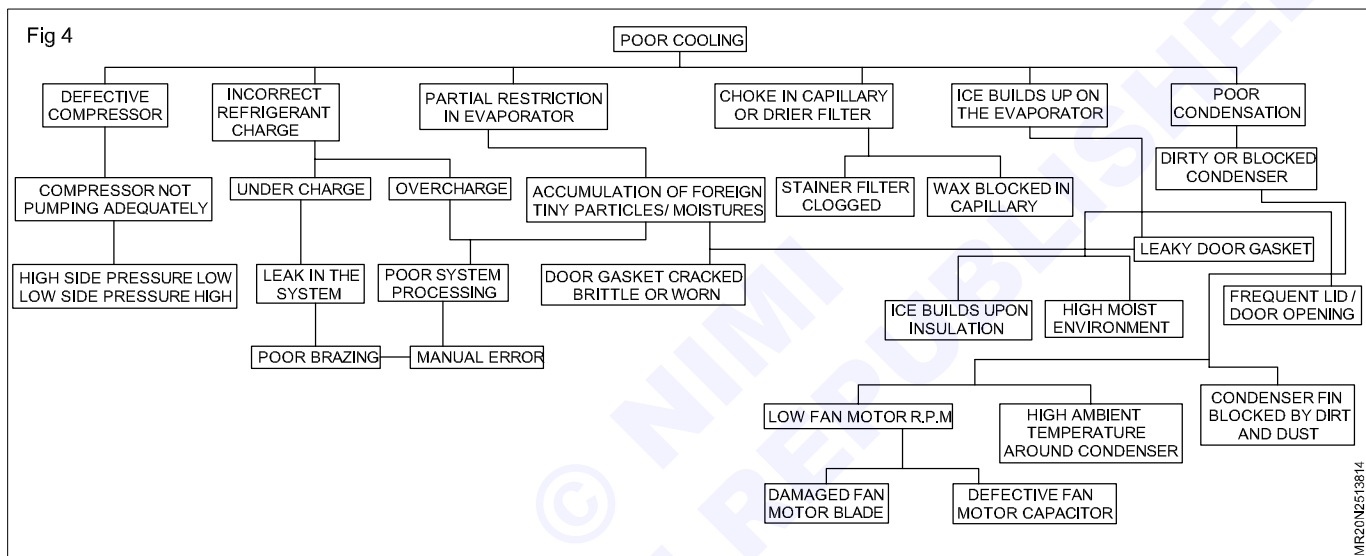
Dirty or obstructed condenser can have great impact on the performance of the system. It will adversely affect by raising the discharge pressure and affecting cooling efficiency and causing poor cooling of the system.

Ways to rectify 'poor cooling' (Fig 4)

Change components which matches the original ones, tighten any loose wiring, Install auto transformer to maintain constant and even voltage, do not overload Deep freezer and do not make frequent opening of door lid to avoid compressor failure causing poor cooling.

Avoid blockage of foreign particles or tiny moisture affecting the system performance. It is advised to thoroughly clean the system with sufficient Dry Nitrogen pressure, leak test with soap solution, vacuumise with 2 stage rotary pump and charge the refrigerant by weight.

Poor brazing and poor system processing are the causes for under or overcharge of refrigerant in the system. System leak-test and brazing to be done perfectly, besides refrigerant has to be charged by weight.



Oil fan motor and bearings, tighten fan blade L-Allen screws also check RPM of fan Motor. Clean condenser fins periodically, straighten fin which are bent or pressed. Also allow enough circulation of air in condenser to give good condensation effects and increase the performance of cooling.

Cause analysis for no cooling in deep freezer

The Complaint 'No Cooling' in a given Deep Freezer will be related to different causes. The fuse will become blow/cut due to high current caused.

Also choke in the system will restrict the flow of refrigerant effecting 'No Cooling' in Deep freezer.

Due to mechanical faults of compressor and due to failure of electrical controls of compressor will make 'no cooling' in Deep freezers.

Analyse cause behind the defects

Poor workmanship and bad handling or mishandling of the Deep freezer are the causes behind the defects 'No Cooling' in Deep freezer.

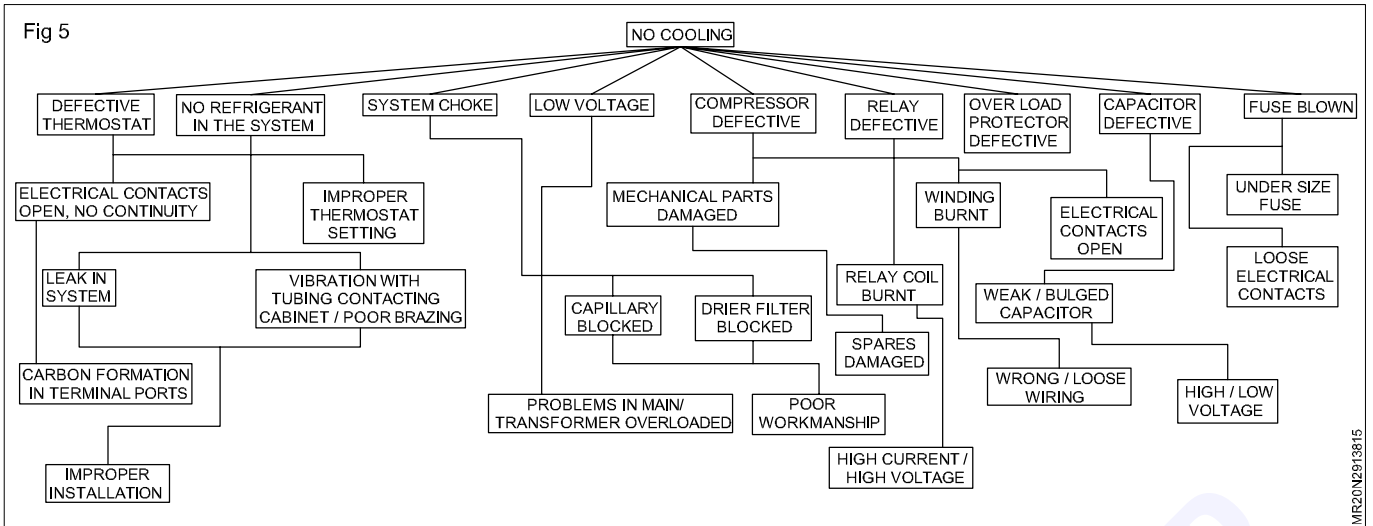
First the electrical circuit of the unit. Before installing the unit service chord has to be checked properly for loose connection to the plug and so as the socket, the input wire connected to socket to be tightened firmly to avoid loose contacts, which leads to frequent tripping of compressor and overheating of terminals and even burning of terminals leading to major damage causing compressor to burn.

Secondly the gas leak in the system or restriction of flow of refrigerant in the system, leading to 'no cooling' and even ceasing of compressor.

Ways to rectify 'No Cooling' (Fig 5)

A blown fuse will cause to stop the compressor from working. The blowing of fuse can be avoided by checking and fixing the exact required fuse size approx. of 225% of Normal usage amperes. Isolate the compressor by disconnecting all its controls and run the compressor directly to check for any short (grounded body) of compressor. The burnt out overload protector will make compressor to take high amps and so as the defective relays and defective capacitors, will make the compressor to draw high amps. When compressor try to start and take very high amps thus causing the fuse to blow out.

Fig 5



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So check independently each controls of compressor (i.e.) relay overload protector, starting capacitor and if found defective replace it. Secondly, check thermostat leads for carbon deposits or melted or broken terminals of thermostat. (Replace the thermostat if the above mentioned defects are identified)

Leak in the system or system choke or restriction in flow of refrigerant can cause 'No Cooling'.

In both the cases the reason for the complaint is due to mishandling of unit or incorrect installation and poor workmanship can cause the system to make gas leak or choke in the system. So charge by weight, pinch and seal by brazing perfectly. Do correct Installation.

Steps to be taken to prevent 'No Cooling'

The following few steps can be carried out when Installing or servicing Deep Freezers to avoid 'No Cooling'

- Check and repair incorrect electrical characteristics
- Wire with shortest possible cable into a 225% fused plug.
- Confirm that the cabinet is levelled from side to side, front to back, using a spirit level, to avoid vibration, rattling and noise.
- Make sure that no external pipes or fittings are in contact with other metallic surface or walls

Ice cube machine - Type function, installation & servicing

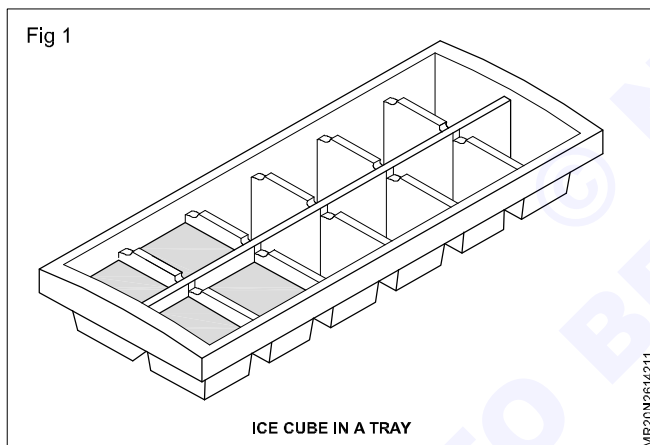
Objectives: At the end of this lesson you shall be able to

- explain one different methods of ice production
- explain principles of ice making
- explain different types of ice cube makers and their working
- explain the installation and servicing of ice cube machine.

Ice cube machine: An ice cube is small, roughly cube-shaped piece of ice (frozen water) conventionally used to cool beverages. Ice cubes are sometimes preferred over crushed ice because they melt more slowly, there are different ice cube maker mechanisms. The simplest and the one used in domestic mechanism freezers, freezer's water in ice cube trays. Ice cube makers used various types of refrigeration systems.

Methods of production: Ice cubes are produced domestically by filling an ice cube tray with water and placing it in freezer. Many freezers also come equipped with an ice maker, which produces ice cubes automatically and stores them in a bin from which they can be dispensed directly into a glass.

Ice cube tray (Fig 1)



An icemaker, ice generator or ice machine may refer to either a consumer device for making ice, found ice cube trays are designed to be filled with water, then placed in a freezer until the water freezes to ice producing ice cubes. Trays are often flexible, so the frozen cubes can be easily removed by flexing the tray. "Twist" ice trays have a simple spring-loaded mechanism with a lever that is used to turn the tray upside down and flex at the same time such that the cubes drop are collected in a removable tray below and return the ice cube tray to its upright position without removing it from the freezer, which can save time and reduces accidents and mess, though the tray has to be removed to be collected and the ice cube tray still has to be removed to be refilled. An alternative system is an aluminium tray with a lever that raises the ice cubes, freeing them from the tray. A motorized version of this is found in most automatic ice-making freezers.

Several companies now offer pre-filled disposable ice trays for home freezing, which they claim provide better taste and reduced risk of contamination.

Inside a home freezer, a stand-alone appliance for making ice, or an industrial machine for making ice on a large scale. The term "ice machine" usually refers to the stand alone appliance.

The ice generator is the part of the ice machine that actually produces the ice. This would include the evaporator and any associated drives/controls/sub frame that are directly involved with making and ejecting the ice into storage. When most people refer to an ice generator, they mean this ice-making subsystems alone, minus refrigeration.

An ice machine however, particularly if described as packaged would typically be a complete machine including refrigeration and controls, requiring only connections to utilise.

The term icemaker is more ambiguous, with some manufacturers describing their packaged ice machine as an icemaker, while others describe their generators in this way.

Principle of ice making: All refrigeration equipment are made off our key components the evaporator, the condenser, the compressor and the throttle valve. Ice machines all work the same way. The function of compressor is to compress of low temp. low-pressure refrigerant vapour to high-pressure of high temp. vapour and deliver it to the condenser. Here, the high-pressure vapour is condensed into high-pressure liquid, and drained out through the throttle valve to become low-pressure of low temp liquid. At this point the liquid is conducted to the evaporator, where heat exchanging occurs, and ice is created. This is one complete refrigeration cycle.

Consumer icemakers

Freezer icemakers

Automatic icemakers for the home were first offered by the several company around 1953. They dire usually found inside the freezer compartment of a refrigerator. They produce crescent-shaped ice cubes from a metal mould. An electromechanical or electronic timer first opens a solenoid valve for a few seconds, allowing the mould to fill with water from the domestic cold water supply. The timer then closes the valve and lets the ice freeze for about 30 minutes. Then, the timer turns on a low-power electric

heating element inside the mould for several seconds, to melt the ice cubes slightly so they will not stick to the mold. Finally the timer runs a rotating arm that scoops the ice cubes out of the mold and into a bin, and the cycle repeats. If the bin fills with ice, ice pushes up a wire arm, which shuts off the icemaker until the ice level in the bin goes down again. The user can also lift up the wire arm at any time to stop the production of ice.

Early icemakers dropped the ice into a bin in the freezer compartment, the user had to open the freezer door to obtain ice. In 1965 Frigidaire introduced icemakers that dispensed from the front of the freezer door. In these models, pressing a glass against a cradle on the outside of the door runs a motor, which turns an auger in the bin and delivers ice cubes to the glass. Most dispenser can optionally route the ice through a crushing mechanism to deliver crushed ice. Some dispensers can also dispense chilled water.

Portable icemakers

Portable icemakers are units that can fit on a countertop. They are the fastest and smallest icemakers on the market. The ice produced by a portable icemaker is bullet shaped and has a cloudy, opaque appearance. The first batch of ice can be made within 10 minutes of turning the appliance on a adding water. The water is pumped into a small tub with metal pegs immersed in the water. The pegs have a heating and cooling system inside that freeze the water around them and then heat up so the ice slips off the peg and into the storage bin. Portable icemakers will not keep the ice from melting, but the appliance will recycle the water to make more ice.

Built in and freestanding icemakers

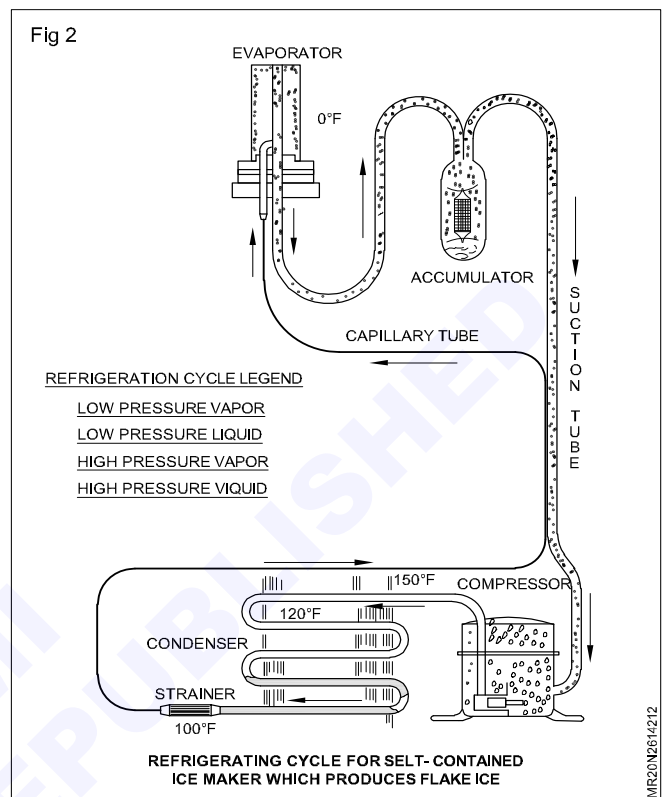
Built-in icemakers are engineered to fit under a kitchen or bar counter, but they can be used as freestanding units. They produce crescent-shaped ice like the ice from freezer icemaker. The ice is cloudy and opaque instead of a clear, because the water is frozen faster than in clear cube icemakers. In the process, tiny air bubbles get trapped, causing a cloudy appearance of the ice.

Industrial icemakers: Commercial ice cube makers improve the quality of ice by using moving water. The water is run down a surface that is constantly at 0°C(32°F) because only water without impurities will freeze at this temperature on a surface. Water with impurities requires lower temperatures to freeze and will continue to wash down the surface and through the drain of a commercial icemaker. Air and undissolved solids will be washed away to such an extent that tin horizontal evaporator machines the water has 98% of the solids removed, resulting in very hard, virtually pure, clear ice. In vertical evaporators the ice is softer, more so if there are actual individual cube cells. Commercial ice machines can make different sizes of ice like flakers, crushed, cube, octagon and tube.

When the sheet of ice on the cold surface reaches the desired thickness, the sheet is slid down on to a grid of wires, where the sheet's weight causes it to be cut into the desired shapes, after which it falls into a storage bin.

Flake ice machine (Fig 2)

Flake ice is made of mixture of brine and water (max 500g [18oz] salt per ton of water), in some cases can be directly made from brine water. Thickness between 1 and 15 mm(1/16 and 9/10 in), irregular shape with diameters from 12 to 45mm (1/2 to 1 3/4 in).



The evaporator of the flake ice machine is a vertically placed drum-shaped stainless steel container, equipped with the rotating blade which spins and scratches the ice of the inner wall of evaporator. When operating, the principal shaft and blade spins anti-clockwise pushed by the reducer. Water is sprayed down from the sprinkler, ice is formed from the water drain on the inner wall

The figure showing the cycle diagram for a flake ice maker, water is made to flow over an evaporator shaped like a cylinder. The surface of the evaporator is cold (0 F or -18c), so that the water is rapidly frozen.

Applications: Sea water flake ice machine can make ice directly from the sea water. The ice can be used in fast cooling of fish and other sea products. The fishing industry is the largest user of flake ice machines flake ice can lower the temperature of cleaning water and sea products therefore it resists the growth of bacteria and keeps the seafood fresh.

Because of its large contact and less damage with refrigerated materials, it is also applied in vegetable fruit and meat storing and transporting.

In baking during the mixing of flour and milk, flake ice can be added to prevent the flour from self-raising. In most cases of biosynthesis and chemosynthesis. Flake ice is used to control the reaction rate and maintain the liveness. Flake ice is sanitary clean with rapid temperature reduction effect.

Flake ice is used as the direct source of water in concrete cooling process, more than 80% in weight. Concrete will not crack if it has been mixed and poured in constant and low temperature.

Flake ice is also used for artificial snowing, so it is widely applied in ski resorts and entertainment park.

Cube icemaker

Cube ice machines are classified as small ice machines, in contrast to tube ice machines, flake ice machines or other ice machines. Common capacities range from 30kg(66lb) to 1755 kg (3,869 lb). Since the emergence of cube ice machines in the 1970s they have evolved into a diverse family of ice machines.

Cube ice machines are commonly seen as vertical modular devices. The upper part is an evaporator and the lower part is an ice bin. The refrigerant circulates inside pipes of self contained evaporator, where it conducts the latent heat from water, and freezes the water into ice cubes. When the water is thoroughly frozen into ice, it is automatically released, and falls into the ice bin.

The ice bin can also be equipped with compressors. Generally ice cube machines with over 320kg (710 lb) capacities have built-in compressors in the ice bin for storage, prior to sales, for use when demands are large.

Ice cube is created in a cubic shape, with each edge usually between 15 and 35mm (9/16 and 13/8 in). The surface area of every ton of cubic ice is approximately 1.383m² (14890 sq ft).

Compressor

Most compressors are either positive displacement compressor or radial compressor. Positive displacement compressors are currently the most efficient type of compressor and have the largest refrigerating effect per single unit 400-2500 TR. They have a large range of possible power supplies and can be 380V, 1000 V, or even higher. The principle behind positive displacement compressors utilize a turbine to compress refrigerant into high-pressure vapor. Positive displacement compressors are of four main types screw compressor, rolling piston compressor, reciprocating compressor, and rotary compressor.

Screw compressors can yield the largest refrigerant effect among positive displacement compressor, with their refrigerating capacity normally ranging from 50TR to 400TR. Screw compressor also can be divided to single-screw type and dual-screw type. Dual-screw type is more often seen in use because it is very efficient.

Rolling piston compressor and reciprocating compressors have similar refrigerating effects and maximum refrigerating effect can reach 600 kW.

Reciprocating compressors are the most common type of compressor because the technology is mature and reliable. Their refrigerating effect ranges from 2.2kW to 200 kW. They compress gas by utilizing a piston pushed by a crank shaft.

Rotary compressors, mainly used in air conditioning equipment, have a very low refrigerating effect, normally not exceeding 5 kW. They work by compressing gas using a piston pushed by a rotor, which spins in an isolated compartment.

Condenser

All condenser can be classified as one of three types air cooled water cooled, or evaporative cooling

- An air cooling condenser uses air as the heat conducting media by blowing air through the surface of condensers, which carries heat away from the high-pressure, high-temperature refrigerant vapour.
- A water cooling condenser uses water as the heat conducting media to cooling refrigerant vapour to liquid.
- An evaporative condenser cools the refrigerant vapour by using heat exchange between the condenser pipes and the evaporated water which is sprayed on the surface of the pipes. This type of condenser is capable of working in warm environments. They are also very efficient and reliable.

Tube ice generator

The tube ice generator in which the water is frozen in tubes, extended vertically within a surrounding casing defining a freezing chamber spaced above, the bottom of which is a distributor plate having apertures surrounding the tubes and defining the separate chamber into a warm gas is passed to heat the tubes to cause the ice rods to slide there from.

The figure shows the process during the freezing part of the cycle of ice cube making. Defrost cycle (hot gas) is shown in figure and figure shows the water circuit with the recirculation pump and ice tube forming tubes.

Another style of ice cube maker is shown in figure. Water flows through vertical stainless steel tubes. When a hollow square length of ice is formed, the refrigeration stops. Hot gas defrosting starts and as the long square rods of ice slide down the tubes, they are cut in to cubes. When all the tubes are empty, the refrigeration cycle starts over again.

Applications

Tube ice can be used in the cooling process, such as temperature controlling fish fresh freezing and beverages bottle freezing. It can be consumed alone and with food or beverages.

Large scale ice cube production

Dedicated ice-maker machines can be used to produce ice cubes for laboratories and academic use. Ice cubes are also produced commercially and sold in bulk these ice cubes, despite their name, are often cylindrical and may have holes through the centre.

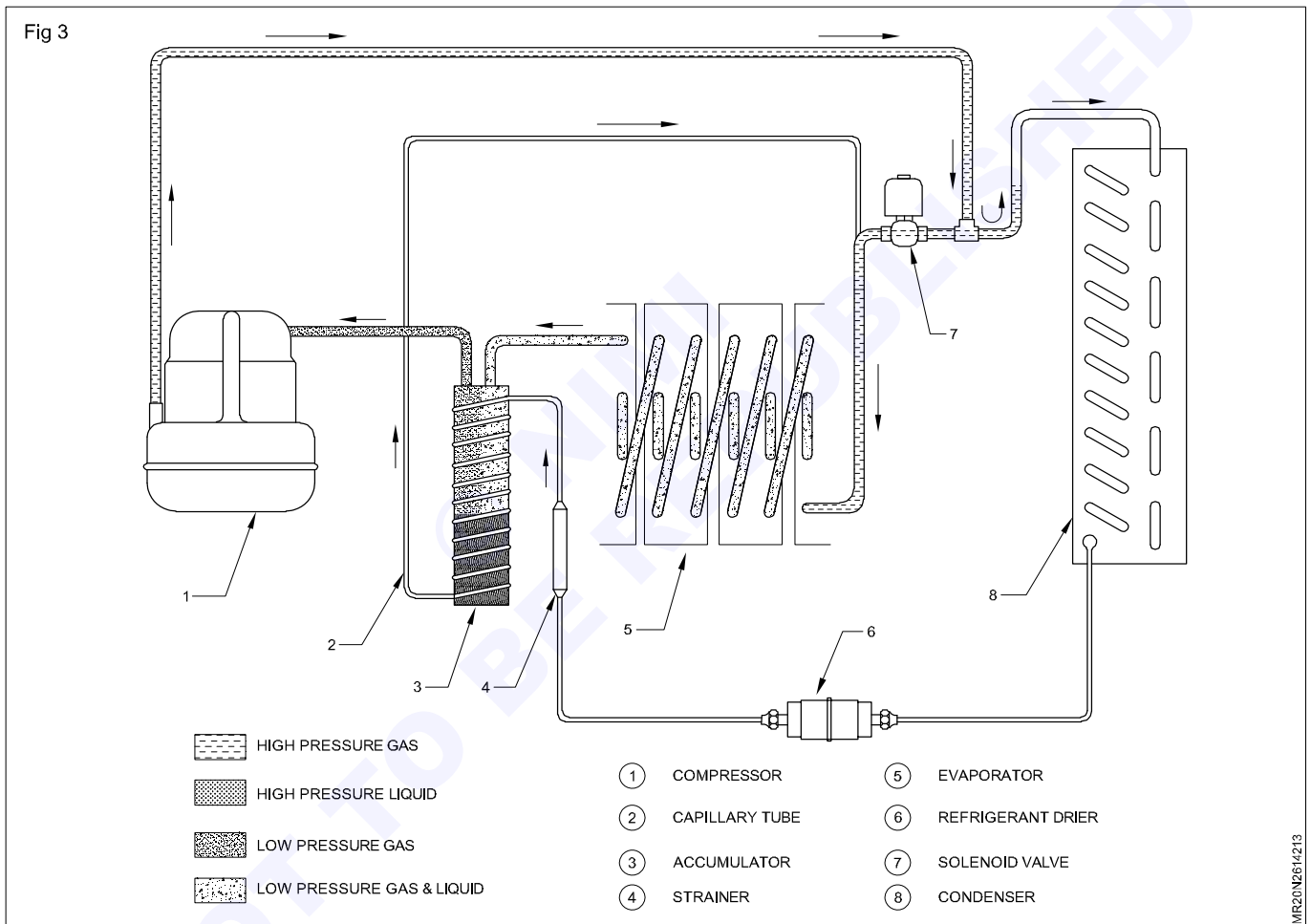
An interesting characteristic of commercially made ice cubes is that they are completely clear, lacking the clouding found in the centre of domestically made ice cubes. Cloudy ice cubes result when water is frozen quickly, or when the water is high in dissolved solids.

When water is cooled to its freezing point and ice starts to form, dissolved gases can no longer stay in solution and come out as microscopic bubbles. However as ice floats in water, once there is enough ice to form a layer on the surface, the ice layer traps all bubbles within the ice cube. Commercial ice-makers use a flowing source of purified water to make ice with cooling elements at the bottom, allowing the bubbles to be washed away from the top as the cube grows.

Working of ice cube machine (Fig 3)

With the ICE/OFF/WASH switch in the ICE position the compressor, water pump and condenser fan motor (when applicable) will get energized starting the freeze cycle. During the freeze cycle, water is circulated over the evaporator(s) where the ice cubes are formed. When the

suction pressure has pulled down to the proper cut-in pressure of the timer initiate (pressure control), the contact will close and energize the time delay module (timer). At this time. The cubes will be close to completion. The remaining portion of the freeze cycle is determined by the timer setting. The timer is pre-set at the factory to achieve the proper ice bridge thickness but may need to be adjusted upon initial start up. Once the amount of time on the timer has passed, the control relay will be energized and the machine will enter harvest. Power is now supplied to the water purge valve, hot gas valve, and the harvest motor. The water purge valve opens, and allows the water pump to purge the water remaining in the water trough, removing impurities and sediment. This allows the machine to produce clear ice cubes and keep mineral build up at a minimum.



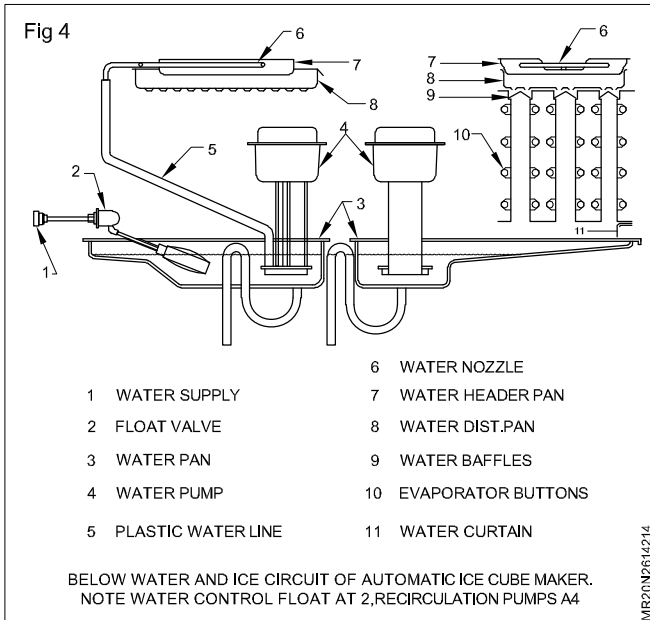
The hot gas solenoid opens allowing hot gas to go directly to the evaporator, heating the evaporator and breaking the bond between the evaporator and the ice slab. The harvest assist motor, which is also energized during harvest, turns a slip clutch, which pushes a probe against the back of the ice slab. Once the evaporator has reached approximately 40°F (4.5°C) in temperature, the slip clutch overcomes the bonding of the ice to the evaporator and pushes the slab of ice off of the evaporator and into the storage bin. The clutch also actuates a switch that rides on the outer edge of the clutch. When the clutch completes one revolution, the switch is tripped and the machine enters the next freeze cycle. When ice drops into a full bin during harvest, the splash curtain is held open which

activates bin switch shutting the machine off. When ice is removed from the bin, the splash curtain will close and the machine will come back on. (Fig 4)

Installation of ice cube machine

It is essential to read the installation parameters specified by the manufacturer prior to installing the machine.

Installation is one of the prime most criteria at which the proper functioning of a machine can be ensured for a long time with minimum maintenance. Every machines should have their own ambient and operating temperatures specified by the manufacturer. The general installation steps is explained as follows.



Ambient Operating Temperatures Minimum Operating Temperature 50°F (10°C)

Maximum Operating Temperature 100°F (38°C), 110°F (43°C) on 50Hz.

Minimum incoming water temperature 100°F (38°C)

Minimum incoming water pressure 20 psi (1.4 bar)

Maximum incoming water pressure 60 psi (4.1 bar)

If water pressure exceeds 60 psi (4.1 bar) a water pressure regulator must be installed.

Drains: Flexible tubing is not recommended. Route bin drain, purge drain and water condenser drain individually to a floor drain. The use of condensate pumps for draining water is not recommended.

If the purge drain fitting is plastic
DO NOT apply heat to the purge drain area
DO NOT overtighten

Water filtration: A water filter system should be installed with the ice machine and install it properly.

Clearance requirement for self-contained air cooled ice machines must have a minimum of 6 inches (15cm) of clearance at the rear, top, and sides of the ice machine for proper air circulation.

Dispenser Application: A thermostatic bin control kit should be installed if the ice cube machine is placed on a dispenser.

Electrical specification refer to the serial plate at the rear of the ice machine to make sure proper voltage and circuit breaker size have been supplied. Make sure the machine is on a dedicated circuit. The electrical supply fixed wiring must be provided with a disconnect means having a separation of at least 3mm in all poles.

Adjustments required while installation

Level the machine within 1/8 inch in all direction and check the bin control for proper adjustment. Ensure the

water in the water trough is always in proper level. Check the ice bridge for proper thickness and check the water regulating valve adjustment if water cooled. A water filtration system should be installed with all ice machines. Check the filter manufacturer's instruction for proper installation. For water supply lines, use 1/4 inch O.D minimum tubing on air cooled machines, and on water cooled machines 3/8 inch O.D. minimum tubing must be run to the condenser. The purge drain should be a minimum of 5/8 inch O.D tubing. The condenser drain on water cooled units should be 3/8 inch O.D. minimum.

Connect power supply to the terminal block in the control box or at the rear junction box if equipped. Ensure the machine is level within 1/8 inch in all directions. Remove any shipping or packaging material. If the machine has been installed, follow the start-up procedures.

Startup procedure

Before starting the machine make sure the machine is level within 1/8 inch in all directions, the bin or dispenser leg height can be adjusted by rotating the leg foot. Check the water level in the water trough. It should be approximately 1/2 inch above the top of the water pump impeller housing. The water level can be adjusted by bending the float arm. Move the ICE-OFF-WASH switch to the ICE position. The switch is located in the control models to access the control box. Check for proper water flow over the evaporator(s). There should be an even flow of water over the evaporator(s). Check the water regulating valve (water cooled machine) for proper adjustment by measuring the water flow over the evaporator(s) during harvest, check the bridge thickness of the ice slab. All water supply lines must be installed as per the bridge thickness of the ice slab. The bridge should be between 3/16 to 1/8 inch depending upon different models. If the bridge thickness is incorrect, the timer will need adjustment. The ice bridge thickness is controlled by the freeze timer located in the control box. To check the timer setting, add the seconds of each dipswitch turned to the "ON" position. The number beside the each dipswitch represents seconds. To increase the bridge thickness increase the timer setting. To decrease the bridge thickness. Decrease the timer setting. The freeze timer can be adjusted by sliding one or more switches to either the "ON" or "OFF" position to obtain the desired setting.

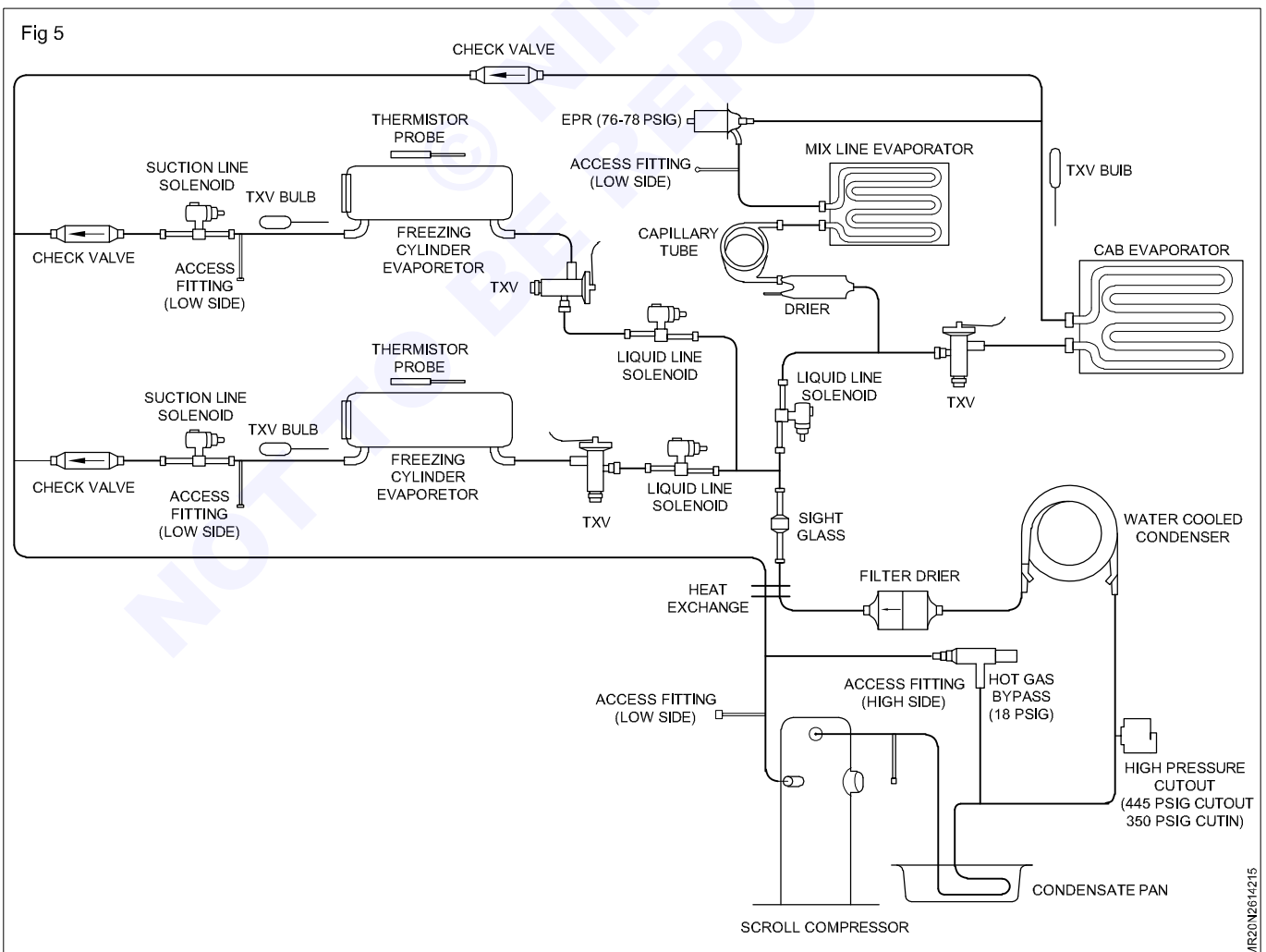
Servicing of ice cube machine (Fig 5)

Ice cube machine cleaning and sanitizing instruction. It is always preferable and less costly in the long run, to avoid possible down time by keeping the ice cube machine clean and adjusted as needed and by replacing worn out components before they can cause failure. The following is a list of recommended maintenance that will help keep the machine running with a minimum of problems.

Maintenance and cleaning should be scheduled at a minimum of twice per year. Note Electrical power will be ON when performing the following cleaning instruction.

- 1 Remove the ice machine front panel

- 2 Make sure that all the ice is off of the evaporator. If ice is being made, wait for cycle completion then turn the machine "OFF" at the ICE/OFF/WASH selector switch.
- 3 Remove or melt all ice in the storage bin.
- 4 Add recommended amount of approved nickel safe ice machine cleaner to the water trough according to label instructions on the container.
- 5 Initiate the wash cycle at the ICE/OFF/WASH switch by placing the switch in the "WASH" position. Allow the cleaner to circulate for approximately 15 minutes to remove mineral deposits.
- 6 Depress the purge switch and hold until the ice machine cleaner has been flushed down the drain and diluted by fresh incoming water.
- 7 Terminate the wash cycle at the ICE/OFF/WASH switch by placing the switch in the "OFF" position. Remove the splash curtain and inspect the evaporator and water spillway to ensure all mineral residues have been removed.
- 8 If necessary, wipe the evaporator, spillway and other water transport surfaces with a clean soft cloth to remove any remaining residue. If necessary, remove the water distribution tube, disassemble and clean with a bottlebrush. Reassemble all components and repeat steps 4 to 7 as required to remove residue.
- 9 Turn OFF ice machine water supply and clean the water trough thoroughly to remove all scale or slime build-up. If necessary, remove the water trough to reach all splash areas and float.
- 10 Prepare 1 ½ to 2 gallons (5.7 to 7.5 liters) of approved (EPS/FDA) sodium hypochloride food equipment sanitizer to form a solution with 100 to 200 maximum ppm free chlorine yield.
- 11 Add enough sanitizing solution to fill the water trough to overflowing and place the ICE/OFF WASH switch to the "WASH" position and allow circulation to occur for 10 minutes and inspect all disassembled fitting for leaks. During this time, wipe down all other ice machine splash area, plus the interior surface of the bin, deflector and door with the remaining sanitizing solution. Inspect to insure that all functional parts, fasteners, thermostat bulbs (if used), etc are in the correct position.
- 12 Depress the purge switch and hold until sanitizer has been flushed down the drain. Turn ON the ice machine water supply and continue to purge to the diluted sanitizing solution for another 1 to 2 minutes.
- 13 Place the ICE/OFF /WASH switch to the "ICE" position and replace the front panel.



14 Discard the first two ice harvests. DO NOT USE any ice produced from the cleaning solution.

Servicing of stainless steel parts of ice cube machine

Cleaning stainless steel commercial grades of stainless steel are susceptible to rusting if not properly maintained. It is important that you properly care for the stainless steel surface of your ice machine and bin to avoid the possibility of rust or corrosion. Use the following recommended guidelines for keeping stainless steel looking like new.

- 1 Clean the stainless steel thoroughly once a week. Clean frequently to avoid build-up of hard, stubborn stains. Also, hard water stains left to sit can weaken the steel's corrosion resistance and lead to rust. Use a nonabrasive cloth or sponge, working with, not across, the grain.
- 2 Don't use abrasive tools to clean the steel surface. Do not use steel wool, abrasive sponge pads, wire brushes or scrapers to clean the steel. Such tools can break through the "passivation" layer the thin layer on the surface of stainless steel that protects it from corrosion.
- 3 Don't use cleaners that use chlorine or chlorides. Don't use chlorine bleach or products like comet to clean the steel. Chlorides break down the passivation layer and can cause rusting.
- 4 Rinse with clean water. If chlorinated cleansers are used, you must thoroughly rinse the surface with clean water and wipe dry immediately.
- 5 Use the right cleaning agent. The table below lists the recommended cleaning agents for common stainless steel cleaning problems. Ammonia, Windex or apply with a clean cloth detergent with water, or sponge. Rinse with fantastic, 409, spic's span clean water and wipe dry. Liquid are also approve for stainless steel. Removing grease or easy-off or similar over apply generously allow fatty acids cleaners to stand for 15-20 minutes. Rinse with clean water. Repeat as required. Removing hard water spots vinegar swab or wipe with clean cloth and scale. Rinse with clean water and dry.

Important

Whenever the ice machine is taken out of operation during the winter months, the produce below must be performed. Failure to do so may cause serious damage and will void all warranties.

- 1 Turn off water to machine
- 2 Make sure all ice is off of the evaporator(s). If ice is being made, initiate harvest or wait for cycle completion.
- 3 Place the ICE/OFF/WASH switch to the "OFF" position . The switch is located in the control box.
- 4 Disconnect the tubing between the water pump discharge and water distribution tube.
- 5 Drain the water system completely.

6 On water cooled machines, hold the water regulating valve open by prying upward on the water valve spring with a screwdriver while using compressed air to blow all the water out of the condenser.

7 Remove all of the ice in the storage bin and discard.

General servicing of ice cube machine : To ensure economical, trouble free operation of ice cube, it is recommended that the following maintenance be performed every 6 months in a service.

Clean the ice-making section as per the instructions below:

- 1 Cleaning should be performed a minimum of every 6 months. Local water conditions may require that cleaning be performed more often.
- 2 Check ice bridge thickness.
- 3 Check water level in trough
- 4 Clean the condenser
- 5 Check for leaks of any kind. Water, refrigerant, oil, etc.
- 6 Check the bin control switch for proper adjustment.
- 7 Check the water valve (water cooled machines) for proper adjustment by measuring the water temperature at the outlet of the condenser. It should be between 100°F and 110° F.(38°C and 43°C)
- 8 Check all electrical connections
- 9 Oil the fan motor if the motor has an oil fitting.
- 10 Check the water filter (if applicable) and replace if dirty or restricted.
- 11 Inspect the evaporator water distribution tube to ensure even distribution of water across the face of the evaporator.

Refrigerant recovery

Recovery of existing refrigerant from the machine is required when it contains any refrigerant while at the time before gas charging. Recovery will help to prevent the exhausting of refrigerant vapour towards the atmosphere . In order to do the recovery at first disconnect the machine from electrical supply before removing any panels for servicing and remove all panels. Connect the recovery unit to the suction and discharge service valves of the compressor. Locate the compressor from the pulleys to allow drive motors to spin freely and connect power to the machine. Turn the main power OFF/ ON switch and freezing cylinder OFF/ON switches to the ON position. Press the push to freeze button. This will energize the solenoid valves and operate the recovery unit as per manufacturer's instructions. if recovery is not completed after 30 minutes, press the Push to freeze buttons again. This will keep the solenoid valves open.

Softy icecream machine

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

- explain the effective usage of softy ice cream machine
- describe the specifications of the machine.

Description

Ice cream mix containing milk, cream, syrup, stabilizers and fruit or other flavouring ingredients, its percentage is important since it lowers the freezing temperature.

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 to meet the demand. This is for batch process, and instant sales.

Construction

The refrigeration system consists of one TR sealed compressor with starting relay, OLP, thermostat

(temperature control), air-cooled condenser, sight glass and filter drier in the liquid line. The expansion valve regulates the liquid refrigerant to evaporator. The master storage tank is made of stainless steel. The evaporator coil is of copper tubes, it is mounted around the master tank outer and the copper tube is soldered to the master tank outer to ensure the best heat transfer. The evaporator coil is insulated with glasswool, thermocole or polyurethane foam (PUF) and then it is clad with aluminium sheet

The churner may be made out of stainless steel or fibre. The outlet tap is stainless steel and easy detachable. The churner motor is 1/2 HP and is connected to the churner by means of V.Belt.

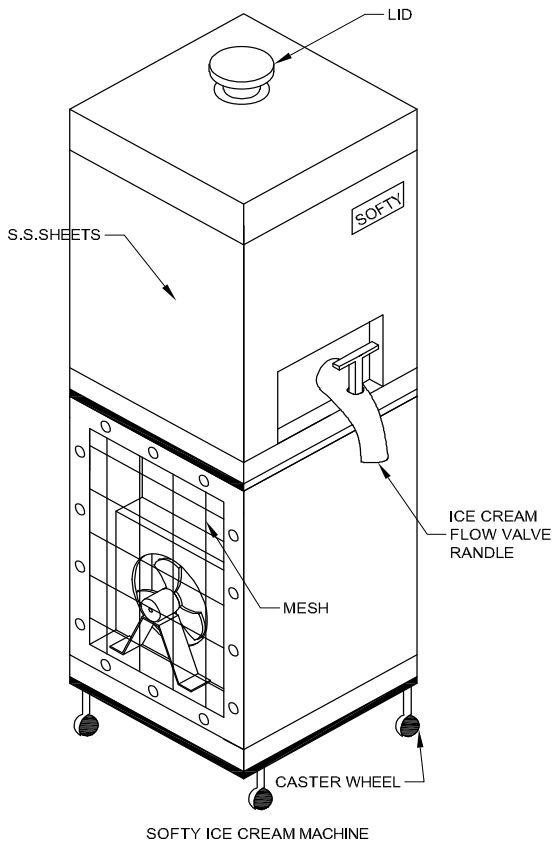
Sl.No	Name of the parts	Functions
1	Churner motor	To rotate the churner
2	Churner driver pulley	Transmit rotation to churner
3	Ice cream outlet pipe	Directs the ice cream flow
4	Ice cream outlet valve	Admits and shuts the flow of ice cream
5	Master tank	To accommodate the ice cream mix
6	Churner shaft with conveyor	Conveys the liquid from end to end
7	Ice cream churner mixing blade	To mix the ice cream
8	Shaft bearing	To hold the churner in position and permit free rotation clothes any foreign body and dries the refrigerant
9	Filter dryer	Free from moisture
10	Sight glass	To view the liquid refrigerant flow
11	Motor pulley	Transmits motor rotation
12	Evaporator coil	Cools the ice cream mix. Regulates the liquid
13	Expansion valve	Refrigerant to evaporator
14	Condenser	Condenses the liquid refrigerant
15	Condenser fan motor	Circulates air through condenser fins to condense refrigerant
16	Compressor	Sucks the vapour refrigerant and compresses it to its condensing pressure and temperature
17	'V' belt driver transmission	Transmits the motor pulley rotation to the churner

The parts and functions of softy ice cream machine.

Where the condensing unit is there at the bottom of the machine, the bottom should be covered fully with stainless wheel sheet without gap for any insects or rat not to entering. The side which condensing fan sucking the

ambient air and the opposite side, the air throw will be covered with mesh or grills, some times with louvers for air to enter and mass away easily to help the condensation. The other two sides can be covered with stainless steel sheets.

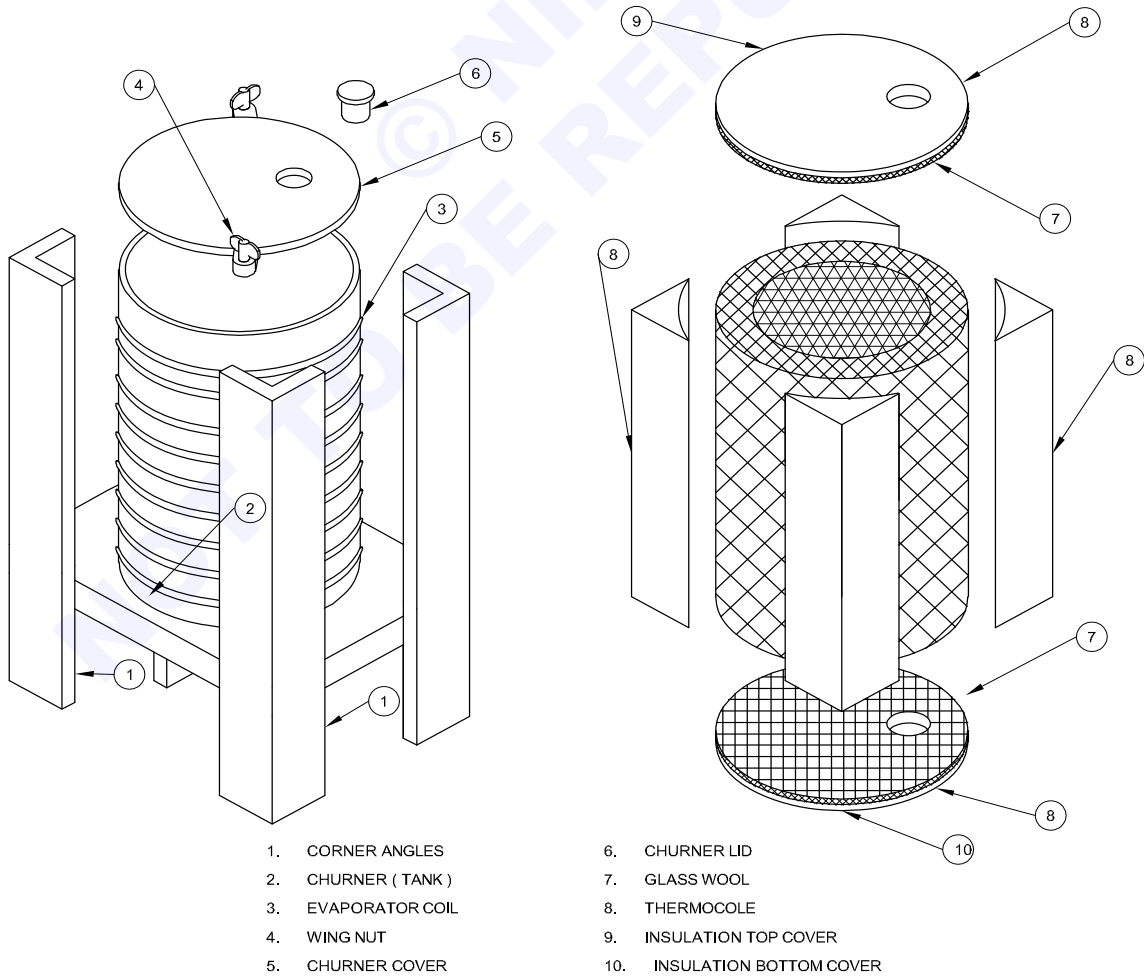
Fig 1



SOFTY ICE CREAM MACHINE

MR20N2614221

Fig 2



CHURNER INSULATION

MR20N2614222

Ice candy and ice cream storage plants

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

- explain the function of ice candy and ice cream plant
- describe the construction of ice cream storage plant and ice candy limit
- read and understand sample specification chart of the manufacture.

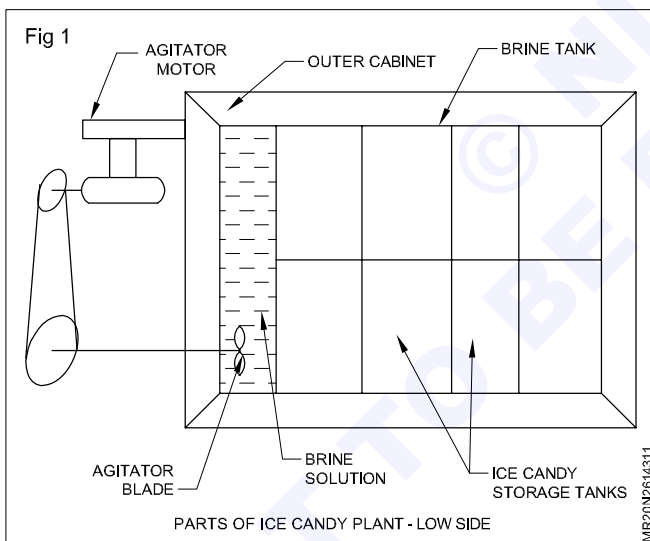
Ice candy plants/Machines: Ice candy units are used to make ice bars (miniature) of different flavours.

This machine uses the refrigeration system, vapour compression type consisting open/sealed compressor, air cooled forced convection condenser with immersion coil type evaporator. An expansion valve is used as refrigerant flow control.

This machine uses secondary refrigerant (Sodium chloride/ glycol solutions) for cooling and freezing the flavoured solutions.

Construction: The whole unit is divided into two portions. First half (Top side) is made for making ice candies and their storage purpose. This is low side of the system.

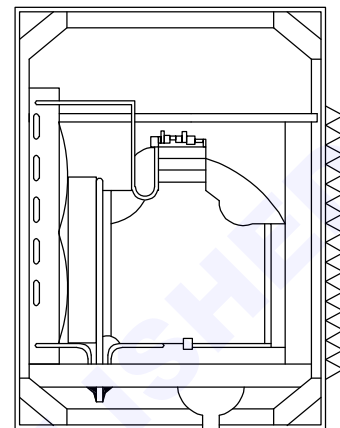
Fig 1 shows the parts arrangement of 'ice candy maker' section, Brine tank is located inside, has two sections which are candy making and storage.



An insulation is provided in between the outer cabinet and brine tank to minimise heat gain by the brine solution due to its temperature is maintained lower (-20 to 25°C) than the surrounding. An ice candy maker/mould (not shown in Fig) will be immersed into the brine solution. The agitator is provided for maintaining the brine solution temperature evenly at all places and it increases the heat transfer rate between ice candy solution to brine solution. The storage section arrangement is provided to keep the ice candy bars, which are harvested already.

The second half (Fig 2) of the unit (bottom portion) is made for locating refrigerating condensing (high side) unit and electrical controls. The outer cover/sheet is made of

Fig 2



OPEN TYPE - CONDENSING UNIT OF ICE CANDY PLANT

CRCA sheet - 18 swg thickness. The brine tank is made with CRCA sheet - 14 swg (2mm) thickness or above.

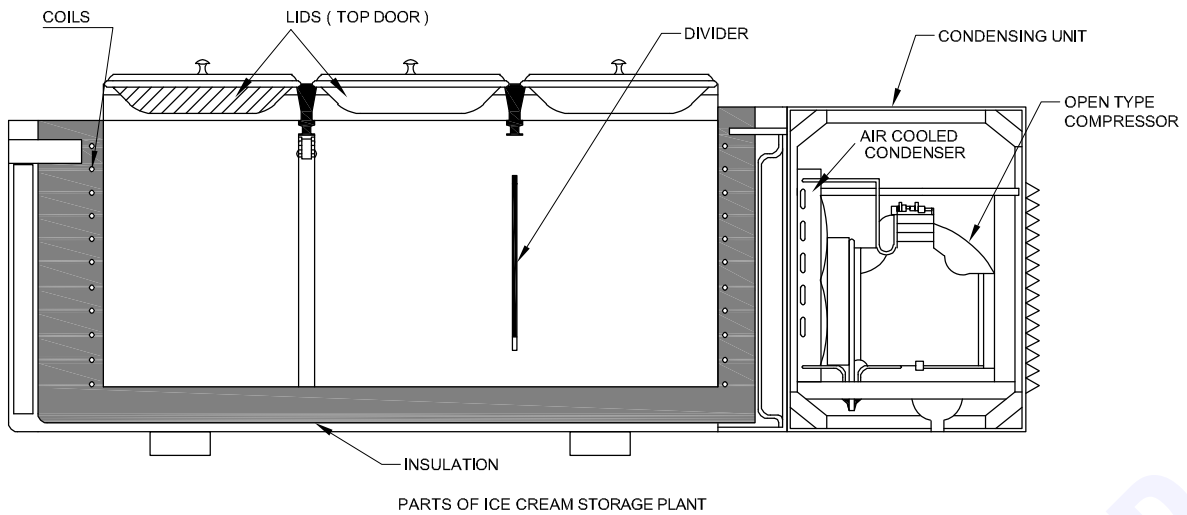
Function : The evaporator coil (copper) is immersed in the brine solution. The refrigerant (R-12 used in earlier, R134 is presently used) absorbs its 'latent heat' from the brine solution and also sensible heat. Then the cooled brine absorbs its 'sensible heat' and latent heat from the 'ice candy mixture/solution' in the tank.

Ice cream storage plants : These units are used to store/maintain ice creams at low temperature (-20°C and below). This machine used the refrigeration system, vapour compression type, which consists of open/sealed compressor, air cooled condenser, capillary tube/expansion valve with direct expansion/indirect expansion evaporator. The refrigerant may be used R134A, recently developed, has no Ozone Depleting Potential (ODP). Indirect system evaporator will be immersed in secondary refrigerant (Brine/Glycol solution).

Construction: Fig 3 shows the sectional view of a 'Ice cream storage system' which employed with an open type compressor, air cooled condenser, expansion valve with direct expansion (DX) evaporator. The storage cabinet is insulated with expanded Poly Urethane (PUF) foam 120-150mm thickness. In this type, the condensing unit is located at one side and the cooling compartment in the other side. This type is called Horizontal/chest type.

The inner cabinet/cooling compartment is made of stainless steel (S.S) sheet/pre coated galvanised plain sheet. The outer cover/sheet is made of CRCA sheet/pre coated G.P/ stainless steel sheets according to the requirement based on the price/cost.

Fig 3



MIR20N26141313

Model F 431	
Dimensions	Machine with crate
Width	19-1/8"(48.6 cm) 27" (68.6cm)
height	67-7/8"(172.4 cm) 78" (198.1cm)
depth	37-3/4" (95.9 cm) 48: (121.9cm)
Weight	500 lbs (226.7 kg) 650 lbs (294.8 kg)
Electrical	1 Phase, 208-240 VAC, 60 Hz
circuit ampacity	24 A minimum
Overcurrent protection device	30A maximum
International option	1 Phase, 220 - 240 VAC, 50 Hz
Compressor	11,000 Btu/hr Scroll™ Compressor
Dirve Motor	Two - 3/4 hp
Air Flow	Air cooled units require 3" (7.6 cm) air space on both sides , 6" back
Plumbing fittings	Water cooled units require 1/2: N.P. T water and drain fittings
Hopper volume	Two- 5.5 gallons (20, 82 liters)
Freezing cylinder volume	Two - 0.85 gallon (3.22 liters)

Menu	Display	Value
Basic	Cutout	*amps
	Cut In T	19°F
	Cycles	20 count
	Stir on	15 seconds
	Stir off	300 seconds
Advanced	On time	28 seconds
	Off time	450 seconds
	Stb time	120 seconds
	SI1DrOff	180 seconds
	SI2CutIn	32°F
	SI2CtOut	28°F
Storage (Left control only)	Refriger	*** 3 cabinet
	Cab cutIn	38°F
	Cab Ctout	34°F
	Cab Off	13 minutes
	Cab On	130 seconds

* Cut Out amps must be set on site.

F431	
Refrigerant Charge	R-404A W/C 26 oz (A/C) 35 oz
Suction Pressure (at 72°F)	One cylinder 20-22 psig Both cylinders 25-27 psig Cab only 18 psig
Discharge Pressure Cab Pressure	240-260 psig 18 psig (maintained by the bypass valve)
(only cab running EPR Valve)	78-80 psig

Brine solution and agitator of ice candy plant

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

- describe about brine water
- explain the chemical used in brine water
- analyse the problem tree for brine leak in ice candy plant
- explain agitator and its function.

Brine water: This kind of water is used as secondary refrigerant in refrigeration field.

The freezing temperature of ordinary water is 0°C. If the plant is holding minus or low temperature, the ordinary water get frost and cause damage.

So the ordinary water is mixed with some chemicals to bring down its freezing temperature low. This mixture of water and chemical is called brine water.

The chemicals used in brine water: Ordinary water mixed with recommended ratio of sodium chloride or calcium chloride mixture used as brine solution in various plants.

According to the cooling temperature the ratio of the chemicals, determine the density of the brine water. Normally, the density will be maintained 7 pH to 8 pH. That can be checked by pH meter.

Usage of brine water: In ice cream plant the cooling coils are immersed in brine tank. When the evaporator coils get cool while the plant is running, this low temperature make the brine water to get low temperature. The brine water around the ice cream tank makes the ice cream to get frost. The advantage of the brine system is, it keeps the low temperature remains for limited long time, even after switch off the refrigeration plant.

Agitator

It is that part of an ice candy plant which circulate the brine solution throughout the brine tank to provide good heat transfer. It consists of agitator fan motor, extended shaft and a fan.

In central A/C plant, large area has to be cooled, the cooling coils cannot be extend so far to cover the entire area and it will be very expensive. So brine water will be

cooled by chillers (evaporators) and that brine water/ chilled water will be circulated. Blowers observe the cool air through chilled water coils and supply to the large area.

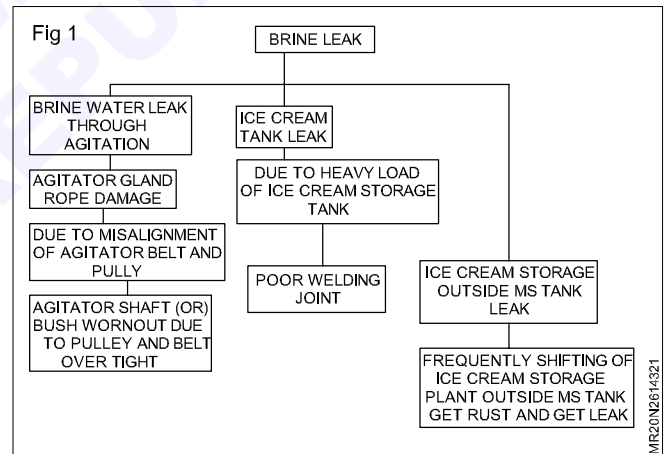
The large plants like central A/C use the brine water combination of sodium chloride.

The small plants like ice cream storage plants use the brine water combination of calcium chloride.

The primary refrigerant (gas) in evaporator cool the brine water. The brine water cools the products, so brine water is known as secondary refrigerant.

Brine solution are made by adding the following chemicals with ordinary water.

- 1 Calcium chloride
- 2 Sodium chloride
- 3 Ethylene glycol
- 4 Propylene glycol



Ice candy plant - circuit diagram

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

- Identify the circuit diagram and its components of ice candy plant
- explain the trouble shooting of ice candy plant.
- explain retrofitting procedure of ice candy plant.

In lower capacity machine 1Ø motors are used

The higher capacity plants (open type compressor) are with 3 phase wiring. Compressor motor capacity varies according to the cooling load as 1/2 H.P to 3 H.P. For indirect cooling ice cream storage plant and wiring refer (Fig1 & Fig 2)

In ice candy and ice cream store plant there are 2 kinds of controls. i.e.

- 1 Mechanical control and
- 2 Electrical control

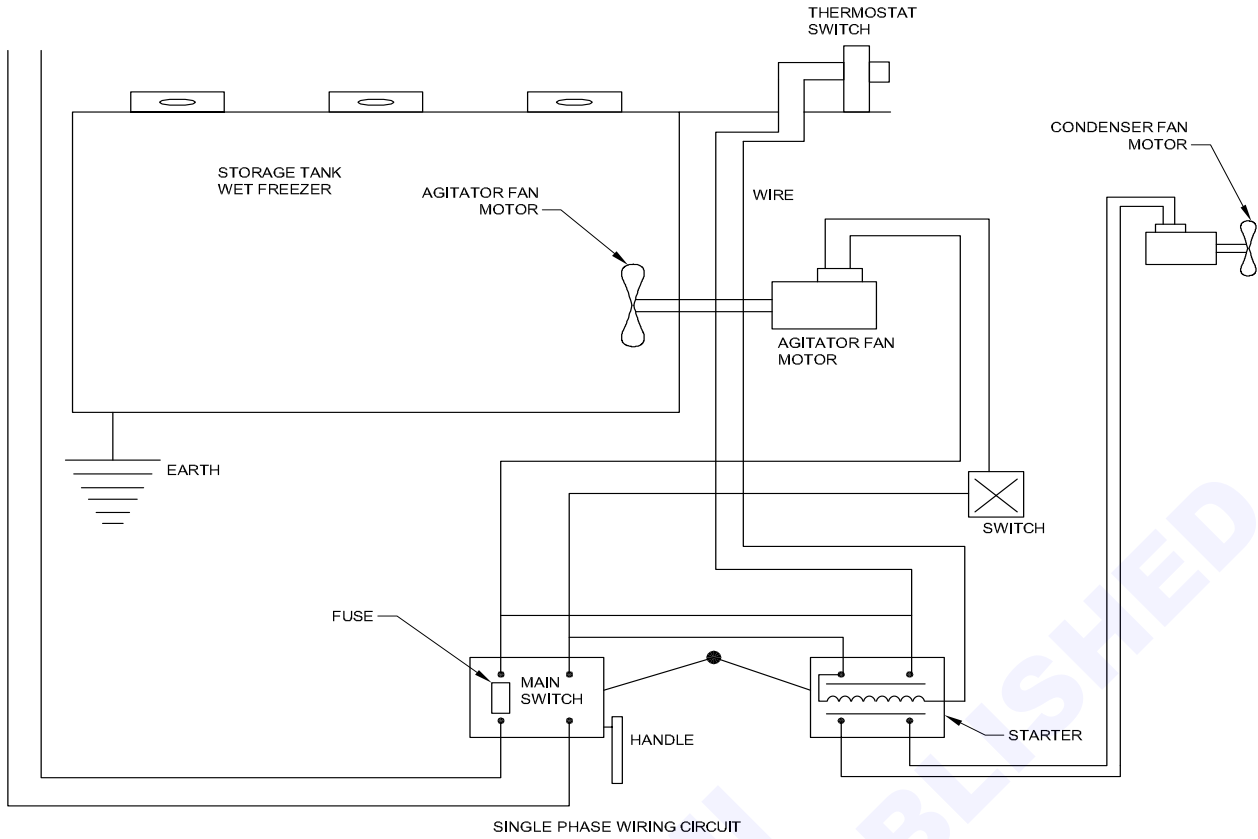
Mechanical Control

- 1 Hand shut off valve
- 2 Compressor service valve

Electrical Control

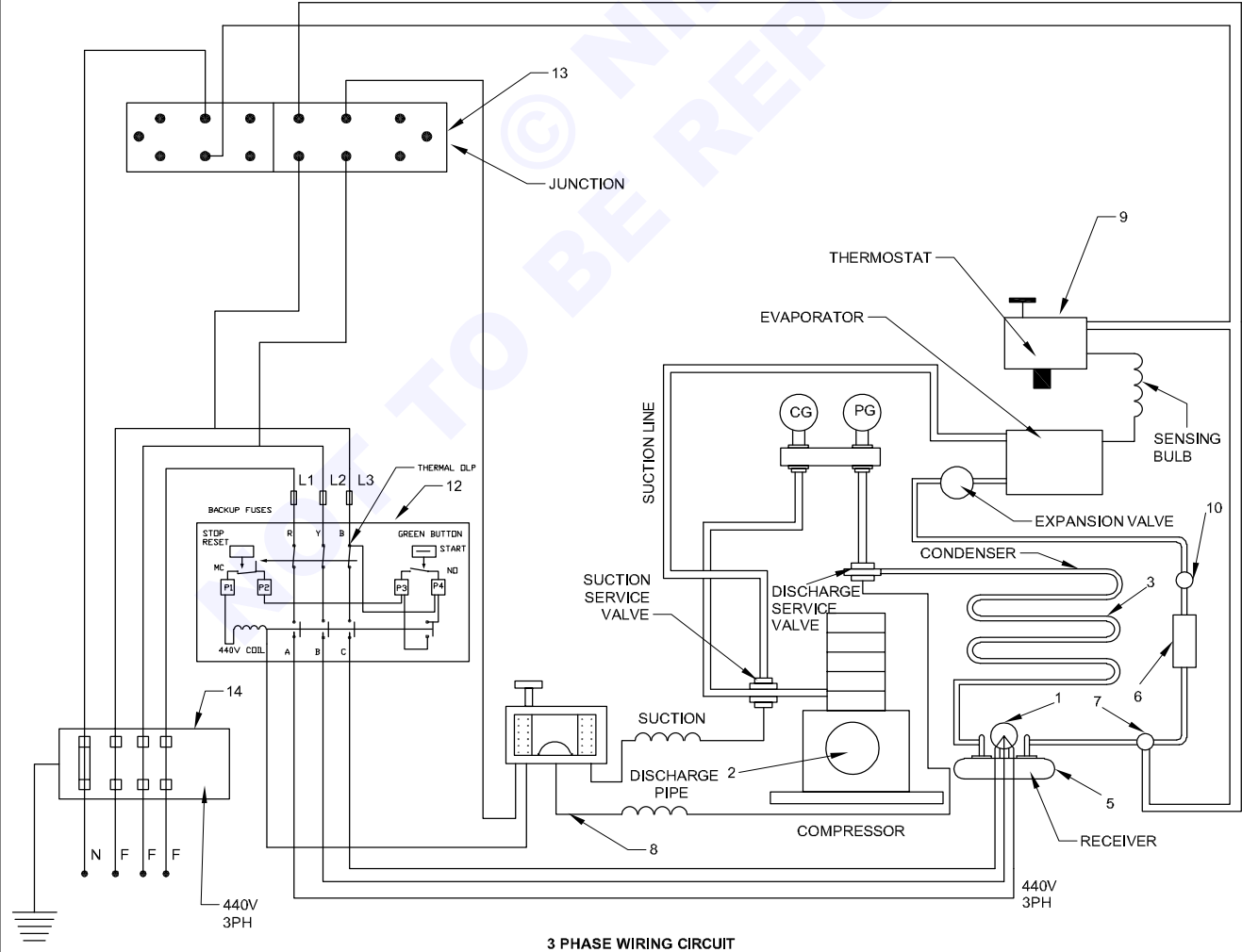
- 1 Thermostatic switch
- 2 Motor switch
- 3 Overload protector
- 4 L.P & H.P cutout switches

Fig 1



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Fig 2



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Reason for control get defective

Thermostatic expansion valve

- Mishandle by mechanic (or) customer
- Heavy vibration of plant - thermostatic expansion valve sensing capillary (or) bulb may get damage (broken).
- Wrongly placement of sensing bulb fixed
- Expansion valve filter may get choked by dirty gas, orifice may be get closed. When removing old valve to be cleaned. Otherwise moisture will affect the system.

Solenoid valve: Solenoid valve get defective due to continuous use. This solenoid valve electrical coil get overheated and valve gas line O ring may get defective and due to this gas may leak.

Due to high or low voltage solenoid valve coil may get burnt out. Due to heavy vibration solenoid valve flare get loose and gas may leak.

Hand shut off valve: Due to long service hand shut off valve and flare nut may get weak and from this flare gas may leak. Due to continuous use hand shut off valve diaphragm or stem gland get loose. This may lead to gas leak.

L.P., H.P. control switch

- Due to high (or) low voltage, this switch electrical points get burnt out.
- If oil get in L.P., H.P. switch bellow may get weak

Compressor service valve

- Due to continuous use of compressor valve stem gland may leak.
- Due to plant vibration service valve pipe joint flare may get weak and through this gas may leak.
- Dirty gas or oil go through this valve. Valve stem not close to valve port.

Hydrocarbon (HC) refrigerants and its retrofitting procedures

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

- explain about Hydrocarbons and its uses
- assess the necessary electrical component change during retrofitting.

Hydrocarbon(HC) refrigerants : Hydrocarbons have been used alternately as refrigerants in refrigeration system. Their use has been increased in the past 10 years and now being used in place of R-12 (CFC group) for medium and low temperature applications such as ice candy plants., Hydrocarbons are absolutely environment friendly refrigerants due to their nil effect on Ozone layer and global warming.

There are 2 kinds of Hydrocarbons commonly used in refrigeration systems, which are

- Isobutane (R-600a)
- Propane / Isobutane blend (HC blend)

Electrical Control

Thermostat switch

- Due to heavy vibration in the plant this switch sensing bulb capillary may get weak/broken.
- Due to plant high amp. this switch electrical terminal get burnt out.

Motor starter: Due to overload of ice cream plant motor take high amps this starter electrical point may get burnt out.

Overload protector: This overload protector will come only in sealed system of ice candy. If compressor take high amps this overload protector will trip and save compressor motor.

Replace the defective control of ice candy and ice cream storage plant

Only the thermostatic expansion valve to be changed pump down system and change and remove thermostatic valve and fix new one.

The other valves like solenoid valve, liquid indicator, drier can be changed by closing hand shut off valve. Both can change without pump down gas, after changing hand shut off valve to be opened.

Hand shut off valve to be opened: Defective L.P., H.P. control changing by closing (back seat of) compressor service valves and after changing LP and HP control service valve stem to be opened for LP, HP control to function. But hand shut off valves to be changed after pump down the system.

Replacement of Defective electrical control: Thermostat switch - This thermostat switch, mount on panel board and its sensing bulb fixed with cooling coil Return (suction) pipe and tide up with asbestos rope it range 0°C-40°C.

Temperature set at -10°C to -20°C

Changing defective motor starter : Replace new starter and same connection to be given. Set amp. in starter to recommended amps on motor.

R 600a is widely used in domestic refrigerators. Its refrigerating capacity is about 60% at that of R-12. Compressors used with R 600 a must have a much higher displacement, but have the same size motor for R-12 appliances: therefore a new model with as different displacement/motor combination. It (R 600a) is NEVER used for conversion/retrofitting of existing CFC-12 or HFC-134 a systems.

Hydrocarbon blend has very similar properties to CFC-12, it gives the same capacity and operates at similar pressures. These are very good refrigerants with different characteristics to CFCS and HFCS with their relative values:

- High latent heat value than CFC & HFC's
- Low liquid density than CFC & HFC's

CAUTION :1 Hydrocarbon refrigerants are flammable when mixed with air and ignited. 2 Necessary safety precautions to be taken by using non-sparking (sealed) electrical components such as door switch, lamp holder, thermostat, Relay, OLP etc.,

Assessment of necessary electrical component changes

Since the Hydrocarbons are flammable type (at particular conditions), it is required proper care must be taken on electrical devices as they may produce sparks at some unsafe conditions. Unsafe devices are those which spark when they operate. Where such devices are attached to or close to the refrigeration circuit, they could ignite leaking Hydrocarbon refrigerant. The electrical devices which is required to examine are usually the compressor relay, compressor overload protector, thermostat, door switch, on/ off switch and light.

Servicing Hydrocarbon (HC) based appliance

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

- explain safe venting of Hydrocarbon refrigerant from the system
- specify the specifications of electrical components, if needs replacement.
- explain the main guide lines on servicing/repairing.

Safe venting of hydrocarbon refrigerants

Hydrocarbon refrigerant should be vented to an area , away from the ignition sources (flames and sparks), preferably outside using piercing pliers/piercing valve and a long hose connected to it.

Hydrocarbons do not need to be recovered as it has no reaction with both ozone and environment.

There will still be some Hydrocarbon in the system after venting. It must be evacuated using a proper 2 stage vacuum pump.

It is not required to use a different vacuum pump for Hydrocarbons

Specifications of electrical components

Depending on capacity and type of compressor

The electrical components for replacement on an Hydrocarbon appliance should be sealed or solid state.

In most Hydrocarbon appliances uses the electrical parts/ components are as follows.

- The compressor relay is solid state (PTC type)
- the overload protector is sealed bimetal
- The thermostat is either located in a sealed electrical box or a solid state.
- ON/OFF and door switches should be sealed type
- Standard capacitors and induction type fan motors are safe to use with Hydrocarbon's as they do not spark. It is strictly advised, if any one of the electrical component found defective, it must be replaced by the similar (sealed /solid state) type only.

These devices must be:

Replaced with sealed or solid state types (that do not spark)

or

Enclosed in a sealed box

or

Moved away from the refrigeration circuit to safe place

(Top side) where leaked refrigerant cannot reach. (Density of Hydrocarbon is more than air)

If the compressor requires replacement, special Hydrocarbon blend compressors will be supplied by the manufacturers with safe relay (PTC type) and over load protector (sealed)

The fan motors and capacitors used in appliances are not ignition sources.

Guidelines on servicing /repairing

Debrazing/unbrazing the old/defective components (Eg.Failed compressor, choked strainer) is essential when replacing them. At this stage, it is very important to make sure that there is no any Hydrocarbon vapour inside the system It is essential that the system has been properly evacuated and de-braze and braze in a well ventilated area-outside. This is also important to prevent outside air entering into the system before carryout brazing. Because, the oxygen in outside air can form an explosive mixture with the residual Hydrocarbon vapour.

Leak detection: It is preferable to use dry, oxygen free nitrogen for pressure/leak testing. The amount of (test) pressure will be equal / 25% more than the maximum operating pressure (High pressure); Leak testing can be carried out using a soap solution on each Joint.

Evacuation: When the system leak tested successfully, it must be vacuumised/evacuated to the level of 100 microns using a high quality 2 stage vacuum pump.

Charging: Normally there are 2 methods are in practice for charging refrigerant into the systems; which are namely

- **Charging by weight:** An electronic balance with accuracy of 1g is recommended when charging the system with less than 1 00g of Hydrocarbon.
- **Charging by volume:** A charging still measures the volume of refrigerant to be charged into an appliance. This method is not as accurate as charging by weight. Test work has shown that the error in refrigerant quantity is greater than 10%, this will reduce the capacity and efficiency of the appliance.

Identification of parts controls with function & specification of ice plant

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

- define ice plant
- state the types and capacity of ice plant
- define principles of ice plant
- know brine solution agitator.

Ice plant

Ice plants are - refrigeration plants, which are used to produce ice from the water, frozen by the vapour compression. Refrigeration system uses mostly Ammonia (R-717) or R-22 as refrigerant.

Types of ice Plant

Ice plants are coming/made of different types with models according to it's shape/appearance, which depends upon the usage. These are:

- 1 Block Ice plants/Block Ice makers
- 2 Flake Ice makers
- 3 Shell Ice machines
- 4 Slush Ice machines.

In the above types, block Ice plants are simple and widely used. Because the main advantage of block ice is its comparative longevity in storage compared with other forms of ice.

Capacity of Ice plant

The capacity of Ice plants are expressed in terms of the mass of ice produced per 24 hours (day). The size of ice (Block ice) are available from 25 kg to 180 kg maximum. Normally Ammonia will be used as refrigerant in most of the ice plants due to economical cost, easy availabilng and higher refrigerating effect.

The consumption of water which is used to produce ice depends upon the capacity of the plant. Similarly the Electrical power required also based on its capacity. (Ref Table) I for specifications of ice making plants, which are follows :

Block Ice Makers - specifications

Capacity of Ice /24 hrs.	Power Required	Block size Recommended	Water Consumption /day (Ltr.)	Dimension of Ice produced	Refrigerant
3 (Tons)	18 H.P.	25 kg.	5,000	6"x10"x36"	NH3
5 (Tons)	24 H.P.	25 kg.	7,500	6"x10"x36"	NH3
10 (Tons)	46 H.P.	25 kg.	15,000	6"x10"x36"	NH3
15, (Tons)	56 H.P.	50 kg.	22,500	8"x16"x36"	NH3
20, (Tons)	70 H.P.	50 kg.	30,000	8"x16"x36"	NH3
25 (Tons)	85 H.P.	50 kg.	37,000	8x16"x36"	NH3
30 (Tons)	110 H.P.	150 kg.	45,000	11"x22"x48"	NH3
50 (Tons)	170 H.P.	150 kg.	75,000	11"x22"x48"	NH3
100 (Tons)	350 H.P.	150 kg.	1,50,000	11"x22"x48"	NH3

Above table is based on following Design parameters.

Condensing Temperature: 40⁰ centigrade. Evaporating Temperature: 10⁰ Centigrade.

Average ice Temperature: -3⁰ Centigrade inlet water Temperature Required 35⁰ Centigrade

Principle of Ice Plant

Ice plants are working on the principle of vapour compression Refrigeration system (Ref. Fig 1) which uses Ammonia (R.717) as refrigerant for Medium & Large capacities (Above 5 Tons/day) and HCFC-22 (R-22) as refrigerant for small capacities (Below 5 Tones/day).

Normally Ice plants with Ammonia Refrigerant system will. Work on flooded systems.

The components used and its types in the ice plants are as follows :

- Compressor - Open type, Reciprocating or screw version.
- Condenser - Shell & tube type, water cooled/ Atmospheric type. Air & water cooled.
- Refrigerant - Flow control - Hand expansion type/ Thermostatic type (R-22)
- Evaporator - Tank & coil type, 'V shaped coil.
- Compressor Drive - Motor - Squirrel cage induction/slip ring type. TEFV/SPDP frame.

- Condenser pump - Centrifugal mono block type
- Agitator Motor - Squirrel cage induction type.

Role of Components

Ammonia Compressors

- Ammonia compressors designed with state-of-the-art technology for industrial & commercial refrigeration and low temperature applications.
- Compressors are V belt driven and are suitable to operate with Ammonia (NH₃) & 22 (CHClF₂) as refrigerant.
- Robust construction, excellent performance and power saving features and hallmarks of the products.

Ammonia Receiver

- Ammonia receiver can control the supply and demand relation between the condensers and the evaporator, prevent excessive liquid ammonia from staying in the condenser, maintain a certain level in the liquid receiver to prevent gas from going into the liquid pipe line.
- The ammonia in the system can be stored in the ammonia receiver to avoid loss of the ammonia before the refrigerating system is repaired. Therefore, the volume of the ammonia storage should be considered before buying it.

Cooling coil/Evaporator

- V shape cooling coils are available in different sizes, usually custom made to the individual applications.

Chilling Tank

Chilling Tank consists of three parts:

- i Ice Tank

- ii Insulation of Ice Tank

- iii Ice Block

Ice Tank

Ice tanks are made of such material as wood, steel As wooden tanks do not last long enough and are liable to leak, they should preferably be made of steel well coated with water proof paint.

The ice tank contains the direct expansion coils, equally distributed throughout the tank and these coils are submerged in brine. The tank is provided with a suitable frame of hard wood for support the ice can and a propeller or agitator for keeping the brine in motion: the brine in the tank acts as a medium of contact only, the ammonia evaporating in the ice coils extracts the heat from the brine, which again absorbs the heat for the water in the cans.

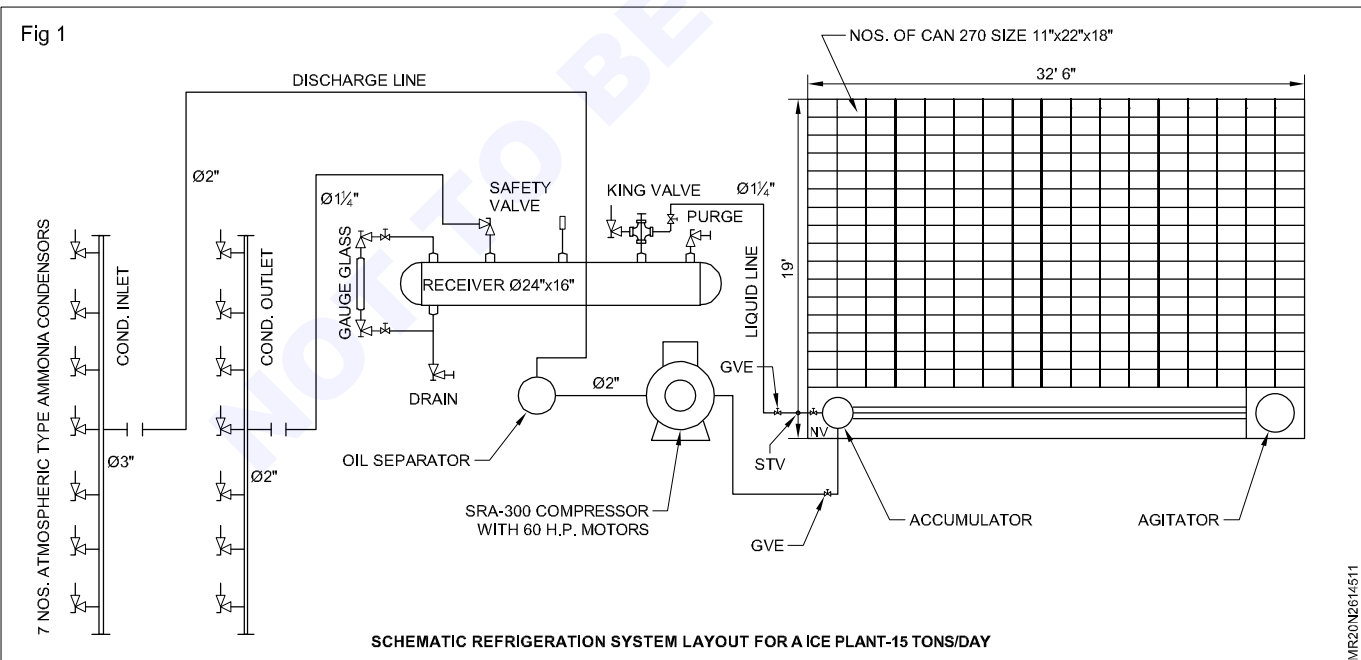
The tank itself should not be much larger than is necessary to hold the cans, the coils, and the agitator. About two inches should be left between the moulds and three inch between the pipes and the moulds.

Insulation of Ice Tank

Insulation of the ice tank is accomplished by using twelve to eighteen inches of good insulating material on each of the sides and not less than twelve inches under the bottom.

Ice Block

Commercial sizes of Ice cans vary with the weight of ice cakes required. The cans are made to contain about 5% more than their rated capacity to compensate for thawing.



Walk in cooler/reach in cabinet

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

- explain in walk in cooler/cold storage.

Walk in coolers and walk-in freezers are enclosed storage spaces that can be walked into. They are used for temporarily store refrigerated or frozen food or other perishable goods and are used primarily in the food service and food sales industry. Walk in coolers operate above 32° F.

The walk in coolers are available from a minimum of 8.5m³ volume to maximum 650m³ volume (or less than 3000 sq feet) and 3 temperature ranges.

Walk in cooler & Freezer application: The walk in coolers and walk in freezers are used in a variety of temperature ranges.

High temperature walk in cooler used for holding fruits, vegetables, eggs, medicine and wood. (ambient to 5° temperature range)

Medium temperature walk in freezer used for holding meats, seafood and stuff that needs the same temperature environment (-5° - 15°C temperature range)

Low temperature walk in freezer used for holding ice cream already frozen food. (-15° - 40°C temperature range).

Ultra low temperature walk in freezer used for freezing food, and in industry and pharmacy field.

Walk in coolers and freezers of different temperature classification are equipped with different insulations and compressor types, therefore high temperature walk in cold room cannot be used as lower temperature walk in cold room. Besides, low temperature walk in cooler room, walk in warehouse refrigeration system are constructed with different materials. As a result they should not replace each other in application. The maximum load limit of a walk in refrigerated warehouse is 15% cold storage warehouse refrigeration system operates with the highest efficiency when working amount is in accordance with design capacity.

Though most people relate to matters of refrigeration by thinking of how their home refrigerator works, a walk-in cooler actually operates in a very different way. Instead of using cold air generated by a connected freezer unit, a walk in cooler actively generates cold air as needed to maintain the temperature set at the thermostat. The cold air is created using fans and an evaporator much like what a window air conditioning unit would use, with the condensing unit cycling on and off to maintain the temperature.

Refrigeration system of walk in cooler

The refrigeration system of walk in cooler has a condensing unit and an evaporator assembly and is supplied charged with refrigerant sufficient for a 50 feet line run (with suction line and liquid line length). The condensing unit assembly

is designed to be remotely located. Installation involves securing the evaporator assembly in the interior of the walk in locating the condensing unit in a suitable area near the walk in and installing refrigerant lines.

The condensing unit has a sealed or semi sealed compressor from ½ hp to 6hp capacity, a forced draft fin & tube air cooled condenser, a liquid receiver and suction and liquid line service valves.

The thermostat and the evaporator unit

The thermostat of the walk in cooler determines the air temperature within it when the temperature rises above the level of the thermostat, the condensing unit turns on to start a new cooling cycle. The indoor units fans pull air into the unit and over the evaporator coils. The refrigerant within the coils pulls the heat from the air as it passes over. The cooled air then continues to move out the back of the unit, cooler than it was when it first entered. As the fans continue to blow air over the evaporator the air temperature within the walk-in cooler will lower until it is once again below the level set by the thermostat. The refrigerant within the evaporator coils will be continually pumped during the cooling cycle.

A second cycle exists in order to prevent the evaporator from freezing up and becoming covered in frost and ice. If the thermostat falls too low (generally 35 degrees Fahrenheit) the fans will start again without the refrigerant cycling. This serves to gradually warm the evaporator coils because the refrigerant is not being cycled and cooled. The defrosting cycle will continue until the temperature rises to within an acceptable range again.

Condenser used is forced draft air cooling type. Expansion valve generally used are thermostatic expansion valve. In high capacity units TEV with external equalizer also used.

The refrigerant generally used are R404 A, R502 etc.

Features and benefits of the system

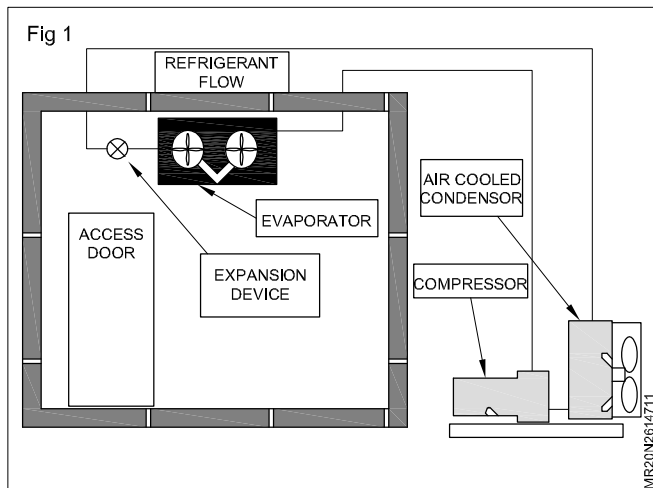
Operates effectively from -20°F to +120°F without exceeding the design and safety criteria of components.

Ease of service with all components conveniently arranged on a heavy duty base to be accessible for adjustment and repairs when necessary

Provides an efficient balance between compressor, condenser surface, air movement and controls. The units are equipped with extra condensing surface, oversized fan blades and PSC fan motors. The oversized fan blade powered by the PSC motor moves air more efficiently to use less electricity.

High accuracy pressure switches are used in place of capillary tubes to eliminate possible leakage points.

Standard components of walk in cooler (Fig 1)



High side assembly

Liquid line filter/ drier

Sight glass/ moisture indicator

Pressure controls

Low ambient controls (outdoor)

Crankcase heater (outdoor)

Oversized receiver

Quick couplers for easy refrigerant line connections

Refrigerant charge for line length selected

Refrigerant lines in 10' sizes up to 40'

Insulated suction line

PSC condenser fan motors

Base valve

Time clocks (medium & low) shipped loose

Weatherproof housing

Valve at receiver

Low side assembly

Thermostatic expansion valve

Solenoid valve

Temperature control

EC fan motors

Quick couplers for easy refrigerant line connections

(See unit cooler catalog for details)

Condenser unit rack

This accessory is used to mount condensing unit assembly. Units can be installed separately, stacked or side-by side. The racks are constructed of heavy-gauge angle iron, welded together and painted to resist rust.

Condensate water evaporator

These units evaporate condensation formed by normal operation of the low-side assembly. It is normally used when a drain is not readily available. Two sizes are available, 50 oz and 7-1/2 quart capacity, each with a heating element of 120-volts and built-in thermostat.

Heat exchanger

A heat exchanger is a device to

Sub cool the liquid refrigerant

Reduce flash gas in the liquid line

Reduce liquid refrigerant in the suction line

This accessory is factory installed on "PCL" system. It is shipped loose for field installation of "PR" or "PC" systems.

Drain line heater

This accessory is required on freezers to prevent drain line freeze up. The heater is available in various lengths or can be provided in a variety of kit forms for field installation.

Fan switch

This option shuts off fans and the compressor when door is opened and will automatically start system when door closes.

Electrical wiring, maintenance and trouble shooting of walk in cooler

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

- explain the maintenance of different parts of walk in cooler
- explain the trouble shooting procedure of walk in cooler
- define the electrical system of walk in cooler.

Compartment maintenance

Use soft cleaning cloth with a mild detergent to wipe away dirt and stains on the interior and exterior metal finishes of the refrigerant warehouse.

Use a clean damp cloth to remove any chemical residue

Use a soft dry cloth to dry up finishes

Warning: Never use abrasive and corrosive type of cleaner

Never use any form of cleaning agent that contains any form of acid to clean galvanised aluminium cold room panel.

Door gasket: Check and clean walk in door gaskets periodically, prevent door gasket stress and leaking

Cam lock plug button

Missing plug buttons should be replaced as necessary to eliminate moisture accumulating in the insulation of the fabricated sandwich PU panel

Heater cable: Ensure that cold room door and pressure relief port heaters function properly to avoid frost or condensation appearing at exterior edges of the door on all sides.

Door hardware

Check and tighten screws on hinge latch, handle and door breaker

Hinges are lubricated at the factory for ease of operation. They should be lubricated every three months with petroleum jelly.

Storage

Overcrowded or improper stocking prevents good air circulation blown from fan blades of the indoor fan coil unit.

Sanitation

Always create a sanitary environment inside the cold storage compartment with periodic cleaning and disinfection.

Refrigeration unit maintenance

Power supply

Check to see that voltage is within system design limits and a balance load is drawn by each phase

Check to see wire mounting nuts are secure

Check contactor for proper operation and for worn contact points.

Heat exchanger inspection and maintenance

After a period operation, air-cooled condenser of the walk in cooler or walk in freezer is accumulated with dust, leavers and other debris, which may cause low heat distribution and efficient operation, consequently, cleaning should be scheduled as often as conditions dictate.

Action: Take off the baffle and use a soft brush to sweep between the fins, then blow it from inside with compressed air. Try to avoid fin stress and bent during cleaning.

Allow sufficient clearance around air-cooled condenser for a supply of ambient air to the condenser, and removal of heated air from the condensing unit. If the condenser unit is located in a hermetic place, a circulating fan with air flow range not lower than condenser fan must be mounted on the wall to remove heated air.

Check to see condenser and fan set screws are tightened as required.

The evaporator section of a system should be checked at least once a month for proper defrosting because the amount and pattern of frosting can vary greatly. The frost build-up is dependent on the temperature of the room, the

type of product being stored inside the cold room, how often new product is brought into the cold storage room and percentage of time the cold room door is opened. If there is occasional heavy frost, defrost manually by pressing on the control board and holding for 4 seconds. Refrigerant resets automatically after manual defrost. If frequent manual defrost is needed, adjust thermostat and shorten defrost cycle.

Check the drain pan for proper drainage

Check piping system

Look for signs of oil stains on interconnection piping, which indicates possible leak inside.

Inspect the oil level. It should be always at or slightly above the centre of the sight glass at normal operation conditions. If the oil level is low, more oil of the same type should be added to bring the level up.

Other general cold room maintenance

Reduce walk in cooler and walk in freezer door opening frequency and time. Add additional PVC strip curtains at the door as needed to.

Avoid collision on unit body, door, fan, motor and electrical cabinet.

Keep water or any moisture stuff away from electrical cabinet

Check for loosen parts on unit body and door hardware and take proper action.

Data reference

High and low pressure gauges (if equipped) should be observed for its value. System design limits are as follows

Electrical system of walk in cooler:

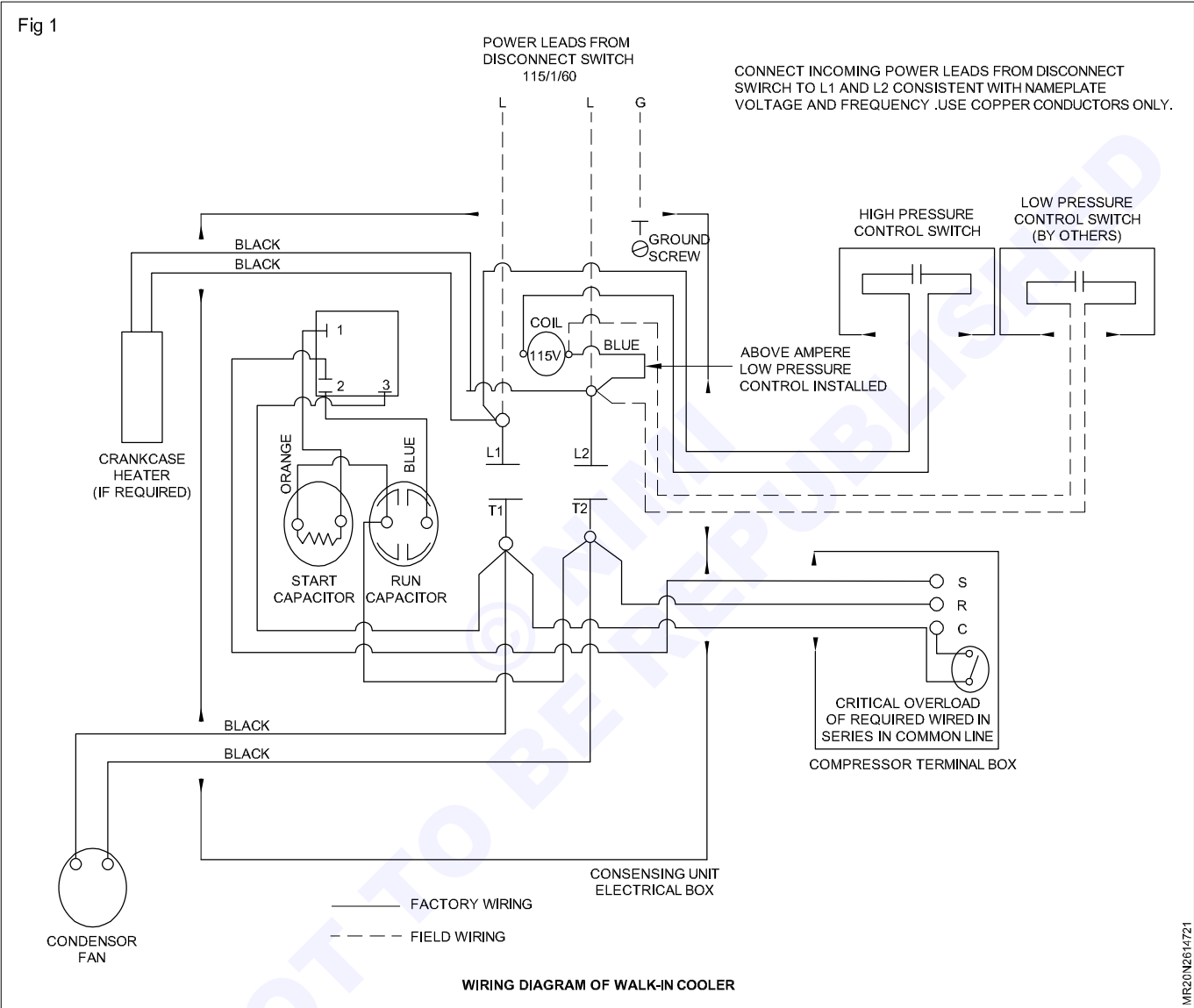
In low capacity walk in coolers PSC motor is used as compressor motor. But medium capacity to high capacity CSCR single phase motor or three phase motors are used there one wiring diagram with CSCR motor, relay and capacitors are included.

In wiring diagram low pressure switch, high pressure switch crank case electric heater, external overload protector and condenser fan are included.

Remote control circuit, thermostat control, evaporator fan and louvers control motor circuits are coming into the indoor unit circuit.

High capacity walk-in coolers up to 6 HP are used with 3 compressors. For 3 compressors 3 DOL starters are used in the place of relay thermostat cut out and protection devices are included in the circuit through inter locking with the no volt coil of DOL starter. (Fig 1)

Cooler type	Refrigerant type	Low pressure range(kg/cm ²)	High pressure range (kg/cm ²)
High temperature	R22	2~ 5	12 ~ 18
Medium temperature	R22	1~ 2	12 ~ 18
Low temperature	R502	0.4~ 1	10 ~ 16



Details of cold storage

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

- explain in walk in cooler/reach in cabinet /mini cold storage
- explain cold storage-functions, types and constructions
- describe the parts, controls and insulation in cold storages
- explain the types of storage and operation of cold storage.

Cold storage functions, type and construction: Cold storage is a process of preserving food stuffs on the large scale by refrigeration. It is mechanical a refrigeration system which is mostly used to preserve the daily used food stuffs such as fruits, vegetables, meat, etc. are to be kept in a preserved condition up to the longer period.

The seasonal fruits and vegetables to be preserved and kept as long as, make their availability of round the whole year. Products which kept in cold storage, for their preservation of its original fresh state and not to be spoiled. It can be kept in long period in cold storage under special conditions.

Types of cold storage

There are three types of cold storages.

- 1 Temporary storage
- 2 Long term cold storage
- 3 Frozen storage.

Temporary storage is used for sometime and cooled the food stuff. These stuffs are stored in the cold storage, little higher than its freezing temperature. It is between -12.2°C to -23.3°C and generally, the temperature remains -17°C . It is used for one or two days, one week up to maximum 15 days.

For long time, the commercial storage is used, its age depends upon the stuffs. In this, the food stuffs can be stored for 7 days to 6 or 8 months, and meat etc. can be stored more than this period.

Frozen storage is used for the preservation of flavour and colour, so as to approach very nearly the fresh product.

Layout of cold storage plant: The essential parts of the cold storage plant is identical to that of mechanical refrigeration system. Its main parts are compressor, condenser, expansion device and evaporator.

It is necessary to heat the compressor crankcase to evaporate the liquid refrigerant trapped in the oil, especially low temperature appliances like cold storage.

Crank case heaters are used in large commercial cold storage plant's compressors. These heaters will be operating during the 'off' cycle and it will be controlled thermostatically.

For small cold storage, the room is cooled by air. The fresh air is drawn in at the room, it passes over the evaporator coils and cool air is blown out through louvers in the room.

These louvers avoid the moisture entering to cool room along with the cooled air. In such units the refrigerant use directly in thin cooling coils and the fan or blower sucks the air through the cooling coils, then send it inside the cold room to maintain the temperature of the food stuffs to preserve.

In large cold storage, the brine refrigeration system is used at high or low temperature than freezing point. The direct expansion, coil is used in this system, where main rooms are to be cooled. If the storage is two or more storey, the brine is the best, which has maximum capacity of absorbing heat.

The cool brine pumped and distributed both the side of the rooms, through fan coil units (F.C) and cools the storeys rooms. This coldness can be controlled as required individually.

The brine which absorbs the heat, from the fan coil sent to balance tank which is provided on top of roof. From the brine tank it returns to the cooler get cooled and pumped again.

Locker type construction: Since refrigeration space is the most expensive, it is necessary that the part of the plant, that is lined with insulation and equipped with coils & constructed with the smallest amount of space possible.

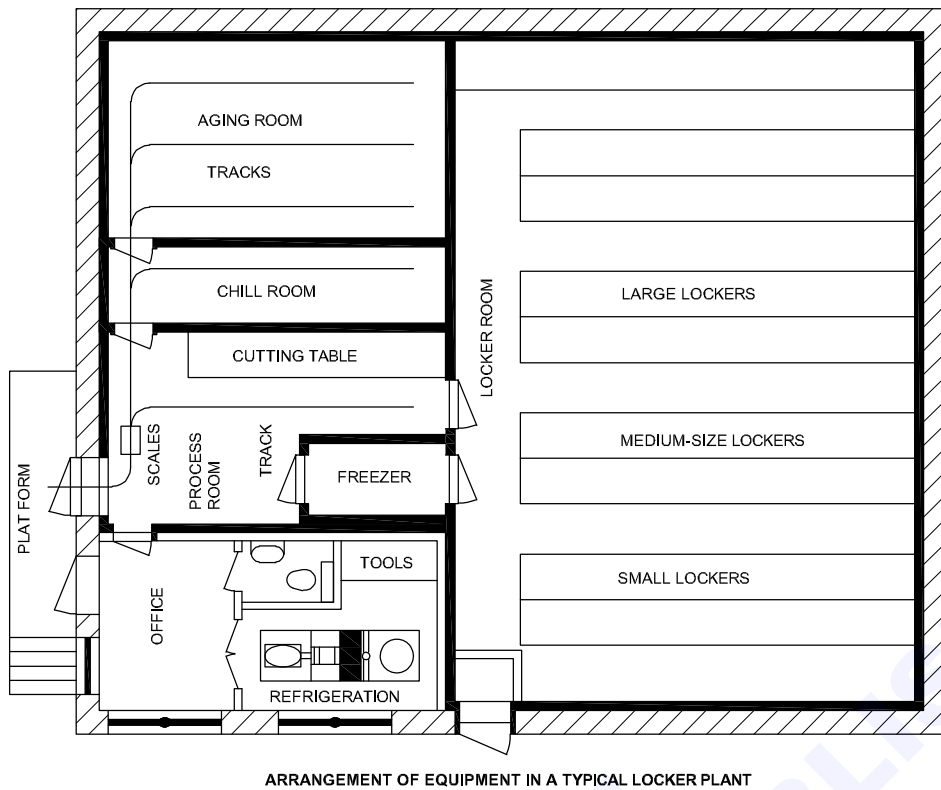
These kind of large commercial cold storage systems consists of:

- 1 Chill room with an air-circulation of ample capacity.
- 2 A well equipped process room (not refrigerated)
- 3 Suitable quick freeze room.
- 4 Locker rooms with a closely controlled temperature.
- 5 Refrigeration machinery of adequate capacity which controlled by automatically.
- 6 In addition to these, customer room, aging room, vegetable storage room and etc.

For the arrangement of equipments in a typical locker plant refer (Fig 1)

Insulation applied in cold storage system: Cold storages are provided with air-tight insulated rooms to preserve the food beverages, the walls of the buildings, roofs are insulated to prevent heat leakage. The insulations refers to any material which slows down the transfer of heat by any one or combination of the, three methods of heat transfer, the conduction, convection and radiation.

Fig 1



ARRANGEMENT OF EQUIPMENT IN A TYPICAL LOCKER PLANT

MR20N2614911

Properties of insulating materials

- 1 It should have low thermal conductivity and high resistance to heat transfer.
- 2 It should be fire proof.
- 3 It should be resist water absorbtion.
- 4 It should be light in weight.
- 5 It should be odourless.
- 6 It should have strength and stability.
- 7 It should be available easy with low cost.

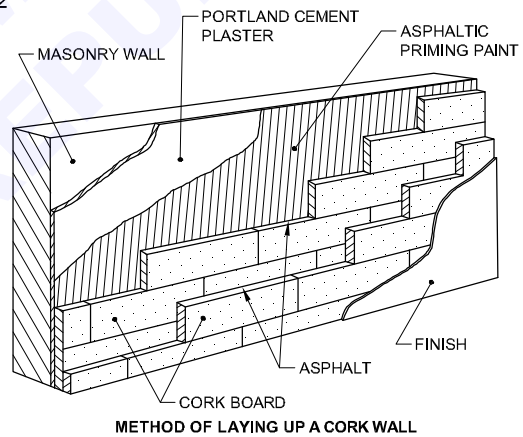
Method to apply insulation: The brick wall is first plastered with 15 mm thickness of portland cement, next to the cement plaster is painted with asphalt paint. Then it is coated with hot asphalt, finally with cork board or thermocole over the insulation (first layer) to provide the wall.

The second layer of cork board or thermocole board is provided, after coating with hot asphalt. Fig 2. The concrete ceiling can be insulated as shown in Fig 3. The common insulating materials used in refrigeration fields are thermocole, cork board, puf insulation and mineral wool.

Cold storage plant operation: Operation of the cold storage plant is not only just starting and stopping, it also includes continues care on the performance of the system, and day to day operational & routine maintenance. Symptoms of some minor malfunction may lead to major defects after sometime.

So the operator should be sharp in detecting, and take timely action to prevent such minor defects, before developing in to major problems.

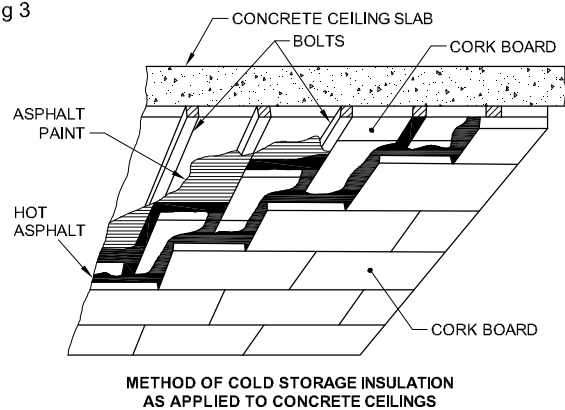
Fig 2



METHOD OF LAYING UP A CORK WALL

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Fig 3



METHOD OF COLD STORAGE INSULATION AS APPLIED TO CONCRETE CEILINGS

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The reading should be taken correctly in time as per log book, and he should have the ability to analyse the readings and decide whether the plant is working satisfactory or not.

Always follow the sequence of starting and stopping and procedures before and after operation. Keen observation should be maintained on the plant while in operation.

In case of power failure, if the plant suddenly stops, normalize the plants conditions and keep ready to start, soon as the power resumes start the unit with usual precautions and procedures as per the sequence.

Food preservation by refrigeration

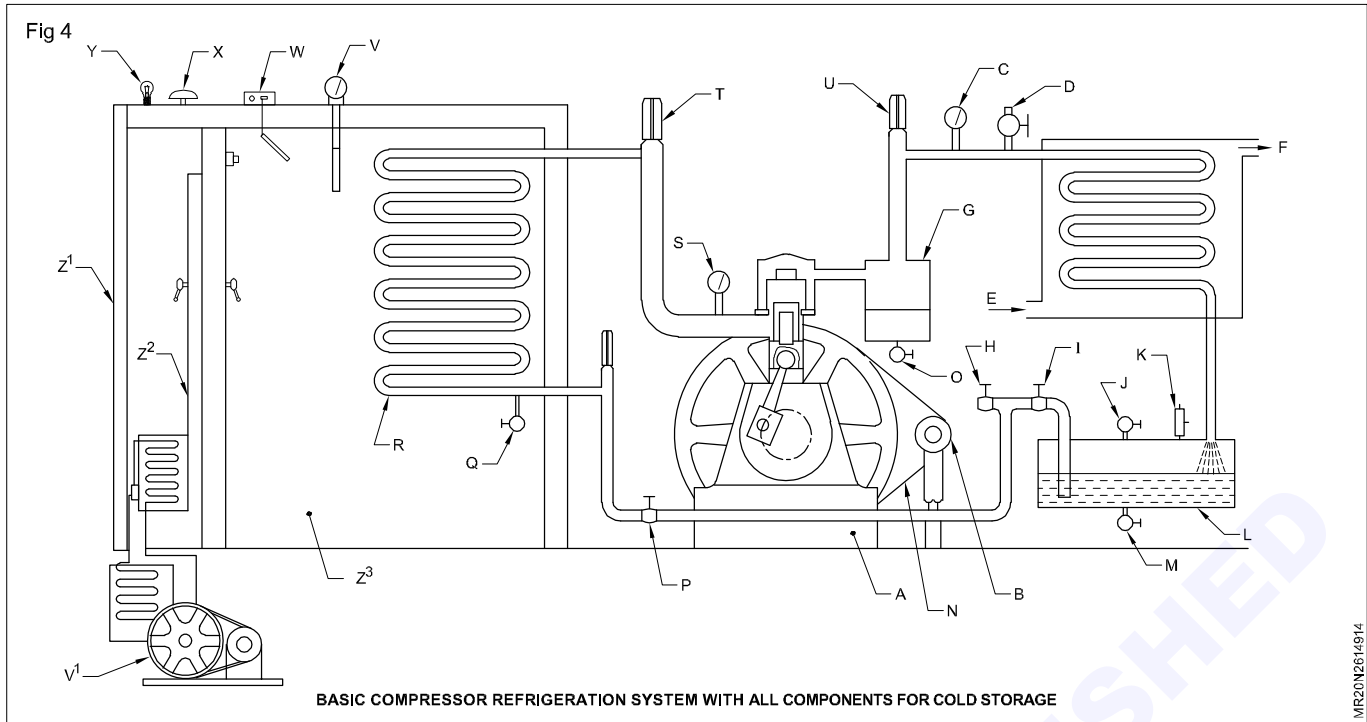
Preservation by refrigeration : The preservation of perishables by refrigeration involves the use of low temperature as means of eliminating or retarding the activity of spoilage agents.

Refrigerated storage : Refrigerated storage may be divided into three general categories

- 1 Short term storage
- 2 Long term storage
- 3 Frozen storage

Functions of parts and controls in cold storage plant (Fig 4)

Labelled Alphabet	Name of the part identified	Function
A	Compressor	To suck the low pressure vapour and compress to high pressure.
B	Electric motor	To drive the compressor
C	High pressure gauge	To indicate the discharge pressure.
D	Vent valve	For releasing non-condensables.
E	Condenser water inlet	Pick up heat from the gas so that it condenses
F	Condenser water outlet	Connects the hot water to cooling tower.
G	Oil separator	Separates the oil from the gas.
H	Charging valve	To charge gas to system.
I	King valve	For pumping down the system
J	Purge valve	For releasing non condensables.
L	Liquid receiver	To collect the liquid from condenser.
M	Drain valve	To drain the liquid from receiver.
N	V belt	To drive the compressor
O	Oil drain	To drain oil from separator.
Q	Oil drain	To drain oil from evaporator.
R	Evaporator	Extracts heat from the medium to be cooled.
S	Suction pressure gauge	Indicates the suction pressure of the system.
V	Dial thermometer	Indicates the room temperature (cold room)
V1	Refrigeration plant	To cool the air lock space.
K	Relief valve	Release the liquid when pressure exceeds normal operating - pressure, saves the vessel from bursting.
P	Expansion valve	Controls the flow of liquid refrigerant in evaporator as per load.
T	Low pressure cutout switch	To stop the compressor drive at the desired set discharge pressure.
U	High pressure cutout switch	To stop the compressor drive at the desired set discharge pressure.
W	Thermostat	To stop the compressor drive at desired set temp.
X	Alarm bell	To be used by the person trapped in the cold room (rescue)
Y	Red indicator lamp	Glows when the bells sounds (indicator rescue).
Z ¹	Air lock door	To avoid atmospheric air entry in cold room.
Z ²	Main cold room door	To keep the room air tight.
Z ³	Cold room	Product storing area, (low temp area)



For short and long term storages, the product is chilled and stored at some temperature above its freezing point.

Whereas frozen storage requires freezing of product and storage at some temperature between -120°C to -23°C with -18°C and below being most frequently employed.

Storage condition: The optimum storage conditions for a product held in either short or long term storage depends. Nature of the individual product, the length of time the product is packed or unpacked in general the conditions required for short term storage are more flexible than those required for long term storage and ordinarily, higher storage temperatures are permissible.

Types of controls in refrigeration system:

Fluid flow control: It is obvious that the fluid flow control (i.e.) the throttling device should automatically feed the required amount of refrigerant depending upon the prevailing conditions. This is accomplished by the automatic liquid feed controls, such as the thermostatic expansion valve, float valves etc. These are automatic throttling devices.

Operating controls to maintain conditions of temperature: For a five ton plant, if the load comes down in cold room. There it becomes necessary to reduce the capacity of the refrigerant plant. The simplest method of reducing the capacity of the plant is to stop the compressor when the room temperature reaches the lowest desirable level. The compressor can be restarted when the room temperature raises above the maximum desirable level. A thermostatic switch is used to accomplish this automatically.

Safety controls: They are installed to protect the various components of the plant against abnormal working conditions.

The commonly used controls are as follows:

High pressure cut-out switch: When the discharge pressure of the compressor exceeds certain point, the high - pressure switch opens its contacts and stops the compressor motor.

Low pressure cut-out switch: When the suction pressure or evaporator pressure falls, the low pressure switch causes the electrical contacts to open, thus stopping the compressor motor. The low pressure switch is also used as a safety switch against freeze ups.

The switch is adjusted to a pressure which is higher than the corresponding to the freezing temperature of the medium cooled. As the temperature of the medium falls down the refrigerant's pressure in the system comes down. The low pressure switch connected to the machine, cut outs and stops the compressor motor when the machine refrigerant pressure reaches the set point of the switch, thus preventing a freeze up.

Both the high pressure and low pressure cut - out switches work on the same principles, as the thermostat. Here instead of the pressure of the thermal bulb actuating the bellows of the thermostat, the system pressure (high pressure side for the high pressure cut-out and low pressure side for the low pressure cut-out switches) actuates the pressure switch.

Cold storages and commercial cabinets:

- Storage temperature
- Relative humidity and air-motion
- Mixed storage
- Frozen storages

Many products can be stored and are stored above freezing temperature but the period of storage will be considerably shorter than the period of storage with freezing.

The storages which are used for short period storage purposes are known as cold storage. The product can be stored under non-freeze condition hardly for few days and not more than 15 days under any circumstances.

The storage period depends upon the type of products and its condition at the time of storages the fresh tomatoes can be stored for maximum for 10 days. Some products cannot be stored under freeze condition like ripped tomatoes and leaf, vegetables because they contain 95 to 98% of water.

Storage temperature: Most of the food are stored above their freezing point where short period storages is necessary. The effect of incorrect temperature maintained in the cold storage is to low the quality of the stored product. The range of temperature maintained lies between -23°C to -29°C .

Relative Humidity and air motion: Both above mentioned points are important to prevent excessive dehydration. Low R.H. and high air velocity cause excessive dehydration in the stored products. The loss of the moisture from vegetables, fruits, meat and fish causes reduction in weight and vitamins, its effect is more aggravated on meat causing shrinkage and discoloration.

Mixed storage: When the store is used to store different types of foods, then it is known as mixed storage. The big storages are used when the quantity of one products is sufficiently large. Generally, the storages of commercial bases are designed to store different foods with limited quantity. The major problem associated with this type of storage is the temperature required for different foods are different. Generally, such storage is divided into different compartments and required temperatures are controlled by control system.

Another problem associated with this type of storage is odour and flavour absorption. Some foods given off the odours and some absorb them and by or absorbing the odours they are deteriorate. Attention should be given that such products should not be stored with fruits, eggs and dairy products which are highly sensitive to odours.

Frozen storages: The purpose of frozen storage is also to preserve the food on longer duration, it differs from cold storage in two respects as listed below:

1 Sizes

2 Temperature range

The size of the frozen storages are considerably smaller compared with the temperatures used for cold storages. This is necessary because the foods are cooled below their freezing temperatures.

The foods which are preserved in frozen storages included vegetable, meat, fruits, fish, poultry, bread, ice cream and wide variety of the precooked foods.

The vegetables and fruits require considerable processing before freezing. The fruits must be harvested just before the maturity and they should be frozen as quickly as possible. This is necessary for maintaining the taste and extended period of preservation. The fruits after harvesting are cleaned and washed and then they are freeze below -20°C . The vegetables after harvesting blanched into hot water at 60 to 70°C . The blanching is necessary to kill the enzymes which are associated with the vegetables. The blanching should not be used for fruits because it effects the taste of fruits. The common temperature used for freezing the vegetables and fruits is -20°C and below.

Meat and fish do not require any preprocessing like fruits and vegetables before freezing. They are directly freezes taking them into frozen storages after washing.

Commercial cabinets: Commercial refrigeration cabinets are designed and constructed to fit the needs of the user. They are named according to the purpose for which they are used. (Fig 5&6)

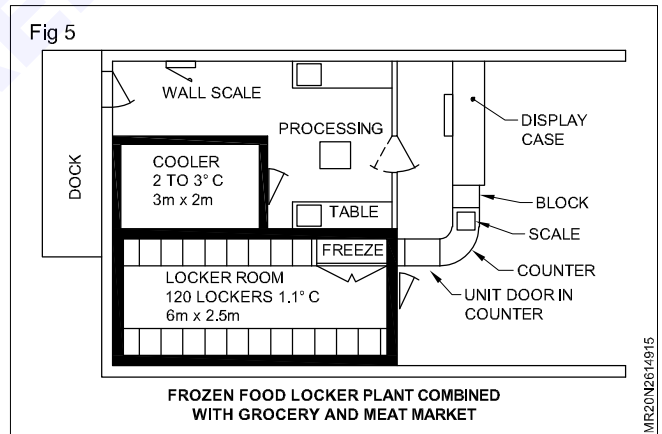
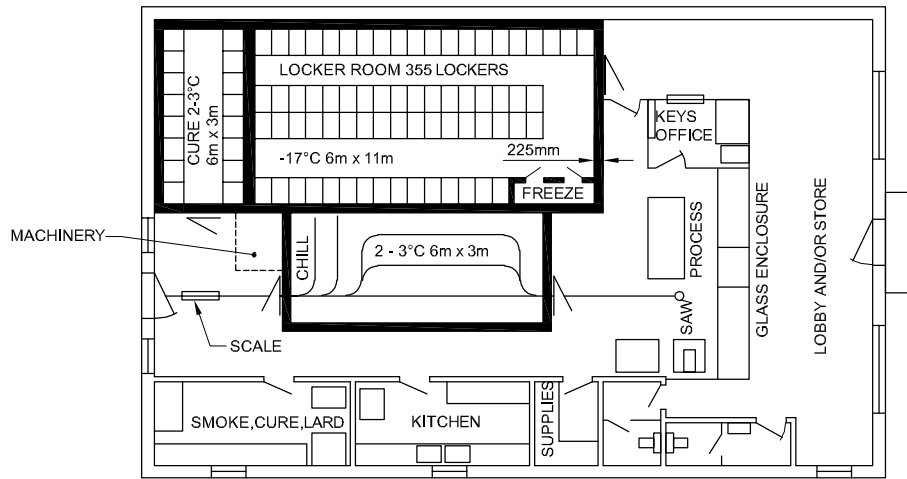


Fig 6



TYPICAL FROZEN FOOD LOCKER PLANT

MR20N2614916

Electrical & cooling systems of cold storage plant

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

- trace the electrical wiring circuit of cold storage
- find the electrical complaints of cold storage
- find the remedies of electrical complaints of cold storage.

Normally cold storage plants are working in three phase compressor motors are 3 ϕ motors and starters used are 3 ϕ DOL starters and for high capacity plants automatic star delta starters are used.

For blower fan 3 ϕ motors and 3 ϕ contactors are used for condenser fan motors single phase motors are used. For controlling and switching condenser fan motors single phase contactors are used. For control supply and compressor motor control diagram is shown below.

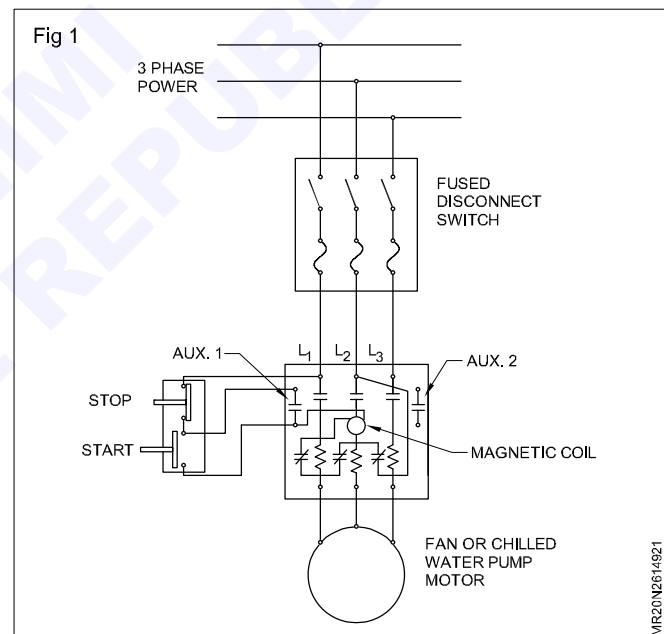
In a cold storage electrical wiring circuit all the protective drives like HP, LP oil pressure cut out and thermostats are also included. Timer delays relay is included to change the motor from star connection to delta connection at the time of star delta motor of compressor starting.

Control sequence : Since the blower fan of a direct expansion evaporator coil is need to start first in the cold storage starting procedure. The condenser fan motors are needed to start second in air cooled condenser system. In water cooled condensing systems, condenser water pump need to start first and cooling tower fan start at second. After starting the fan, then start the compressor motors (Fig 1) illustrates the typical three wire control of a magnetic contactor type on line starter.

The motor control device used in a manual stop start push button switch.

(Fig 2)

The push button switch has one normally closed contact. The stop button and one normally open contact the start button. Upon depressing the start button a line voltage circuit is completed from L1 through the stop contacts of the push button switch, through the magnetic coil to L2. This energizes the magnetic coil closing the starter main contacts and auxiliary contacts.



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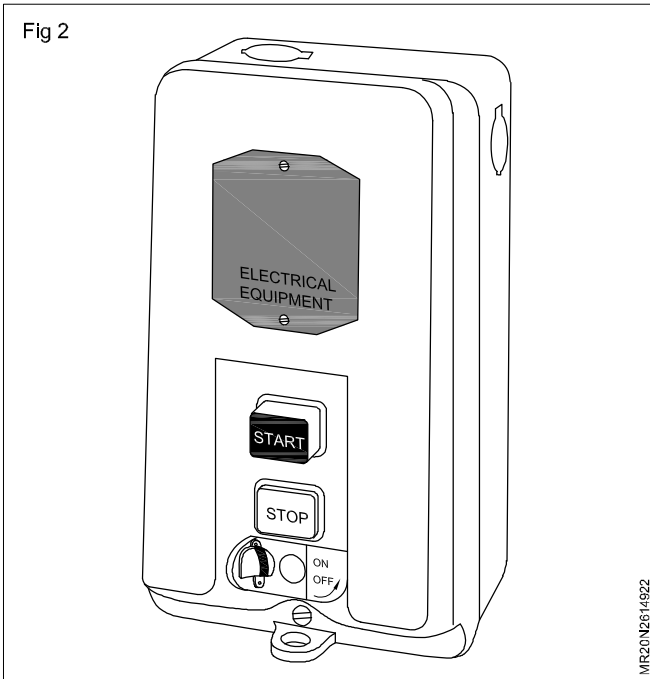
Thus the compressor motors are started; after the compressor is started watch the suction, discharge and oil pressure and all the temperature readings.

Circuit diagram of the compressor and control circuit. Control thermostat cut off the pump down solenoid valve and the LP control will cut off the compressor motor.

When the temperature inside the cold storage is reduced to the point till the thermostat set point is reached the temperature controller opens the circuit of pump down solenoid valve and control relay. De-energizes the control solenoid valve, and stopping the flow of liquid refrigerant to the evaporator and opening a portion of the control circuit.

This is where the remaining refrigerant is pumped from the evaporator.

Fig 2



Once the evaporator is pumped down to the cut-out setting of the Refrigerant control (RPC), its contact open de-energizing the compressor starter.

This in turn opens its auxiliary contacts de-energizing the control circuit.

Interlocking circuit : Note that the auxiliary contacts of the system fan or chilled water pump starter (aux2) and the condenser water pump (aux3) must be closed, proving that these two vital pieces of equipment are operating before the compressor can be started. This is called interlocking circuit. If either of these starter fails to energize or is de-energized by any of its safety devices (fuses overloads etc) the auxiliary contacts open, stopping the compressor.

Control relay : One of the functions of the control relay is to prevent compressor short cycling, if the liquid valve are controller by the temperature controller and the start stop function of the compressor are controlled solely by the refrigerant pressure control (RPC) the opening of the temperature controller would close other liquid line valve.

In turn the refrigerant pressure control would stop the compressor when the low side pressure reached its cut out point. However if the liquid line valve did not close tightly or the compressor valves leaked. High side pressure back to suction the low side pressure would rise to cut in setting RPC restarting the compressor, the compressor would then run only long enough to reduce the low side pressure to the cut out point of RPC. This short cycle operation would repeat itself causing hardship on the compressor motor and starting equipment.

Once the temperature controller de-energizes the control relay, control power is re-moved from RPC, Preventing its closing from restarting the compressor.

Refer the (Fig 4, Fig 5 & Fig 6) for different control and power wiring circuits used in cold storage.

Cooling system of cold storage plant : (Fig 3) describe the typical vapour compression cooling system of cold storage plant.

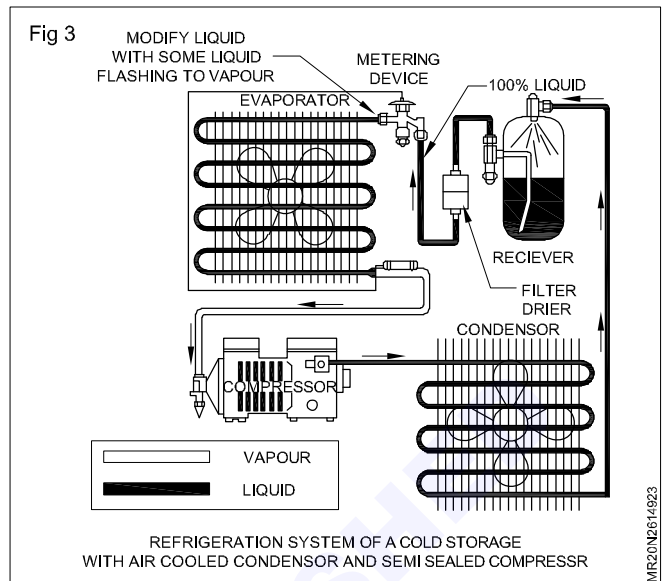
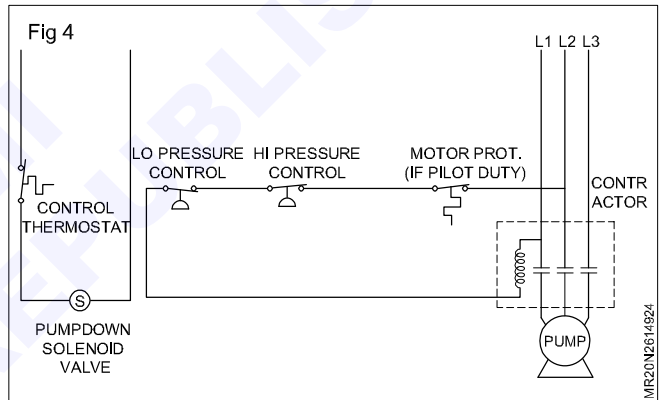


Fig 4



Common troubles and remedies for cold storage:

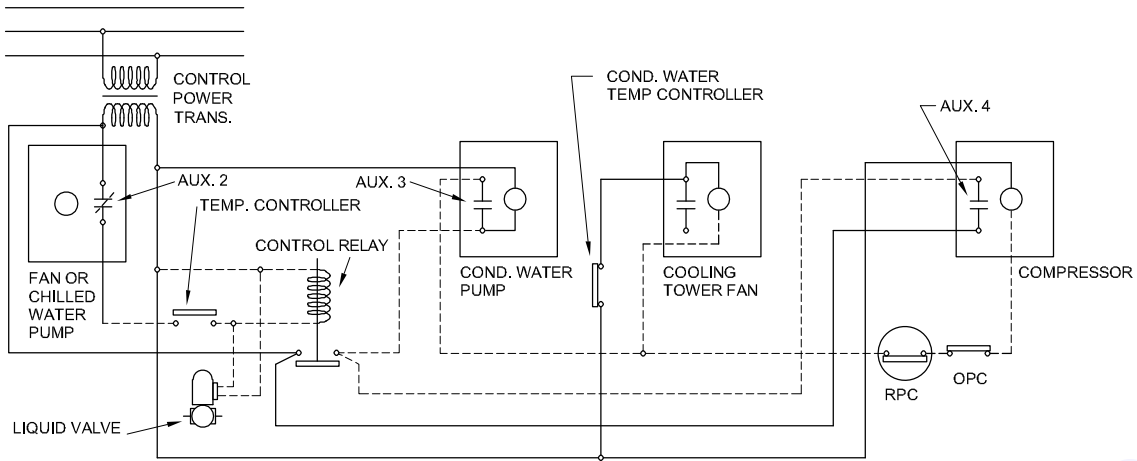
Normally the water vapour pressure of the cold storage is 5.59 mm Hg. abs and the outside water vapour (moisture) pressure being much higher at 21.5mm Hg. abs. The water vapour will try to rush into the cold storage room from outside, because of the pressure difference.

The moisture from the outside air will enter through the door opening, any cracks in the wall etc. The cold storage walls, roof and floor are insulated and plastered to reduce the heat transmission in to the cold storage. The insulation material and plastered walls / ceilings can be porous to some extent, and the moisture can pass through them from outside to cold storage room.

The mechanical troubles and remedies of the plant is similar to all the other 5TR. refrigeration plants only.

But if the water vapour enters the cold storage, it begins to condense, especially on the evaporator coils. The heat load for the removal of latent heat for condensing this water vapour results in tremendous extra load on the refrigeration system, and the moisture will frost fast on the cooling coils of the low temperature systems like cold storage.

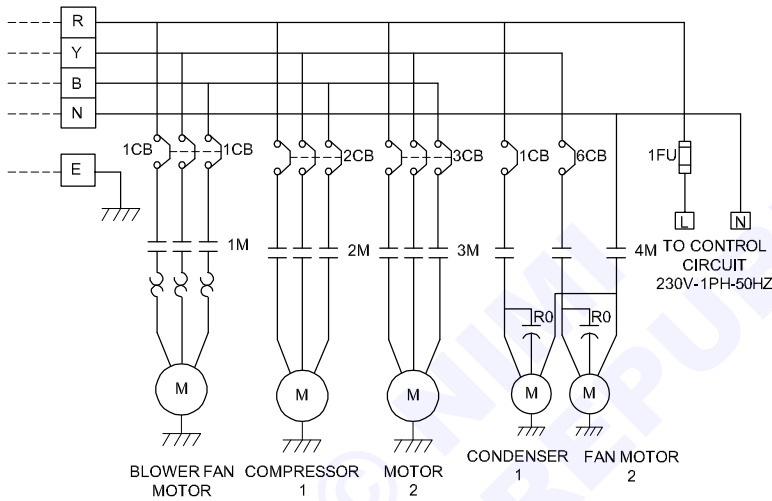
Fig 5



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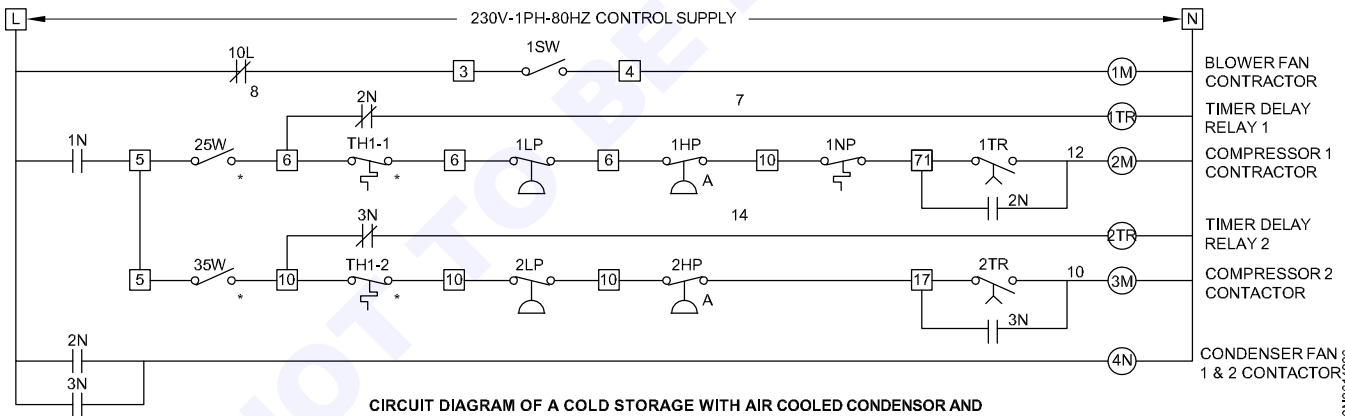
Fig 6

400V-3PH-50HZ
POWER SUPPLY
FROM FUSED
DISCONNECT SWITCH



LEGEND

- N = CONTRACTOR
- CB = CIRCUIT BREAKER
- CDH = CRANKCASE HEATER
- FLA = FULL LOAD AMPERE
- FU = FUSE
- Hp = MOTOR HP POWER
- HP = HIGH PRESSURE SWITCH
- LP = LOW PRESSURE SWITCH
- LPA = LOCKED MOTOR AMPERE
- MP = MOTOR PROTECTOR
- MCA = MINIMUM CIRCUIT AMP
- MF3 = MAXIMUM FUSE SIZE
- MP = MOTOR PROTECTOR
- MTA = MAXIMUM MUST TRIP AMPERE
- NRA = NORMAL RUNNING AMPERE
- TR = TIMER DELAY RELAY
- RLA = RATED LONG AMPERE
- SN = SWITCH
- TB = TERMINAL BLOCK
- * = FIELD SUPPLY
- A = MANUAL RESET
- = FIELD VANC
- = FACTORY WIRING



CIRCUIT DIAGRAM OF A COLD STORAGE WITH AIR COOLED CONDENSOR AND 3Ø COMPRESSOR MOTOR AND ALL INTERLOCKING CONTROLS

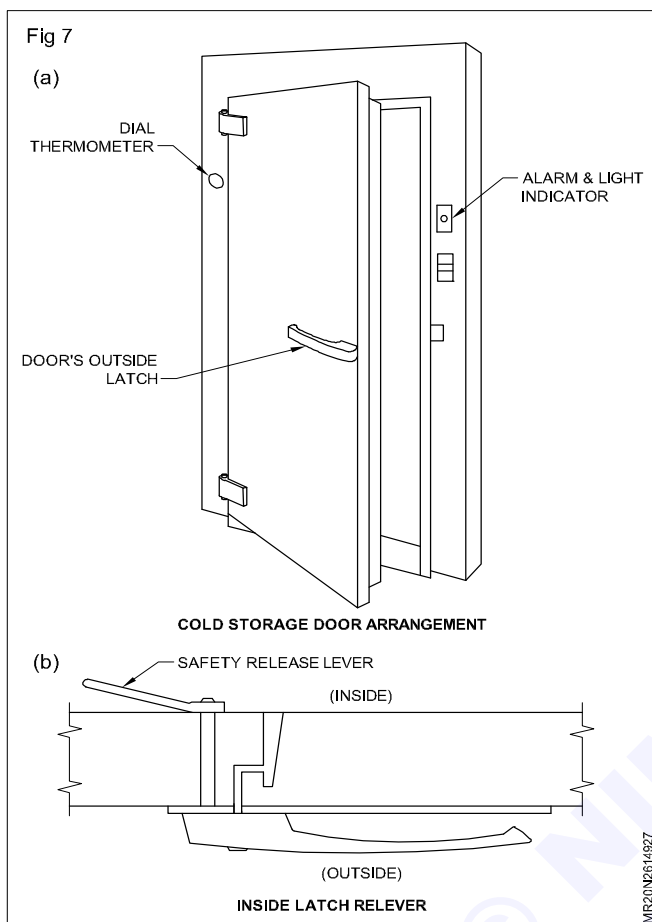
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It will form as an insulation on the evaporator coils, against the heat transfer between the room air and the evaporator. This further deteriorates the situation, resulting in poor cooling of cold storage. Therefore it is absolutely necessary to provide aluminium foil to prevent the infiltration of the moisture into the cold storage room.

The joints between the insulation boards should be filled with vapour-barrier solutions / compounds such as bitumen. Periodical care should be taken on insulations and the door mechanisms to avoid unnecessary heat load to the cold storage.

Safety precautions of the cold room: The safety alarm and light indication should be checked periodically and keep in good condition. Inside the cold storage, the temperature maintaining may be very low example -40°C . Suppose if the door get stuck when the person is inside, he cannot survive the low temperature for long time. It will give a serious reactions in the human body. In these situations he can call the other person to help and open the door from outside, if he gives the alarm signal.

The doors of the cold storage provided with inside latch releases or safety release lever. When we pull that handle it has to release the latch, and the door can be opened. Fig 7a & 7b.



While leaving the cold room always check, if any person who came along with us, is left inside, before latch the door.

The person who does not know the seriousness of the freezing danger or un-authorized person, should not be allowed inside the cold storage.

If the food beverages gets perished due to long time shut-down of the plant or often electrical power interruption, should not leave to remain in the cold room.

It should be removed immediately, before it spoils the other fresh things which kept later inside.

Trouble shooting common cold room problems

Because cold rooms are generally used in storing large quantities of produces or goods that requires low temperature it is important that you keep it in shape to operate smoothly and avoid problems. Following are the list of the most common cold room problems that you may encounter what causes them and why and how best to solve them.

Condensing walls: Condensating walls usually happen when the internal surfaces are colder than the room air hitting it. Solve this problem by warming up the wall surfaces through installing more insulation. Other solutions include tightening or providing better airflow inside.

Moulds walls: Unstable levels of moisture together with varying surface temperature are catalytic to mould growth. Growing moulds are a common problem with cold rooms

but you can remedy this by making sure that your storage rooms are dry, clean and disinfected. Moulds are likely to re develop over time so aside from cleaning, prevent it from occurring once more by installing enough insulation to avoid condensation.

Rotting walls: The absence of a vapour barrier or having one that is wrongly installed can be the reason why your cold room storage walls are rotting. Moisture seeping into the wood cladding is also another cause to be aware of. Resolve this problem by using a different kind of material for insulation or try to re-insulate. Since using a vapour barrier is not always dependable, finding ways to prevent moisture from seeping back in would be your best solution.

Dripping ceiling: Another cause of a missing or inadequately installed vapour barrier is dripping ceilings. It can also be caused by poor attic insulation and ventilation. Since the lack of insulation and vapour barrier are the common causes of this problem, the easiest solution would be to provide enough insulation as well as placing a vapour barrier with regards to the drive direction of the vapour pressure.

Air temperature problems: Temperature changes during storage- this may be due to inadequately located or insensitive and poor quality thermostats thus failing to sense the average room temperature. Evaporator coils with large temperature difference are also a factor for temperature changes as well as an un even air flow.

Solve this by installing the thermostats properly or use one which is a good quality. Allow more even air flow by rearranging storage containers or do some quick relocation of the evaporator coils or install extra fans or air tubes.

- Warmer or colder temperature than the preferred temperature during storage- may be due to poor quality thermostats once more. However, insufficient insulation in the summer as well as poor attic ventilation and not enough refrigeration causes inside air to be warmer or colder.

Practical solutions involve using quality thermostat and installing them properly. For more cooling capacity, install more refrigeration. Installing air tube as well as increasing the fan's capacity or having extra fans will also do depending on the problem that you have to solve.

Uneven internal air temperature are mainly caused by insufficient storage capacity leading to fluctuating airflow and short circuits the air right back to the evaporator coils.

The best solution for this will be to use a smoke generator to locate dead coils air spots and examine possible short circuiting of air. Installing air tubes, extra fans, and rearranging storage containers are also plausible solutions to follow.

Smelly storage airs: Gases like carbon dioxide and ethylene are usually emitted from decaying or "sweating" products. These gases in excessive quantity can cause your cold rooms to smell bad and will require you the use of a small exhaust fan for proper ventilation. Another thing that you can do is look for a decaying product and dispose it right away to rid your cold room of the bad smell.

About these ads.

Problems and Remedies

Problem	Cause	Remedy
Compressor does not run (Motor runs if belts or tyre coupling removed)	Compressor jammed	Compressor to be overhauled.
Compressor motor is not running	Main switch may be 'off' Fuse burned out Control 'off' due to thermostatic or low pressure cutout Faulty control Faulty motor or wiring damage	Switch 'on' the main switch. Analyse Analyse the reason for fuse blown and change the fuse. Wait till the required temperature or pressure raises and reset Service the control Change the motor, replace new wiring
Units runs but poor cooling (Low suction pressure)	Liquid line strainer may be choke Expansion valve plugged with dirt, ice or wax Defrost timer problem	Clean strainer Service the expansion valve Check and set the timer properly
(Evaporator coil frosting)	Evaporator fan not running	check the fan motor and wiring and rectify the problem. Lubricate the fan bearings
Normal or high suction pressure and high discharge pressure	System overloaded Short of refrigerant Non condensable gas over the condenser Condenser cooling medium is too warm Condenser efficiency is poor Refrigerant overcharge	Reduce the heat load Top up gas Purge the noncondensable gas Take steps to reduce the temperature of the cooling medium if it is possible Descale the condenser Recover the excess charge
Compressor short cycling	Leaky compressor valves Expansion valve starving coil (under charge) Improper setting range in HP cutout	Service or replace the valves Charge required gas Set the proper range in HP cutout
Erratic refrigeration effect (Too cold then too warm) Frost back	Sticky control, oil glogged at evaporator coils Improper setting of expansion valve Thermostatic expansion valves thermal bulb not in position (loose) Expansion valve stuck open or Dirt in expansion valves seating Lack of gas due to leak may be joints, gaskets, service valves, gauge port, bellows or diaphragms, oil plugs, compressor cap screws, oil seal etc.	Service the control Evaporator should be flushed Set the expansion valve properly Thermal bulb should be clamped firmly at proper place Service the expansion valve Arrest the leaks, vacuumise and charge the required quantity of refrigerant
Noise in compressor and other part of the plant	Worn parts, squeaking shaft seal, slugging oil or refrigerant loose flywheel. Poor lubrication compressor base bolts are loose Foundation bolts become loose Chattering water valves Rattling refrigerant lines Squeaking bolts Weak tyre coupling	Overhaul the compressor and check the efficiency, replace the lubricating oil & contaminated gas. Tighten the flywheel and compressor base bolts Tighten the foundation bolts Water valves should be fixed firm, need give support Put clamp where ever necessary Change the bolts Charge the tyre coupling

Introduction to HVAC

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

- fundamentals of HVAC Systems
- fundamentals of HVAC Systems
- comparison of HVAC systems
- central HVAC Systems and types
- requirement of HVAC Systems
- use of Psychrometric chart.

Introduction & Selection of HVAC System

Heating, ventilation, and air conditioning (HVAC) system is designed to achieve the environmental requirements of the comfort of occupants and a process.

HVAC systems are more used in different types of buildings such as industrial, commercial, residential and institutional buildings. The main mission of HVAC system is to satisfy the thermal comfort of occupants by adjusting and changing the outdoor air conditions to the desired conditions of occupied buildings. Depending on outdoor conditions, the outdoor air is drawn into the buildings and heated or cooled before it is distributed into the occupied spaces, then it is exhausted to the ambient air or reused in the system. The selection of HVAC systems in a given building will depend on the climate, the age of the building, the individual preferences of the owner of the building and a designer of a project, the project budget, the architectural design of the buildings.

HVAC systems can be classified according to necessary processes and distribution process. The required processes include the heating process, the cooling process, and ventilation process. Other processes can be added such as humidification and dehumidification process. These process can be achieved by using suitable HVAC equipment such as heating systems, air-conditioning systems, ventilation fans, and dehumidifiers. The HVAC systems need the distribution system to deliver the required amount of air with the desired environmental condition. The distribution system mainly varies according to the refrigerant type and the delivering method such as air handling equipment, fan coils, air ducts, and water pipes.

HVAC System selection depends on three main factors including the building configuration, the climate conditions, and the owner desire. The design engineer is responsible for considering various systems and recommending more than one system to meet the goal and satisfy the owner of a building. Some criteria can be considered such as climate change (e.g., temperature, humidity, and space pressure), building capacity, spatial requirements, cost such as capital cost, operating cost, and maintenance cost, life cycle analysis, and reliability and flexibility.

However, the selection of a system has some constraints that must be determined. These constraints include the

available capacity according to standards, building configuration, available space, construction budget, the available utility source, heating and cooling building loads.

Basic components of HVAC Systems:

The basic components or equipment of an HVAC system that delivers conditioned air to satisfy thermal comfort of space and occupants and the achieve the indoor air quality are listed below :

- Mixed-air plenum and outdoor air control
- Air filter
- Supply fan
- Exhaust or relief fans and an air outlet
- Outdoor air intake
- Ducts
- Terminal devices
- Return air system
- Heating and cooling coils
- Self-contained heating or cooling unit
- Cooling tower
- Boiler
- Control
- Water chiller
- Humidification and dehumidification equipment

Classification of HVAC systems

The major classification of HVAC systems is central system and decentralized or local system. Types of a system depend on addressing the primary equipment location to be centralized as conditioning entire building as a whole unit or decentralized as separately conditioning a specific zone as part of a building. Therefore, the air and water distribution system should be designed based on system classification and the location of primary equipment. The criteria as mentioned above should also be applied in selecting between two systems. Tables below show the comparison of central and local systems according to the selection criteria.

Comparison of central and local HVAC systems

Criteria	Central system	Decentralized system
Temperature, humidity and space pressure requirements	Fulfilling any or all of the design parameters	Fulfilling any or all of the design parameters
Capacity requirements HVAC diversity factors to	Considering reduce the installed equipment capacity	Maximum capacity is required for each equipment
Redundancy	Significant first cost and operating cost Standby equipment is accommodated for troubleshooting and maintenance	Equipment sizing diversity is limited No backup or standby equipment
Special requirements	An equipment room is located outside the conditioned area, or adjacent to or remote from the building	Possible of no equipment room is needed
First cost	Installing secondary equipment for the air and water distribution which requires additional cost High capital cost	Equipment may be located on the roof and the ground adjacent to the building Affordable capital cost
Operating cost	Considering longer equipment services life to compensate the high capital cost More significant energy efficient primary equipment	A proposed operating system which saves operating cost Less energy efficient primary equipment Various energy peaks due to occupants' preference
Higher operating cost		
Maintenance cost	Accessible to the equipment room for maintenance and saving equipment in excellent condition, which saves maintenance cost	Accessible to equipment to be located in the basement or the living space. However, it is difficult for roof location due to bad weather
Reliability	Central system equipment can be an attractive benefit when considering its long service life	Reliable equipment, although the estimated equipment service life may be less
Flexibility	Selecting standby equipment to provide an alternative source of HVAC or backup	Placed in numerous locations to be more flexible

HVAC system requirements

Four requirements are the bases for any HVAC systems. They need primary equipment, space requirement, air distribution, and piping.

Primary equipment includes heating equipment such as steam boilers and hot water boilers to heat buildings or spaces, air delivery equipment as packaged equipment to deliver conditioned ventilation air by using centrifugal fans, axial fans, and plug or plenum fans, and refrigeration equipment that delivers cooled or conditioned air into space. It includes cooling coils based on water from water chillers or refrigerants from a refrigeration process.

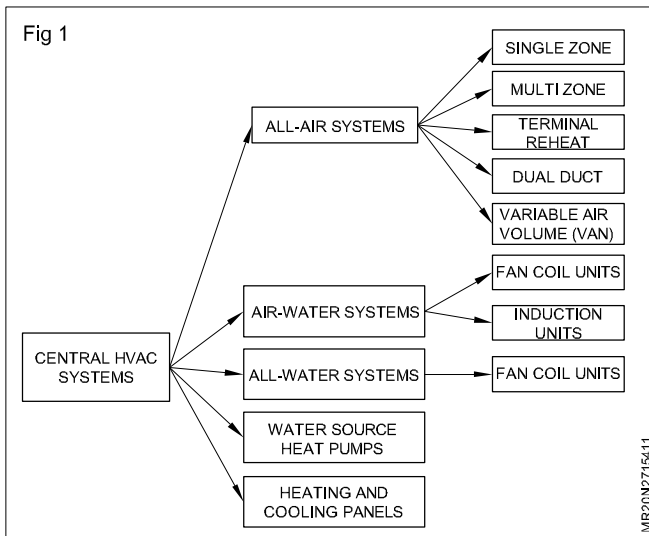
Space requirement is essential in shaping an HVAC system to be central or local.

1 Central HVAC systems (Fig 1)

A central HVAC system may serve one or more thermal zones, and its major equipment is located outside of the served zone(s) in a suitable central location whether inside, on top, or adjacent to the building. Central systems must condition zones with their equivalent thermal load. Central HVAC systems will have as several control points such as thermostats for each zone. The medium used in the control system to provide the thermal energy sub-classifies the central HVAC system.

The thermal energy transfer medium can be air or water or both, which represent as all-air systems, air-water systems, all-water systems. Also, central systems include water-source heat pumps and heating and cooling panels. All of these subsystems are discussed below. Central

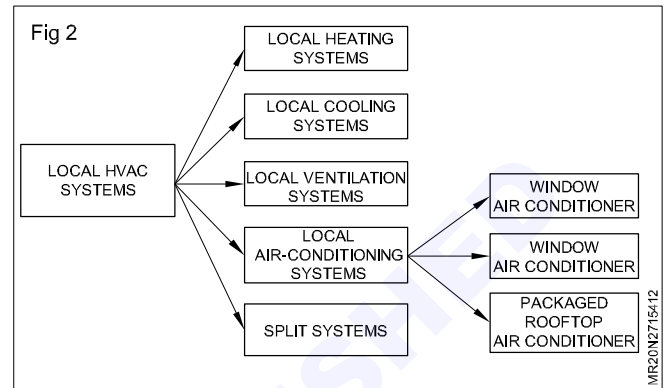
HVAC system has combined devices in an air handling unit, which contains supply and return air fans, humidifier, reheat coil, cooling coil, preheat coil, mixing box, filter, and outdoor air.



Local HVAC System classifications:

Local ventilation systems (Fig 2)

Local ventilation systems can be forced systems by using devices such as window fan to allow air movement between outdoor and a single zone without changing in the thermal environment of the zone. Other systems used for ventilation are air circulation devices such as desk or paddle fans to improve thermal comfort of the space by allowing the heat to be transferred by conventional mode.



Psychrometry

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

- definition of psychrometry
- psychrometric terms
- types and function of psychrometer
- use of psychrometric chart
- parameters finding using chart.

Psychrometry: Psychrometry is a branch of science which mainly deals with the study of atmospheric moist air. Dry air mixed with water vapour or humidity. It also includes the study of the behavior of dry air and water vapour mixture under various sets of conditions. Air is a mixture of several gases.

Psychrometric chart: A psychrometric chart is a graphical representation of the physical properties of moist air based on atmospheric pressure. The chart graphically expresses how various properties relate to each other, and is thus a graphical equation of state. It plays a very important role in air conditioning calculation. Chief advantages of this chart without any tedious calculation: only knowing two properties of air we can figure directly from the chart.

Psychrometric terms

Dry air: Dry air is the mixture of the following gases: 78.03% of Nitrogen, 20.99% of Oxygen, 0.03% of Carbon dioxide and 0.01% of hydrogen and rest other gases.

Moist air: Moist air is the mixture of dry air and water vapors. The amount of water vapors present in the air depends upon the temperature of the air.

Saturated air: When moist air contains maximum amount of water vapour, i.e., air is fully saturated (100% RH) that it can hold it is called saturated air.

Unsaturated air: Moist air which is not saturated is called unsaturated air.

Degree of saturation: It is the ratio of actual mass of water vapour in a unit mass of dry air to the mass of water vapour in the same mass of dry air when it is saturated at the same temperature. Or

The ratio of the prevailing humidity ratio of moist air to the humidity ratio of saturated air at the same temperature and pressure.

Dry bulb temperature (DBT) (Fig 1)

The temperature of air is measured by ordinary thermometer is called Dry Bulb Temperature. It is expressed in degree Celsius (°C), or degree Fahrenheit (°F).

The temperature which is recorded by a thermometer whose reading is not affected by the humidity ratio or by thermal radiation.

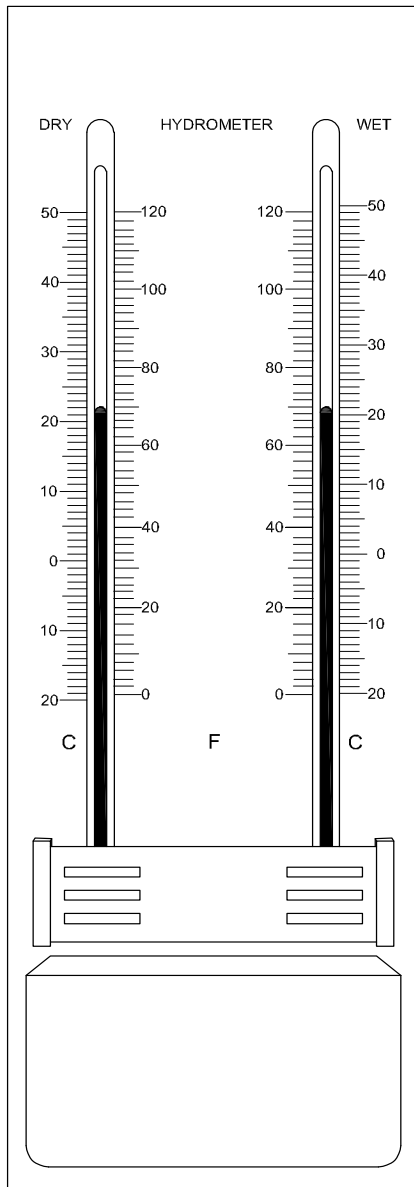
Wet bulb temperature (WBT) (Fig 1): It is the temperature of the air measured by a wet bulb thermometer whose bulb is covered with wet wick or cloth. It is measured in °C or °F.

The temperature which is recorded by a thermometer when its bulb is covered with wet cloth and is exposed to a moving air.

Wet bulb depression: The difference between the dry bulb temperature and wet bulb temperature is called wet bulb depression.

$$W.B.D. = DBT - WBT$$

Fig 1



Dew point temperature: Dew point temperature (DPT) is that temperature at which a moist air sample at the same pressure would reach water vapor saturation. At this saturation point, water vapor would begin to condense into liquid. OR The temperature at which the moisture present in the air starts to condense is called dew point temperature.

Dew point depression: The temperature difference between the dry bulb temperature and dew point temperature is called dew point depression.

$$DPD = DBT - DPT$$

Humidity

The presence of moisture or water vapour in the air is called humidity. Humidity of air measured in terms of grains.

1 grain is small amount that is 1 pound of water contains 7000 grains

Humidity is measured by an instrument known as hygrometer

ABSOLUTE HUMIDITY

The amount of water vapour present in unit volume of air is known as absolute humidity. It is indicated in grains/cubic foot or grains/m³

1 pound of water = 7000 grains of moisture.

1 Kg of water = 15430 grains of moisture.

Humidity ratio or specific humidity

The actual weight of water vapour present in unit weight of air is known as humidity ratio or specific humidity. It is indicated in grains/lbs of air, or kj/kg of dry air

The weight of water vapor per unit weight of dry air in a vapor air mixture.

Relative humidity (R.H.)

It is the ratio of actual amount of moisture present in one cubic foot or one cubic meter of the air at constant temperature, to the amount of moisture needed to saturate the air at that same temperature. It is expressed in percentage (%).

$RH = \frac{\text{Actual amount of water vapours present in one cu.foot or one cu.Meter of air}}{\text{amount of moisture needed to saturate the air at that same temperature}}$

or The ratio of actual weight of water vapor in a given volume to the weight of water vapor contained in the same volume at the same temperature when the air is saturated.

Enthalpy

Enthalpy of the air is the sum of the sensible heat of dry air and latent heat of water vapour associated with dry air.

$$\text{Enthalpy} = SH + LH$$

Effective surface temperature: The assumed uniform surface temperature of heating/cooling coil which would produce same conditions of leaving the coil as the actual non-uniform surface temperature of the coil varying through-out as air passes over it.

Apparatus Dew point temperature (ADP): It is the dew point temperature of the cooling coil which should be below the dew point of return air entering the cooling coil.

Psychrometer: The equipment which is used for measuring the dry bulb temperature and wet bulb temperature simultaneously is known as psychrometer.

- Laboratory psychrometer or Fixed psychrometer.
- Sling psychrometer.
- Aspirating psychrometer.

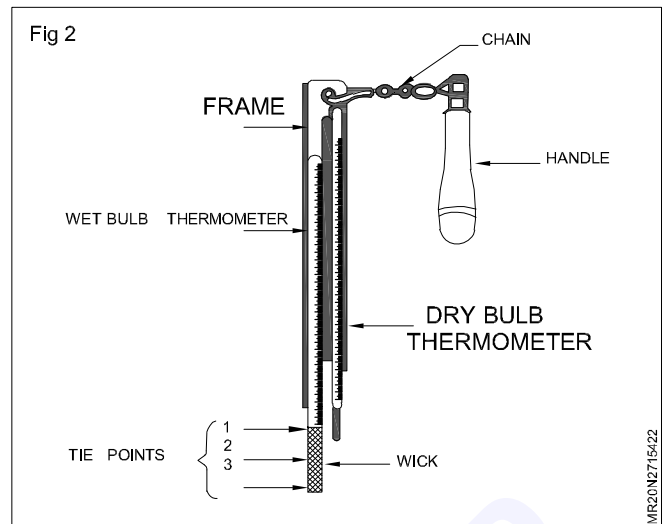
Laboratory psychrometer: It is a simple type of psychrometer. It is generally fixed on a wall and it continuously reads dry and wet bulb temperature of the surrounding air.

Sling psychrometer: The sling psychrometer is the device constructed with two thermometers secured to a frame. The frame either pivots on a handle or is attached to a handle by means of a chain. A cotton wick, which is wetted prior to use, covers the bulb of one of the thermometers. This thermometer is referred to as the wet bulb, while the other thermometer is termed the dry bulb. The dry bulb measures room temperature. The thermometers may be graduated in degrees Celsius or degrees Fahrenheit. By using a psychrometric chart or slide rule to compare the dry bulb (room temperature) reading to the wet bulb reading, the relative humidity is determined. Sling psychrometer are available in various sizes ranging from pocket-size models to larger units approximately a foot in length. The longer the thermometer, the smaller the increments, and the more accurate the reading. The sling psychrometer, though simple and reliable, can be incorrectly used; however, with proper instruction and practice, the user can become expert at measuring relative humidity.

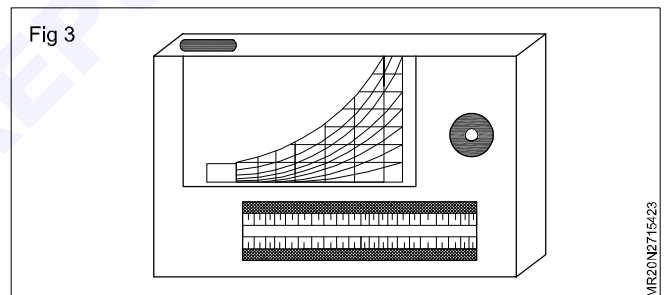
Using of sling psychrometer (Fig 2): Prior to use, read both thermometers. When they are dry, they should register the same temperature. Otherwise, results may be inaccurate. Thoroughly saturate the wick on the wet bulb using distilled or de-ionized water only. Tap water may contain salts and other contaminants that could prevent uniform evaporation, thus interfering with an accurate reading. Some wick materials may contain sizing that interferes with proper wetting. It is advisable to wash a new wick in distilled water to remove the sizing before installing. Tie the wick securely with string or white sewing thread to the bulb while wet to allow it to conform to the bulb while drying. First, tie the wick onto the stem near the bottom of the thermometer; second, tie the wick at the top of the bulb; third, stretch the wick over the bulb and tie it firmly below the bulb. Avoid touching the wick with bare fingers. Oils and dirt that accumulate on the wick from handling or improper storage will result in error readings. Change the wick when it becomes dirty. When using the psychrometer to calibrate another instrument, e.g., a hygromograph, take readings as close to the instrument as possible. Patches of sunlight and conditions away from the instrument may be different from near by conditions.

Ensure that there is sufficient space to swing the psychrometer safely. Droplets of water may fly off the wick as it is whirled. Use caution that the droplets do not land on surrounding museum objects. Because body heat and body moisture may affect the reading, hold the instrument at arm's length when swinging it. Whirl the instrument.

Inaccurate RH measurements will result if calculations are not adjusted for changes in atmospheric pressure due to high altitude. A minimum of these successive readings are advised to ensure accuracy. In consistent readings may indicate procedural error.



Aspirating psychrometer (Fig 3): The aspirating psychrometer is a mechanized unit, compact and easily transportable, that functions much like the sling psychrometer. The typical battery powered model will be discussed here. A fan inside the unit circulates a steady stream of air over the wet bulb. Advantages of the mechanized device are accuracy, less chance for procedural error, and usefulness in confined areas where there might not be space to whirl a sling psychrometer. Some models are equipped with a lamp for illuminating the thermometers in dark areas. Body heat and moisture are less likely to affect the aspirating psychrometer.



Using of aspirating psychrometer: The aspirating psychrometer is prepared for use in much the same way as the sling psychrometer. Thoroughly saturate the wick on the wet bulb with distilled or de ionized water, in this case using a dropper. A small dropper bottle is often provided with the instrument. Take the reading as close to the instrument to be calibrated as possible. After the psychrometer is turned on, check the reading of the wet bulb after 30 seconds and then every - 15seconds as it descends. After 1 to 2 minutes the wet bulb temperature should appear constant. Equilibrium has been achieved. Immediately turn off the psychrometer and take the readings from both thermometers, wet bulb first. Use caution that the psychrometer is not allowed to run too long, as this will cause the wick to dry out and the wet bulb temperature to rise from its minimal reading, resulting in an error relative humidity reading. Determine the relative humidity by reading the chart or slide rule provided with the psychrometer. Although the aspirating psychrometer is recognized as the more accurate of the two types, a second reading is advisable, especially if the user is

inexperienced with the instrument. Check the batteries in the unit periodically and replace them as needed. Weak batteries can affect fan speed and thus effect the accuracy of the reading. The batteries should be removed from the unit when it is not going to be used for a long period.

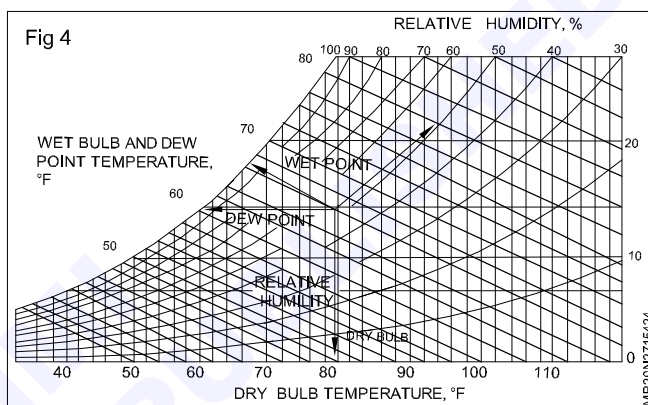
Psychrometer and psychometric charts are intended for use within a certain range of atmospheric pressure. High altitude, above 900m (approx.3,000 ft), will directly affect the accuracy of the RH reading unless a pressure correction formula is applied or a psychometric chart or slide rule for the appropriate pressure is used.

Psychrometric chart (Fig 4&5): It is graphical representation of various thermodynamic properties of moist air. The psychrometric chart is very useful for finding out the properties of air (which are required in the field of air condition) and eliminate lot of calculations. There is a slight variation in the charts prepared by different air-conditioning manufacturers but basically they are all alike. The psychrometric chart is normally drawn for standards atmosphere pressure of 760 mm of HG (or 1.01325 bar). In a psychrometric chart, dry bulb temperature is taken as abscissa and specific heat i.e. moisture content as ordinate, as shown in Figs 1&2. Now the saturation curve is drawn by plotting the various saturation points at corresponding dry bulb temperatures. The saturation curve is drawn by plotting the various saturation points at corresponding dry bulb temperatures. The saturation curve represent 100% relative humidity at various dry bulb temperatures. It also represents the wet bulb and dew point temperatures. Though the psychrometric chart has a number of details, yet the following lines are important from subject point of view. At first appearance the psychrometric chart is quite confusing, however with some practice it becomes an extremely useful tool for rapidly evaluation air conditioning processes. The most popular chart in common usage is that developed by ASHRAE (American Society of Heating, Refrigeration and Air-Conditioning Engineers), however we feel that the construction of a simplified version of the chart based on approximations of the various equations can be a very useful tool for developing and understanding of it's usage. The equations relating relative an specific humidity, temperature (wet and dry bulb), pressure (air, vapour) and enthalpy are quite tedious and inconvenient. For this reason a Psychrometric Chart relating all the relevant variables was developed which is extremely useful for designing and evaluating air-conditioning and cooling tower systems. Psychrometric is the study of the thermodynamic properties of gas-vapour mixtures. Despite their numerous applications, psychrometric properties of the air are useful in heating, ventilating, air-conditioning, meteorology and grain storage. A psychrometric chart is a graph of the physical properties of moist air at a constant atmospheric pressure. It expresses how various properties related each other, and is thus a graphical equation of state. The thermo physical properties found on most psychometric charts.

1 Dry bulb temperature

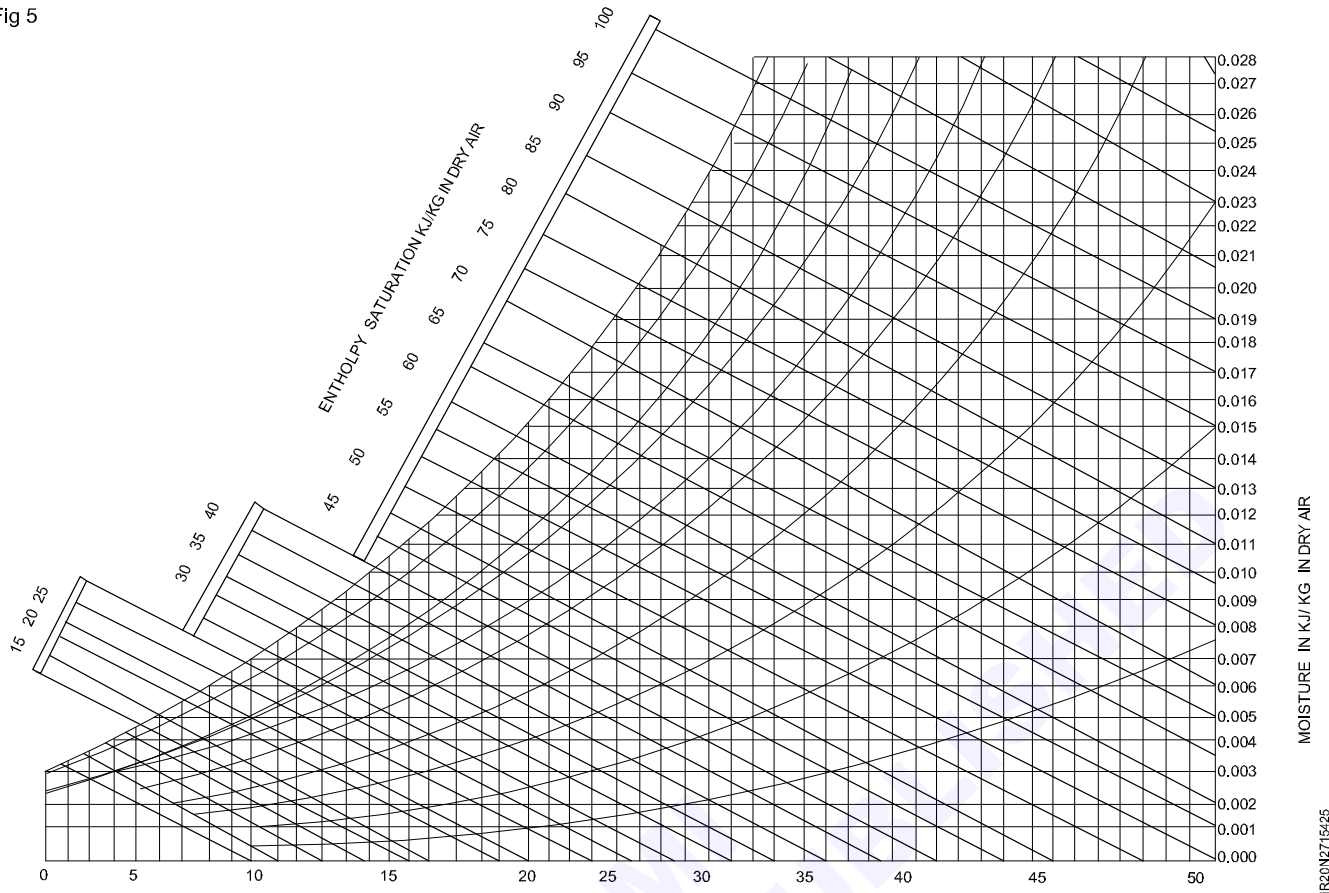
- 2 Wet bulb temperature
- 3 Dew point temperature
- 4 Relative humidity
- 5 Humidity ratio (specific humidity)
- 6 Specific volume
- 7 Enthalpy

The versatility of the psychometric chart lies in the fact that by knowing two independent properties of some moist air, the other properties can be determined. The most widely used combinations are dry bulb temperature and relative humidity, dry and wet bulb temperatures and dry bulb and dew point temperatures psychometric chart available in two system British (Fahrenheit) and metric (Centigrade).



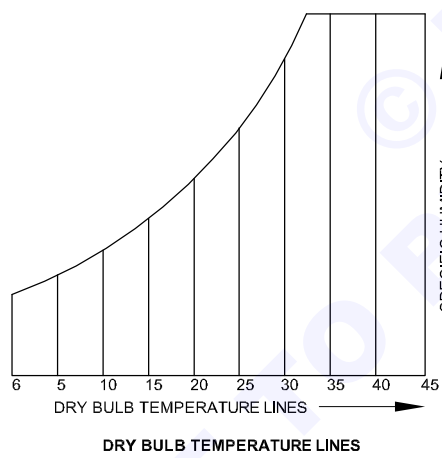
- 1 **Dry bulb temperature lines (Fig 6):** The dry bulb temperature lines are vertical i.e. parallel to the ordinate and uniformly spaced as shown in Fig 3 Generally, the temperature range of these lines on psychrometric chart is from -6 °C to 45 °C. The dry bulb temperature lines are drawn with difference of every 5 °C and up to the saturation curve as shown in the figure. The values of dry bulb temperature are shown on the saturation curve. The dry bulb temperature is the most common used property of air. Its value refers basically to the ambient air and is measured by the normal thermometer freely exposed to the air but shielded from radiation and moisture.
- 2 **Wet bulb temperature:** Wet bulb temperature is that of adiabatic saturation. This property is indicate by a moistened thermometer bulb exposed to the airflow. The adiabatic evaporation of water from the thermometer and the cooling effect is indicated by the wet bulb temperature lower or equal to the dry bulb temperature of the air. The rate of evaporation from the wet bandage on the bulb and the temperature difference between the dry bulb and wet bulb depend on the humidity of the air. The evaporation is reduced when the air contains more water vapour. The wet bulb temperature lines are inclined straight lines and non uniformly spaced as shown in Fig 7. At any point on the saturation curve, the dry bulb and wet bulb temperatures are equal. The values of wet bulb temperatures are generally given along the saturation curve of the chart.

Fig 5



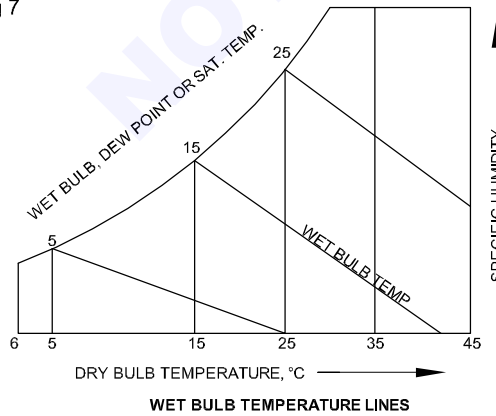
MOISTURE IN KJ/KG IN DRY AIR
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Fig 6



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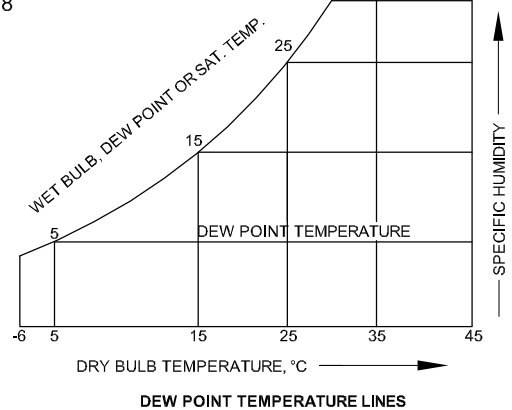
Fig 7



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3 Dew point temperature lines: The dew point temperature lines are horizontal i.e. parallel to the abscissa and non-uniformly spaced. Fig 5. At any point on the saturation curve, the dry bulb and dew point temperatures are equal. The values of dew point temperatures are generally give along the saturation curve of the chart as shown in the Fig 8. The dew point temperature is that at which water vapour starts to condense out of the air or the temperature at which air becomes complete saturated. If the dew point temperature is close to the air temperature.

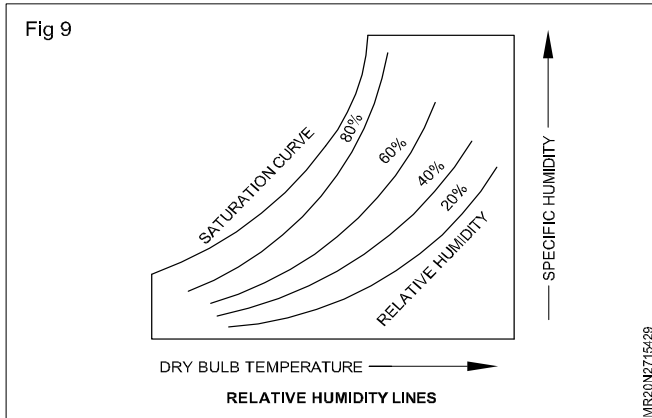
Fig 8



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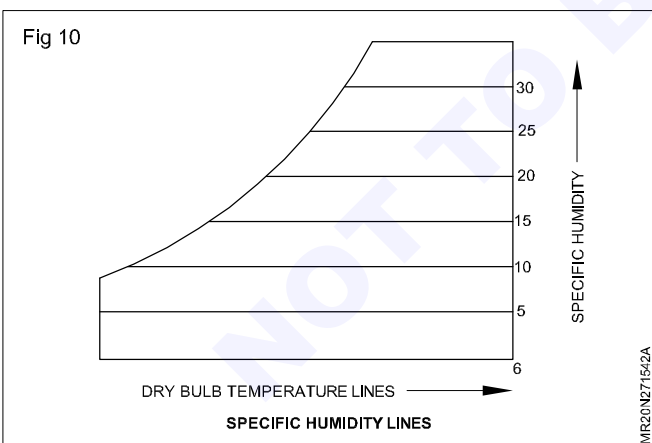
4 Relative humidity: The relative humidity is high and if it is well below the air temperature, the relative humidity is low humidity is the quantity of water vapour present in air. Relative humidity is the ratio of the mole fraction of water vapour to the mole fraction of saturated moist air at the same temperature and pressure. It is

dimensionless and is usually expressed as a percentage. The relative humidity lines are curved and follow the saturation curve. Generally, these lines are drawn with values of relative humidity 10%, 20%, 30% etc. and up to 100%. The saturation curve presents 100% relative humidity. The values of relative humidity lines are generally given along the lines themselves as shown in Fig 9.

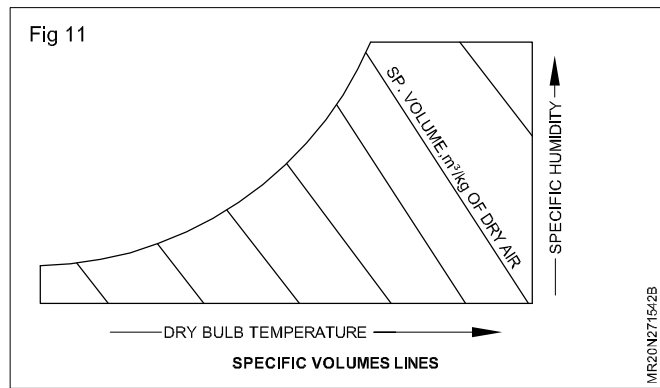


5 Specific-humidity / humidity ratio or moisture content lines: Humidity ratio is the moisture content or humidity of air refer to the same quantity. The property differs from relative humidity in that it is the amount of water vapour by weight in the air. Generally it is defined as the mass of water contained in one kilogram of dry air.

The specific humidity (moisture content) lines are horizontal i.e. parallel to the abscissa and are also uniformly spaced as shown in Fig 10. Generally, moisture content range of these lines on psychrometric chart is from 0 to 30g / kg of dry air (or from 0 to 0.030 kg / kg of dry air). The moisture content lines are drawn with a different of every 1 g (0.001 kg) and up to the saturation curve as shown in the figure.

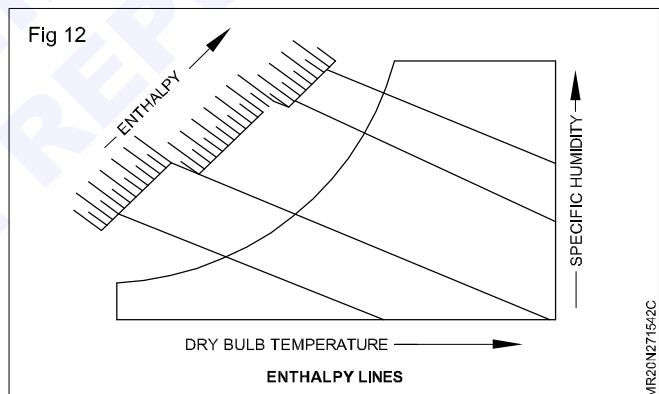


6 Specific volume: Specific volume is the volume per unit mass of the air sample. In other words, this property represents the space occupied by a unit weight of dry air and is the reciprocal of the density. The specific volume lines are obliquely inclined straight lines and uniformly spaced as shown in Fig 11. These lines are drawn up to the saturation curve. The values of volume lines are generally given at the base of the chart.



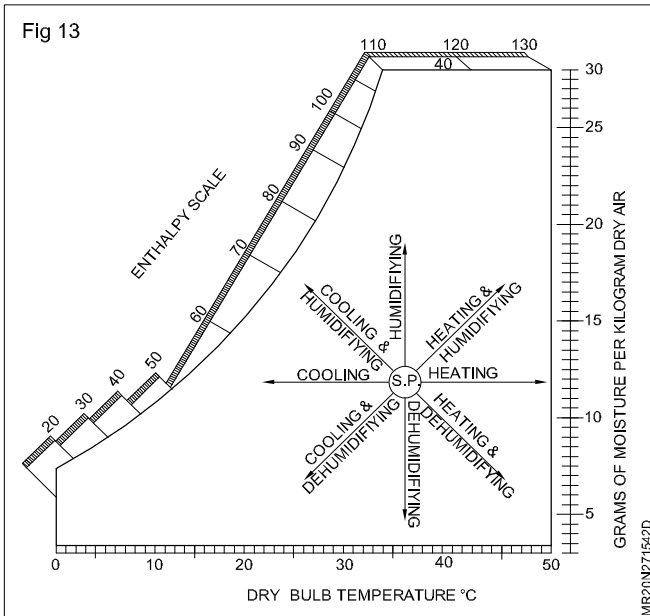
7 Enthalpy

Enthalpy is the measure of the total energy in the air or the energy content per unit air weight. That is, enthalpy is the sum of the internal energy of the moist air in question, including the heat of the air and water vapour within. This property is read from where the appropriate wet-bulb line crosses the diagonal scale above the saturation curve. Air with same amount of energy may either be dry hot air (high sensible heat) or cool moist air (high latent heat). The enthalpy (or total heat) lines are included straight lines and uniformly spaced. These lines are parallel to the wet bulb temperature lines, and are drawn up to the saturation curve. Some of these lines coincide with the wet bulb temperature lines also. The values of total enthalpy are given on a scale above the saturation curve as shown in the Fig 12.



Psychrometric processes (Fig 13): The various psychrometric processes involved in air conditioning to vary psychrometric properties of air according to the requirement are as follows:

- 1 Sensible heating
- 2 Sensible cooling
- 3 Humidification and dehumidification
- 4 Cooling and humidification
- 5 Cooling and dehumidification
- 6 Heating and humidification
- 7 Heating and dehumidification
- 8 Adiabatic mixing of air streams
- 9 Heating & humidification by steam injection
- 10 Adiabatic chemical dehumidification



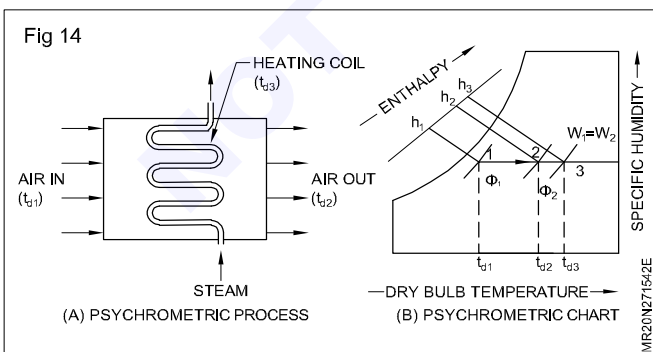
1 Sensible heating (Fig 14)

The heating of air, without any change in its specific humidity, is known as sensible heating.

Sensible heating process is opposite to sensible cooling process. In sensible heating process the temperature of air is increased without changing its moisture content. During this process the sensible heat, DB and WB temperature of the air increases while latent of air, and the DP point temperature of the air remains constant.

Sensible heating of the air is important when the air conditioner is used as the heat pump to heat the air. In the heat pump the air is heated by passing it over the condenser coil or the heating coil that carry the high temperature refrigerant. In some cases the heating of air is also done to suit different industrial and comfort air-conditioning applications where large air conditioning systems are used.

In general the sensible heating process is carried out by passing the air over the heating coil. This coil may be heated by passing the refrigerant, the hot water, the steam or by electric resistance heating coil. The hot water and steam are used for the industrial applications.

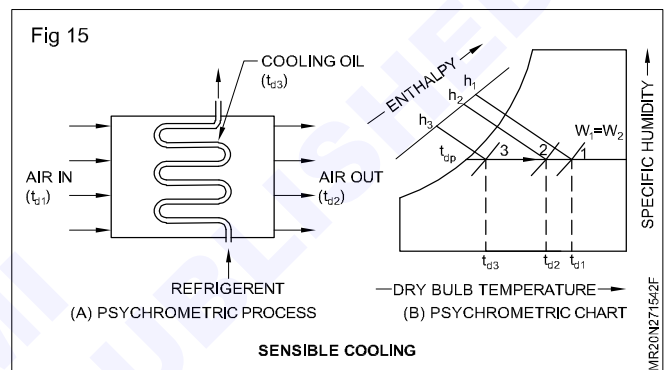


Like the sensible cooling, the sensible heating process is also represented by a straight horizontal line on the psychrometric chart. The line starts from the initial DB temperature of air and ends at the final temperature extending towards the right (see the figure). The sensible heating line is also the constant DP temperature line.

2 Sensible - cooling (Fig 15)

The cooling of air, without any change in its specific humidity, is known as sensible cooling.

Cooling of the air is one of the most common psychrometric processes in the air conditioning systems. The basic function of the air-conditioners is to cool the air absorbed from the room or the atmosphere, which is at higher temperatures. The sensible cooling of air is the process in which only the sensible heat of the air is removed so as to reduce its temperature, and there is no change in the moisture content (kg/kg of dry air) of the air. During sensible cooling process the dry bulb (DB) temperature and wet bulb (WB) temperature of the air reduces, while the latent heat of the air, and the dew point (DP) temperature of the air remains constant. There is overall reduction in the enthalpy of the air.

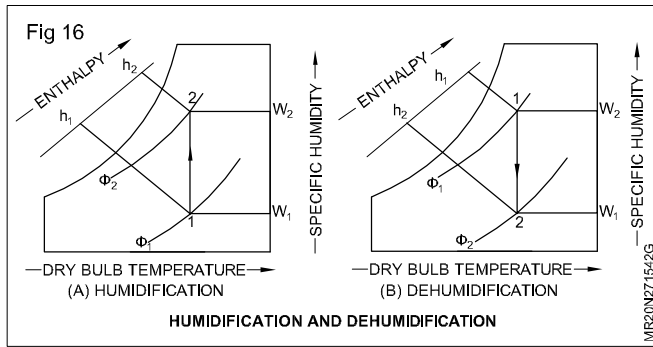


In the air conditioner the cooling of air is carried out by passing it over the evaporator coil, also called as the cooling coil. The room air or the atmospheric air passes over this coil carrying the refrigerant at extremely low temperatures, and gets cooled and passes to the space which is to be maintained at the comfort conditions.

In general the sensible cooling process is carried out by passing the air over the coil. In the unitary air conditioners these coils are cooled by the refrigerant passing through them and are also called evaporator coils. In central air conditioners these coils are cooled by the chilled water, which is chilled by its passage through the evaporator of the large air conditioning system. In certain cases the coil is also cooled by the some gas passing inside it.

The sensible cooling process is represented by a straight horizontal line on the psychrometric chart. The line starts from the initial DB temperature of the air and ends at the final DB temperature of the air extending towards the left side from high temperature to the low temperature (see the figure below). The sensible cooling line is also the constant DP temperature line since the moisture content of the air remains constant. The initial and final points on the psychrometric chart give all the properties of the air.

Humidification and dehumidification (Fig 16): The addition of moisture to the air, without change in its dry bulb temperature, is known as humidification. Similarly, removal of moisture from the air, without change in its dry bulb temperature is known as dehumidification. The heat added during humidification process and heat removed during dehumidification process is shown on the psychrometric chart.

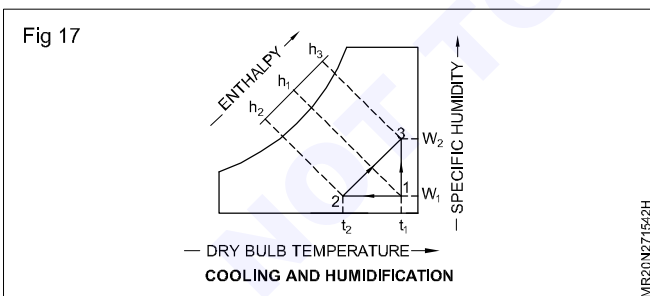


Humidification process: The process in which the moisture or water vapor or humidity is added to the air without changing its dry bulb (DB) temperature is called as humidification process. This process is represented by a straight vertical line on the psychrometric chart starting from the initial value of relative humidity, extending upwards and ending at the final value of the relative humidity. In actual practice the pure humidification process is not possible, since the humidification is always accompanied by cooling or heating of the air. Humidification process along with cooling or heating is used in number of air conditioning applications.

Dehumidification process: The process in which the moisture or water vapor or the humidity is removed from the air keeping its dry bulb (DB) temperature constant is called as the dehumidification process. This process is represented by a straight vertical line on the psychrometric chart starting from the initial value of relative humidity, extending downwards and ending at the final value of the relative humidity. Like the pure humidification process, in actual practice the pure dehumidification process is not possible, since the dehumidification is always accompanied by cooling or heating of the air. Dehumidification process along with cooling or heating is used in number of air conditioning applications.

4 Cooling with humidification (Fig 17)

In this process the moisture is added to the air by passing it over the stream or spray of water which is at the temperature of lower than the dry bulb.



When air is passed through an insulated chamber having spray of water (air washer) temperature maintained higher than Dew point temperature and lower than it's Dew point temperature of entering air or equal to the Wet bulb temperature of air then air is said to be cooled and humidified. So no heat is supplied or rejected.

Cooling and humidification process is one of the most commonly used air conditioning application for the cooling purposes. In this process the moisture is added to the air

by passing it over the stream or spray of water which is at temperature lower than the dry bulb temperature of the air. When the ordinary air passes over the stream of water, the particles of water present within the stream tend to get evaporated by giving up the heat to the stream. The evaporated water is absorbed by the air so its moisture content, thus the humidity increases. At the same time, since the temperature of the absorbed moisture is less than the DB bulb temperature of the air, there is reduction in the overall temperature of the air. Since the heat is released in the stream or spray of water, its temperature increases.

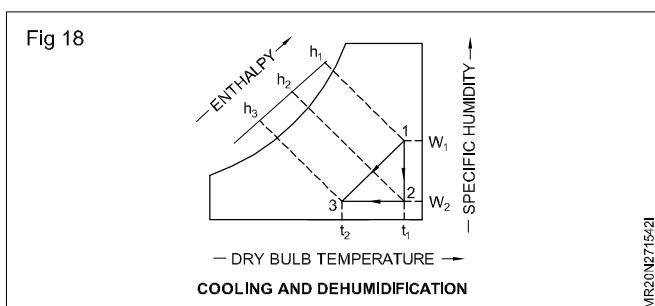
One of the most popular applications of cooling and humidification is the evaporative cooler, also called as the desert cooler. The evaporative cooler is the sort of big box inside which is a small water tank, small water pump and the fan. The water from the tank is circulated by the pump and is also sprayed inside the box. The fan blows strong currents of air over the water sprays, thus cooling the air and humidifying it simultaneously. The evaporative cooler is highly effective cooling devise having very low initial and running cost compared to the unitary air conditioners. For cooling purposes, the cooling and humidification process can be used only in dry and hot climates like desert areas. This cooling process cannot be used in hot and high humidity climates.

The cooling and humidification process is also used in various industries like textile, where certain level of temperature and moisture content has to be maintained. In such cases large quantity of water is sprayed, and large blowers are used to blow the air over the spray of water.

During the cooling and humidification process the dry bulb of the air reduces, its wet bulb and the dew point temperature increases, while its moisture content and thus the relative humidity also increases. Also, the sensible heat of the air reduces, while the latent heat of the air increases resulting in the overall increase in the enthalpy of the air.

Cooling and humidification process is represented by an angular line on the psychrometric chart starting from the given value of the dry bulb temperature and the relative humidity and extending upwards toward left.

5 Cooling and dehumidification (Fig 18)



This process is generally used in summer air conditioning to cool and dehumidify the air. The air passed over a cooling coil or through a cold water spray. In this process, the dry bulb temperature as well as the specific humidity of air decreases. The final relative humidity of the air is generally higher than of the entering air. The humidification

of air is only possible when the effective surface temperature of the cooling coil is less than the dew point temperature of the air entering the coil. The effective surface temperature of the coil is known as apparatus dew point (briefly written as ADP).

The process in which the air is cooled sensibly and at the same time the moisture is removed from it is called as cooling and dehumidification process. Cooling and dehumidification process is obtained when the air at the given dry bulb and dew point (DP) temperature is cooled below the dew point temperature.

When the air comes in contact with the cooling coil that is maintained at the temperature below its dew point temperature, its DB temperature starts reducing. The process of cooling continues and at some point it reaches the value of dew point temperature of the air. At this point the water vapor within the air starts getting converted into the dew particles due to which the dew is formed on the surface of the cooling and the moisture content of the air reduces thereby reducing its humidity level. Thus when the air is cooled below its dew point temperature, there is cooling as well as dehumidification of air.

The cooling and dehumidification process is most widely used air conditioning application. It is used in all types of window, split, packaged and central air conditioning systems for producing the comfort conditions inside the space to be cooled. In the window and split air conditioners the evaporator coil or cooling coil is maintained at temperature lower than the dew point temperature of the room air or the atmospheric air by the cool refrigerant passing through it. When the room air passes over this coil its DB temperature reduces and at the same time moisture is also removed since the air is cooled below its DP temperature. The dew formed on the cooling coil is removed out by small tubing. In the central air conditioning systems the cooling coil is cooled by the refrigerant or the chilled water. When the room air passes over this coil, it gets cooled and dehumidified.

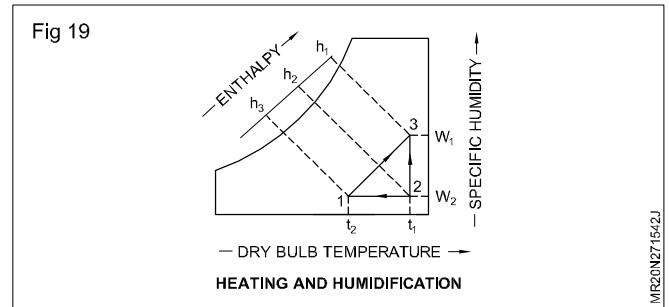
In the general the cooling and dehumidification process is obtained by passing the air over coil through which the cool refrigerant, chilled water or cooled gas is passed.

During the cooling and dehumidification process the dry bulb, wet bulb and the dew point temperature of air reduces. Similarly, the sensible heat and the latent heat of the air also reduce leading to overall reduction in the enthalpy of the air. The cooling and dehumidification process is represented by a straight angular line on the psychrometric chart. The line starts from the given value of the DB temperature and extends downwards towards left.

6 Heating and humidification (Fig 19)

This process generally used in winter A/c to warm & humidify the air.

When air is passed through a humidifier having spray water temperature higher than Dew bulb temperature of air entering air. Then air becomes heated and humidified.



A psychrometric process that involves the simultaneously increase in both the dry bulb temperature and humidity ratio of the air.

In heating and humidification psychrometric process of the air, the dry bulb temperature as well as the humidity of the air increases. The heating and humidification process is carried out by passing the air over spray of water, which is maintained at temperature higher than the dry bulb temperature of air or by mixing air and the steam.

When the ordinary air is passed over the spray of water maintained at temperature higher than the dry bulb temperature of the air, the moisture particles from the spray tend to get evaporated and get absorbed in the air due to which the moisture content of the air increase. At the same time, since the temperature of the moisture is greater than the dry bulb temperature of the air, there is overall increase in its temperature.

During heating and humidification process the dry bulb, wet bulb, and dew point temperature of the air increases along with its relative humidity. The heating and humidification process is represented on the psychrometric chart by an angular line that starts from the given value of the dry bulb temperature and extends upwards towards right (see the figure below).

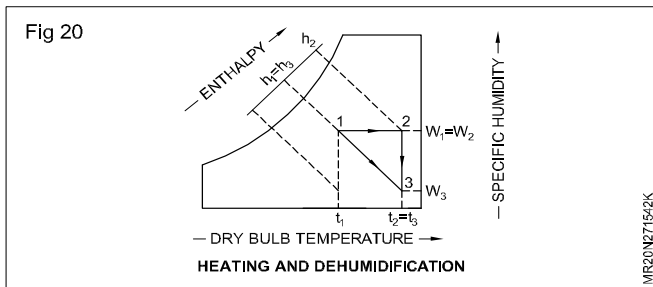
7 Heating and dehumidification (Fig 20)

The process in which the air is heated and at the same time moisture is removed from it is called as heating and dehumidification process. This process is obtained by passing the air over certain chemicals like alumina and molecular sieves. These elements have inherent properties due to which they keep on releasing the heat and also have the tendency to absorb the moisture. These are called as the hygroscopic chemicals.

In actual practice the hygroscopic elements are enclosed in the large vessel and the high pressure air is passed inside the vessel through one opening. When the air comes in contact with the chemicals the moisture from the air is absorbed and since the chemicals emit heat, the DB temperature of the air increases. The hot and dehumidified air comes out from the vessel through other opening in the vessel. The inlet and outlet openings of the vessel are controlled by the valve.

The heating and humidification process is commonly used for reducing the dew point temperature of air. There are number of automatic valves in the chemical plants that are operated by the compressed air at high pressure. If the dew point temperature of this air is high, there are chances of formation of dew inside the valves which can

lead to their corrosion and also faulty their operation. Thus it is very important that the air passing to such automatic valves have very low dew point temperature. The heating and dehumidification process by using hygroscopic materials is used often in the air drying units.



During the heating and dehumidification process dry bulb temperature of the air increases while its dew point and wet bulb temperature reduces. On the psychrometric chart, this process is represented by a straight angular line starting from the given DB temperature conditions and extending downwards towards right to the final DB temperature conditions

Adiabatic mixing of two air streams: When two quantities of air having different enthalpies and different specific humidities are mixed, the final condition of the air mixture depends upon the masses involved, and on the enthalpy and specific humidity of each the constituent masses which enter the mixture.

Heating & humidification by steam injection: In this process the steam is normally injected into the air in order to increase the specific humidity.

This process is used for the air conditioning of textile mills where higher humidity is to be maintained. Slightly the Dry bulb temperature of air changes during this process.

Adiabatic chemical dehumidification: This process is mainly used in industrial air conditioning. In this process air is passed once the chemical contact, moisture gets condensed out of the air. Due to the condensation specific humidity decreases heat of the condensation supplies sensible heat for heating the air and this increasing it Dry bulb temperature.

Sensible heat factor: Actually, the heat added during a psychrometric process may be split up into sensible heat and latent heat. The ratio of the sensible heat to the total heat is known as sensible heat factor (briefly written as SHF) or sensible heat ratio (briefly written as SHR). Mathematically,

$$SHF = SHR = \frac{\text{Sensible heat}}{\text{Total heat}} = \frac{SH}{SH + LH}$$

Where SH = Sensible heat, and
= Latent heat

By pass factor of heating and cooling coil (Fig 21)

The inefficiency of the heating coil or cooling coil is not being able to heat or cool the incoming air to the heat or cool the incoming air to the temperature of cooling coil. The percentage of air that passes through the coil unchanged is called the by pass factor of coil.

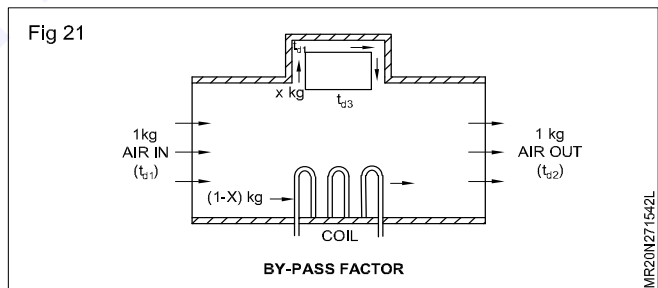
The amount of air that by-passes or by-pass factor depends upon the following factors:

- 1 The number of fins provided in a unit length i.e. the pitch of the cooling coil finds.
- 2 The number of rows in a coil in the direction of flow; and
- 3 The velocity of flow air.

It may be noted that by-pass factor of a cooling coil decreases with decrease in fin spacing and increase in number of rows.

Problem: Solve using psychrometric chart.

- 1 If Dry bulb temperature is 25 °C and Wet bulb temperature is 22 °C. Find the other properties.
- 2 If Dew point temperatures is 20 °C and relative humidity is (RH) is 60%. Find the remaining properties.



Description of various types of fans and blowers used in air-conditioners

- Objectives:** At the end of this lesson you shall be able to
- various types of fans and blower used in air-conditioners
 - static and velocity pressure.

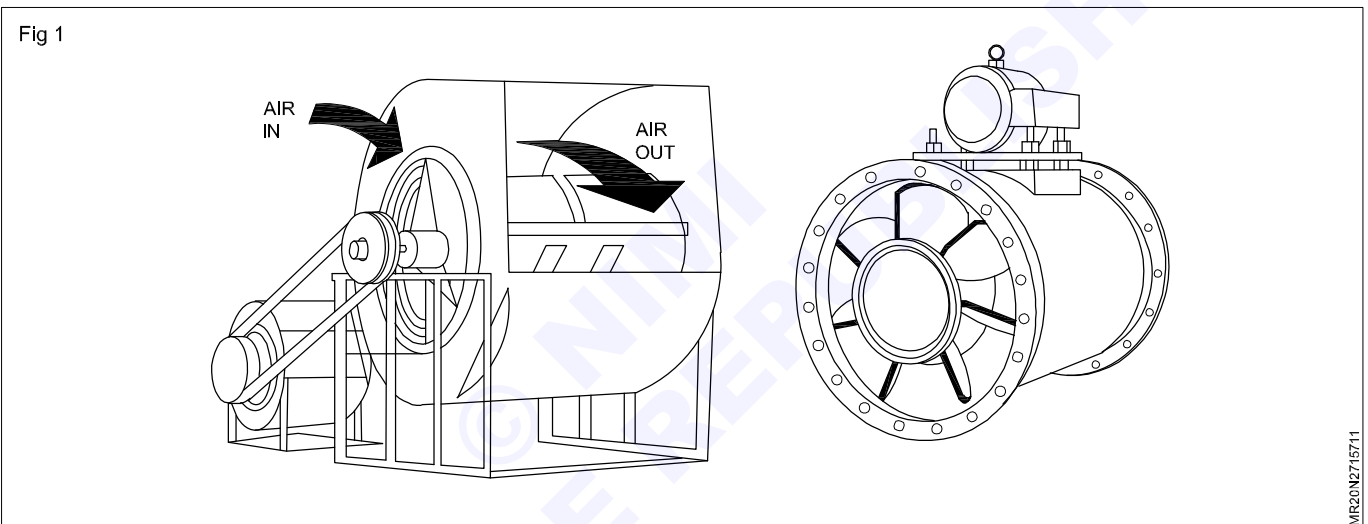
Introduction

Fans and blowers provide air for ventilation and industrial process requirements. Fans generate a pressure to move air (or gases) against a resistance caused by ducts, dampers, or other components in a fan system. The fan rotor receives energy from a rotating shaft and transmits it to the air.

Centrifugal Axial Fan (Fig 1): Fan and blower selection depends on the volume flow rate, pressure, type of

material handled, space limitations, and efficiency. Fan efficiencies differ from design to design and also by types. Fans fall into two general categories: centrifugal flow and axial flow.

In centrifugal flow, airflow changes direction twice - once when entering and second when leaving (forward curved, backward curved or inclined, radial). In axial flow, air enters and leaves the fan with no change in direction (propeller, tubeaxial, vaneaxial)



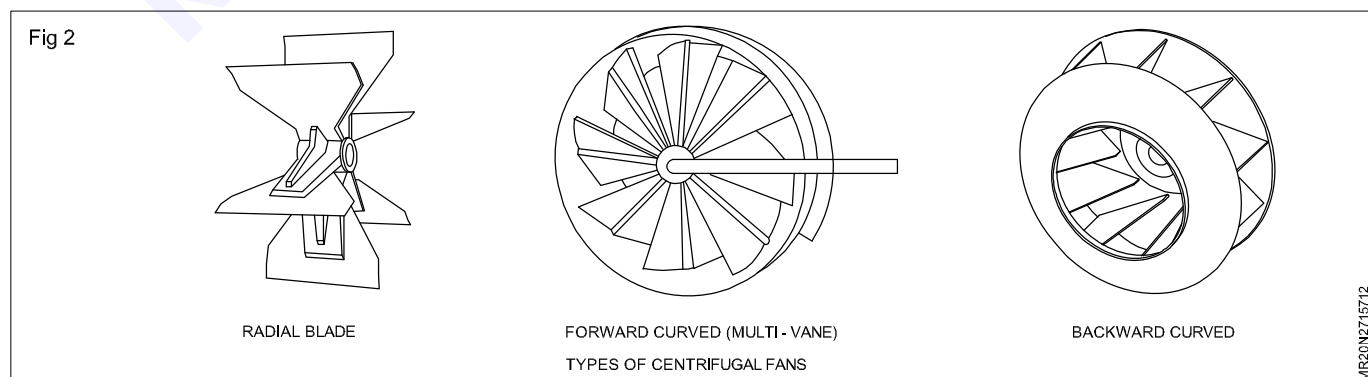
Types of Centrifugal Fans (Fig 2)

The major types of centrifugal fan are: radial, forward curved and backward curved, Radial fans are industrial workhorses because of their high static pressures and ability to handle heavily contaminated airstreams. Because of their simple design, radial fans are well suited for high temperatures and medium blade tip speeds.

Forward-curved fans are used in clean environments and operate at lower temperatures. They are well suited for low tip speed and high-airflow work - they are best suited

for moving large volumes of air against relatively low pressures.

Backward-inclined fans are more efficient than forward-curved fans. Backward-inclined fans reach their peak power consumption and then power demand drops off well within their useable airflow range. Backward-inclined fans are known as "non-overloading" because changes in static pressure do not overload the motor. changes in static pressure do not overload the motor.



Axial Flow Fan Types (Fig 3)

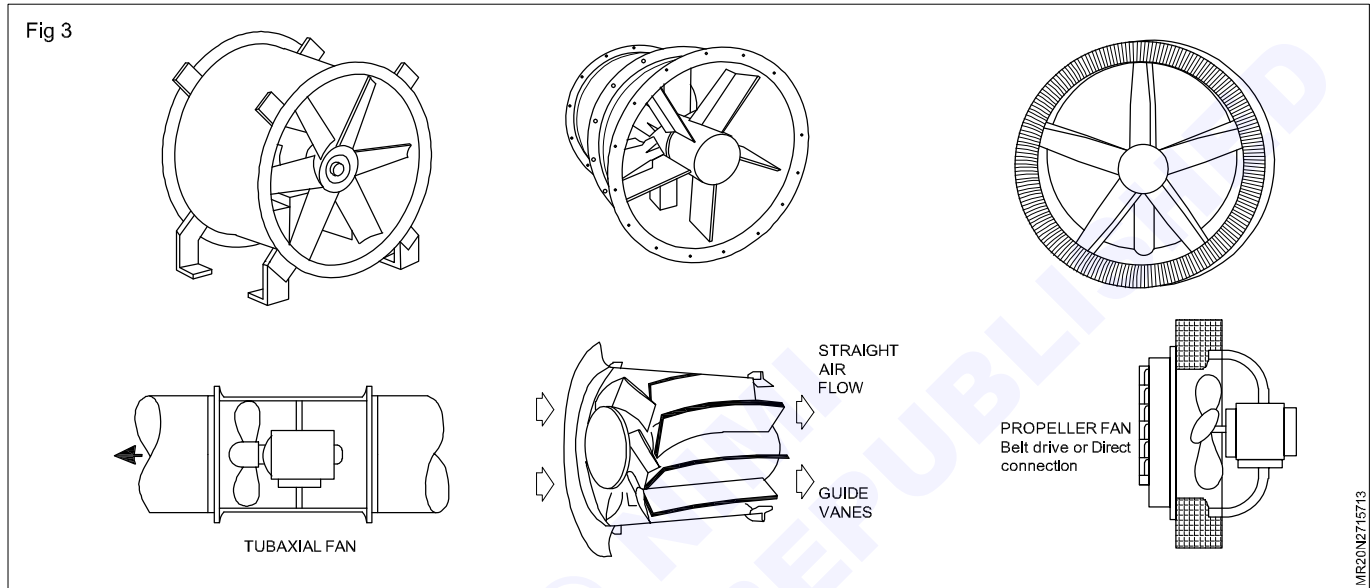
The major types of axial flow fans are: tube axial, vane axial and propeller:

Tubeaxial fans have a wheel inside a cylindrical housing, with close clearance between blade and housing to improve airflow efficiency. The wheel turn faster than propeller fans, enabling operation under high-pressures. The efficiency is up to 65%.

Vaneaxial fans are similar to tubeaxials, but with addition of guide vanes that improve efficiency by directing and straightening the flow. As a result, they have a higher static pressure with less dependence on the duct static

pressure. Such fans are used generally for pressures upto 0.7 psi. Vaneaxials are typically the most energy-efficient fans available and should be used whenever possible.

Propeller fans usually run at low speeds and moderate temperatures. They experience a large change in airflow with small changes in static pressure. They handle large volumes of air at low pressure or free delivery. Propeller fans are often used indoors as exhaust fans. Outdoor applications include air-cooled condensers and cooling towers. Efficiency is low - approximately 50% or less.



Common Blower Types (Fig 4)

Blowers can achieve much higher pressures than fans, as high as 1.20 kg/cm². They are also used to produce negative pressures for industrial vacuum systems. Major types are: centrifugal blower and positive-displacement blower.

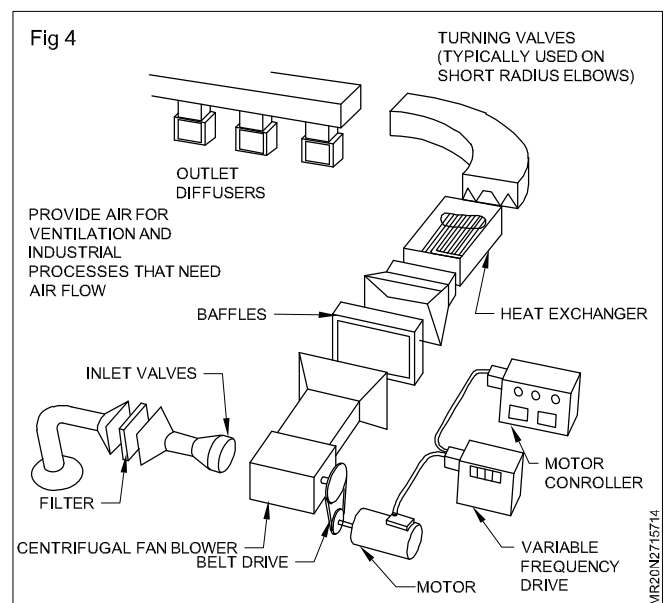
Centrifugal blowers look more like centrifugal pumps than fans. The impeller is typically gear-driven and rotates as fast as 15,000 rpm. In multi-stage blowers, air is accelerated as it passes through each impeller. In single-stage blower, air does not take many turns, and hence it is more efficient.

Centrifugal blowers typically operate against pressures of 0.35 to 0.70 kg/cm², but can achieve higher pressures. One characteristic is that airflow tends to drop drastically as system pressure increases, which can be a disadvantage in material conveying systems that depend on a steady air volume. Because of this, they are most often used in applications that are not prone to clogging.

Positive-displacement blowers have rotors, which "trap" air and push it through housing. Positive-displacement blowers provide a constant volume of air even if the system pressure varies. They are especially suitable for applications prone to clogging, since they can produce

enough pressure - typically up to 1.25 kg/cm² - to blow clogged materials free. They turn much slower than centrifugal blowers (e.g. 3,600 rpm), and are often belt driven to facilitate speed changes.

Components of fan/blower system

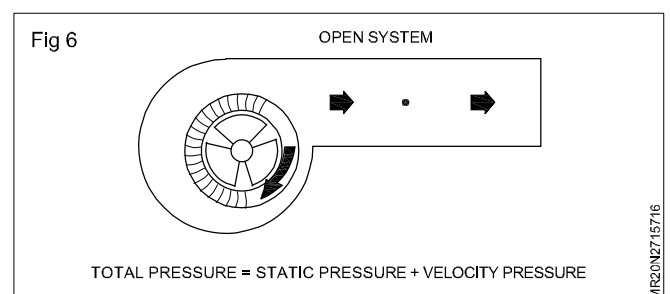
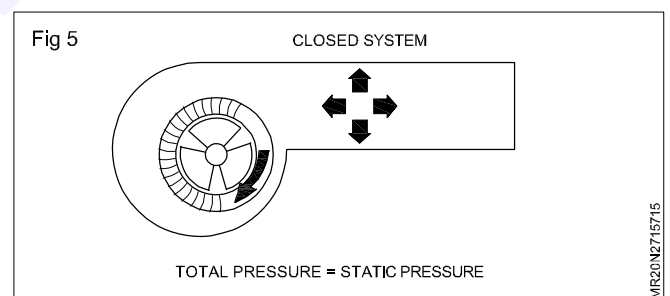


Characteristics of different fans

Types of fans characteristics, and typical applications					
Centrifugal Fans			Axial-flow Fans		
Type	Characteristics	Typical Applications	Type	Characteristics	Typical Applications
Radial	High pressure, medium flow, efficiency close to tube-axial fans, power increases continuously	Various industrial applications, suitable for dust laden, moist air/ gases	Propeller	Low pressure, high flow, low efficiency, peak efficiency close to point of free air delivery (zero static pressure)	Air-circulation, ventilation, exhaust
Forward-curved blades	Medium pressure, high flow, dip in pressure curve, efficiency higher than radial fans, power rises continuously	Low pressure HVAC, packaged units, suitable for clean and dust laden air / gases	Tube-axial	Medium pressure, high flow, higher efficiency than propeller type, dip in pressure-flow curve before peak pressure point.	HVAC, drying ovens, exhaust systems
Backward curved blades	High pressure, high flow, high efficiency, power reduces as flow increases beyond point of highest efficiency	HVAC, various industrial applications forced draft fans, etc.	Vane-axial	High pressure, medium flow, dip in pressure-flow curve, use of guide vanes improves efficiency exhausts	High pressure applications including HVAC systems,
Airfoil type	Same as backward curved type, highest efficiency	Same as backward curved, but for clean air applications			

Static and velocity pressure (Fig 5&6): To explain duct pressures, let's use a forward curved centrifugal fan and a section of duct work containing a 100% shut-off damper. If the fan is operating and the damper is closed, the fan will pump air into the duct work and as a result of the air being compressed, the duct pressure will increase. The pressure in the duct work is attempting to expand the duct and cause it to bulge as in Figure. This pressure is known as static pressure. Static pressure is defined as a pressure at rest, it possesses potential energy and the ability to do work. The direction of the lines of force of static pressure are exerted in all directions. It is the same force as air pressure in a balloon or tire. Like the balloon, static pressure in a duct causes no movement of air. When air does move, it moves from areas of higher to lower static pressures. The total duct pressure in this example with the damper closed, is equal to static pressure.

If the damper is partially open, see Figure, the static pressure or potential energy in the air is converted to kinetic energy. Kinetic energy is energy in motion. This air movement through the duct can be felt and is called velocity pressure. The same thing happens when an expanded balloon is let loose. The static pressure converts to velocity pressure and propels the balloon through the air.



Velocity pressure has its lines of force in one direction, which is always toward the path of least restriction or in the direction of the air flow. Velocity pressure is the force that closes a sail switch to sense air flow movement or turn a child's pinwheel. The total pressure in the duct system with the damper partially open equals the sum of the static pressure plus the velocity pressure.

Duct

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

- function of ducts
- types of duct layout
- design of ducts.

Function of duct

Ducts are used to carry air from air conditioning room to fan coil unit (FCU) and returned to air conditioning room with the help of blower in air conditioning system. There are two types of air transmission system adopted for air conditioning systems. One is low velocity and other is high velocity systems. The low velocity is with 760m/min. The high velocity is above 760m/min. The low velocity system is adopted for comfort AC systems with the range of 360 to 600m/min.

Types of duct

The ducts are classified in to three types with respect to the function.

- 1 Supply duct
- 2 Return duct
- 3 Fresh air duct

Supply duct

This duct carry the conditioned air from AHU and supply into the air conditioned room.

Return duct

This duct carry the used air from the air conditioned room and supply it to the AHU.

Fresh air duct

This duct serves the function of carrying out side fresh air into AMU room.

According to the shape, the ducts may be of three types.

- 1 Round duct
- 2 Square /Rectangular duct
- 3 Flexible duct

The round duct is made of G.I sheet or aluminum sheet in the shape of a round pipe. Air can pass through it very easily. It is easy in making. The square or rectangular duct is in the shape of square or rectangular form and made up of G.I or aluminum material. This duct more popular than round duct. The flexible duct is generally made of wire of spring steel is the shape of round. This duct is more flexible and can be adjusted in the different direction.

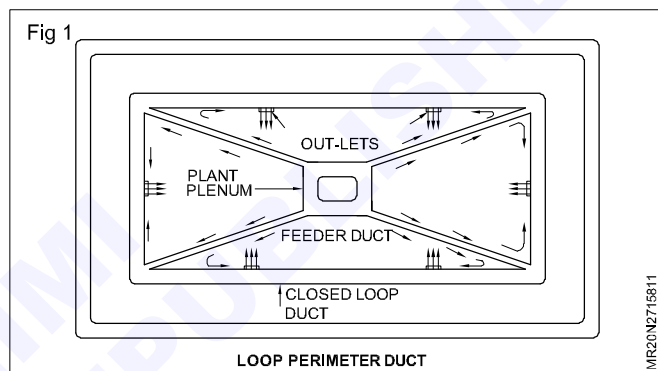
According to the fitting, the ducts may again classified in to three types.

- 1 Loop perimeter duct
- 2 Radial perimeter duct

3 Extended plenum duct

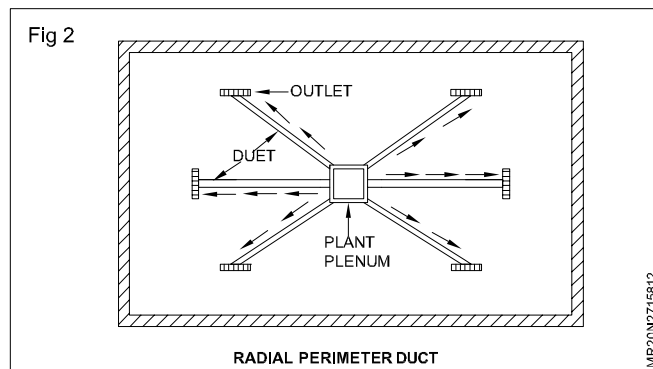
Loop perimeter duct (Fig 1)

In loop perimeter duct the conditioned air is taken from the AHU through a joint duct to the space to be air conditioned. So the conditioned air is evenly distributed through several branch ducts running from the plenum to the perimeter of the building to be air conditioned.



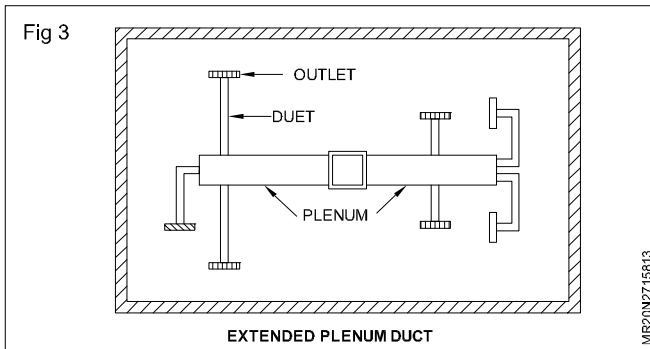
Radial perimeter duct (Fig 2)

In radial perimeter duct, the conditioned air is taken from the AHU through a joint duct to the air conditioned room to be air conditioned. So the conditioned air is equally distributed in all directions through several branch ducts fitted around the radius of the joint duct.



Extended plenum duct (Fig 3)

In this type of duct conditioned air is brought from the AHU - through a joint duct and extended along the centre beam of the air-conditioned room to be air-conditioned. The conditioned air is equally distributed in all directions through several parallel branch ducts running from the joint duct to each outlet.



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, aluminum, stainless steel etc. the term 'sheet metal' generally applies to metals and alloys in sheets rolled into various thicknesses less than 5mm. sheets over 5mm 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.

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: Aluminum 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.

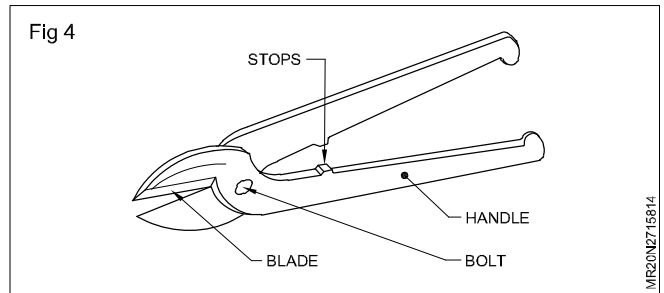
Brass sheet: Brass is an alloy of copper and zinc in various proportions. It will not corrode and is extensively used in craft.

Snip: A snip is a cutting tool and is used for cutting thin sheets of metal. There are two types of snips.

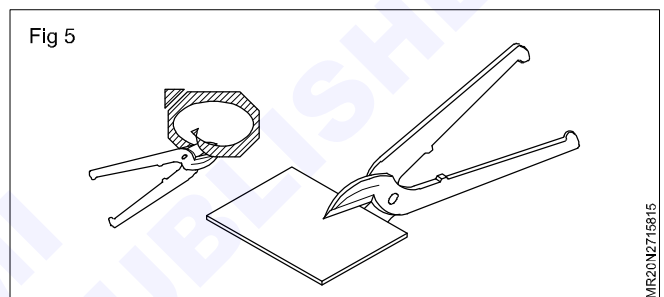
- Straight snips
- Bent snips

Parts of a straight snip (Fig 4)

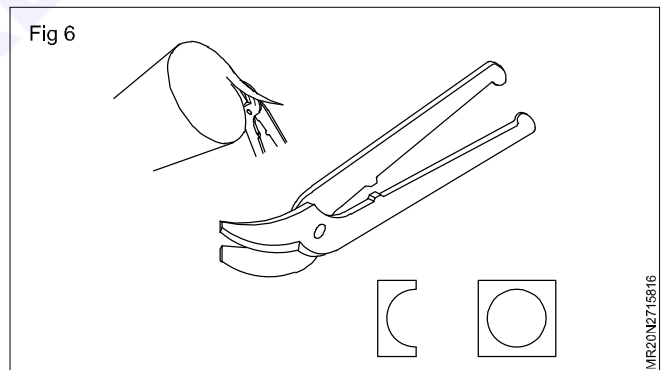
- Handle (1)
- Blade (2)
- Stops (3)



Straight snips: A straight snip has straight blades for straight line cutting. It can also be used for external curved cuts. (Fig 5)



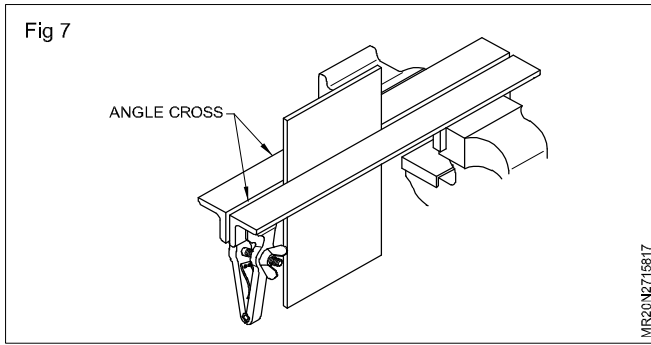
Bent snip: Bent snips have curved blades used for cutting internal curves. For trimming a cylinder keep the lower blade on the outside of cut. (Fig 6)



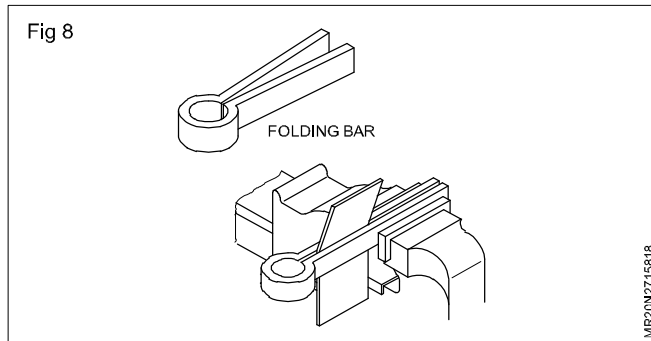
The common tools used in the folding of sheet metal are:

- Angle steel and folding bar
- C clamp
- Stakes
- Mallet

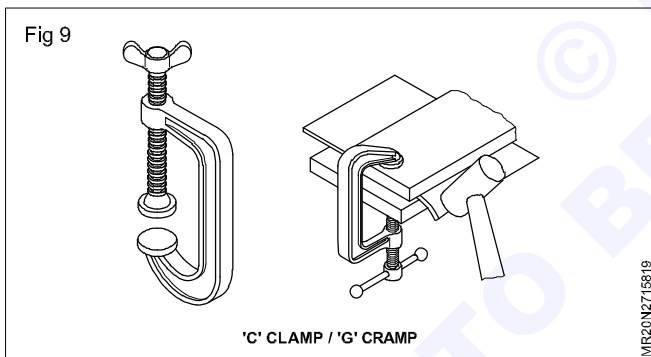
Angle steel: Two pieces of angles are used for folding at 90°. For longer sheets lengthy angles will be used along clamp (or) hand vice. (Fig 7)



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 8)



'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 of the jaws. (Fig 9)

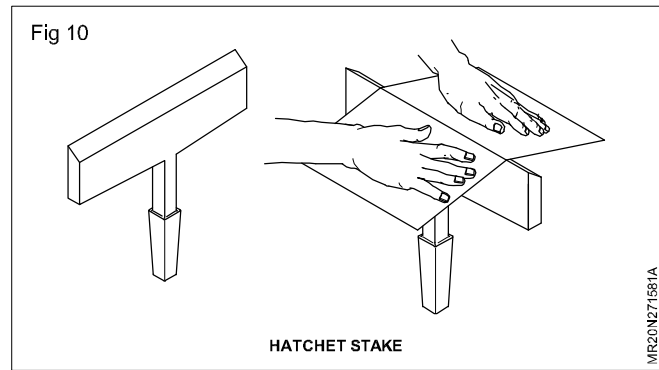


Stakes: Stakes are used for bending, seaming and forming of sheet metal that cannot be done on any regular machine. For the above purposes, different stakes are used. Stakes are made of forged steel or cast steel.

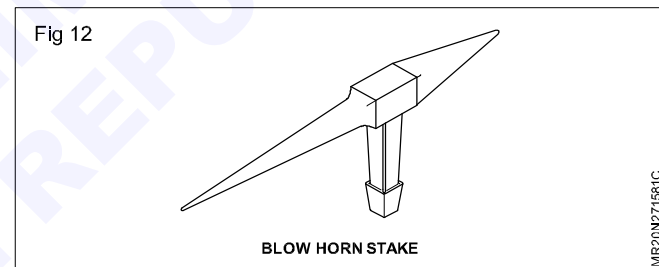
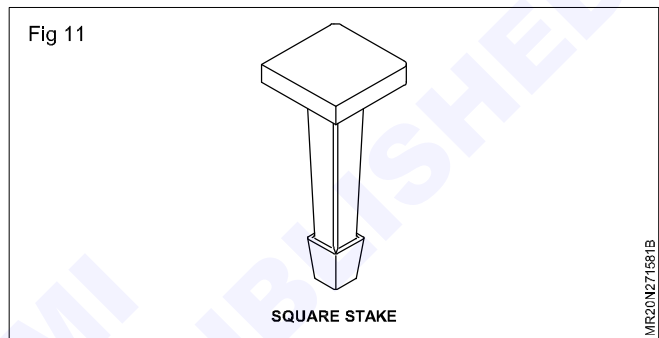
Types of stakes

- Hatchet stake
- Square stake
- Blow-horn square stake
- Bevel-edge square stake

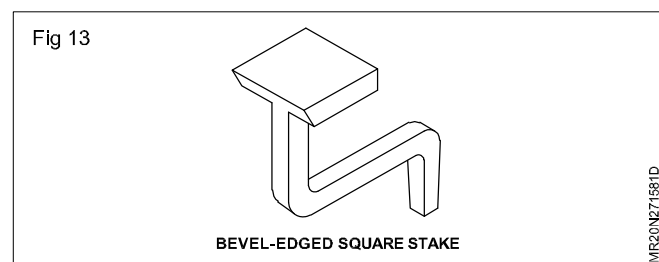
Hatchet stake: A hatchet stake has a sharp straight edge beveled on one side. It is used for making sharp bends, for bending edges and for folding sheet metal. (Fig 10)



Square stake: A square stake has a flat and square head with a long tapered shank at the other end. It is used for general purposes (Fig 11) like used in forming, riveting or seaming tapered, cone shaped articles such as funnels etc. (Fig 12)



Bevel-edged square stake: A bevel-edged square stake is used to form corners and edges. (Fig 13)



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 14)

Duct Insulation

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

- duct insulation
- properties of insulating materials 'K' factors
- acoustic insulation
- vapour barrier.

Introduction and properties of insulating materials

Insulating Ducts and Pipes

It is important to insulate all ducts and pipes where they pass through unconditioned space that is not air conditioned. This includes heating, air conditioning, and return air.

Before insulating ducts

- Prepare duct joints.
- Check the ductwork for leaks or any fault, and repair any that being find.

Reasons for insulating ducts

- To maintain desired temperature of air or water, and save energy.
- To restrict condensation on ducts or pipes.

Insulating materials for ducts

- Fiberglass
- Bubble wrap
- Rock and slag wool
- EPDM, etc.
- Reflective insulation

EPDM (Ethylene Propylene Diene Monomer) Insulation

EPDM insulation is a flexible, closed cell and lightweight elastomeric material designed for insulating liquid cooling lines. EPDM insulation provides many advantages over most rigid insulation such as

- It can easily resist Moisture and vapour, so no vapour barrier is needed.
- Due to its dense surface and closed cell characteristics it has Stable thermal conductivity
- Flexibility
- Environment friendly

EPDM Insulation prevents heat gain and condensation problem on chilled water and refrigerant pipelines.

Reflective Insulation

Reflective insulation consists of two outer layers of aluminum foil that can reflect most of radiant, heat each layer of foil is bonded to a layer of polyethylene for strength. Reflective insulation are used in rectangular or round ductwork in HVAC system.

Fibre glass

Fiberglass is a lightweight, extremely strong, and robust material.

Fiberglass is resistant to mould, but growth can occur if the fiberglass becomes wet and contaminated with organic material.

Polystyrene

Polystyrene also known as 'thermocole', is polymer made from the monomer styrene, a liquid hydrocarbon that is manufactured from petroleum.

Pure solid polystyrene is a colourless, hard plastic with limited flexibility. It can be cast into moulds Polystyrene can be transparent or can be made to take on various colours.

Polystyrene foams are good thermal insulators and are, therefore, often used as building insulation materials.

Expanded Polystyrene

Expanded Polystyrene (EPS) is a rigid and tough, closed-cell foam. It is usually white and made of pre-expanded polystyrene beads. Familiar uses include moulded sheets for building insulation and packing material.

Like other organic compounds, polystyrene is flammable. Although it is an efficient insulator at low temperatures, in any exposed installations its used is prohibited.

Method of Laying

Duct Insulation

When there is no chance of moisture condensation on the duct, glasswool can be used since it is economical and fire resistant. However, if moisture condensation can occur, greater care should be taken in case of glasswool. First, a uniform coat of bitumen is applied to the duct surface and the glasswool is stuck to that. the insulation is then covered with a suitable vapour barrier. The surface can be plastered after spreading chicken-wire mesh as reinforcement. Glasswool, when laid inside the duct surface also acts as an acoustic treatment. But the insulation should be covered with perforated sheets or fibreglass to prevent the flying off the fibers due to the air velocity.

Expanded polystyrene can be load easily as it is rigid. Bitumen is applied on the duct and the insulation is stuck. Joints are also sealed with an adhesive. No separate vapour barrier is needed.

SUMMARY - INSULATION MATERIALS AND APPLICATION WITHIN THE GENERAL TEMPERATURE RANGES:

Low Temperature range:

-75 C (-103 F) through 15 C (60 F)

Type	Form	Temp. Range	K-Factor	Mean Temp. C (F)	Notes
GLASS CELLULAR	Pipe Covering Block -	-268°C to 427°C 450°F to 800°F	.048	4° (40°)	Good strength, water and vapour resistant, non- combustible, poor abrasion resistance.
GLASS FIBER	Pipe Covering Board Blanket.	to 455°C to (850°F) to 538 C to (1000 F) to 538 C to (1000 F)	.035 .032 .030	4° (40°) 4° (40°) 4° (40°)	Good workability, non-combustible, water absorbent. Readily available. Vapour retarder required. Low compressive strength.
ELASTOMERIC FOAM	Pipe Sheet Roll	-40°C to 104°C -40°F to 220°F	.038	10°(50°)	Closed cell good workability, finish not required. Limited thickness to meet flame spread/ smoke. Required UV protection
POLYSTYRENE (Extruded)	Pipe Covering Board	-183°C to 74°C -297°F to 165°F	.035	4°(40°)	Lightweight, good, workability. Check manufacturers' data. Combustible. Some are treated for fire retardancy. All are closed cell except polystyrene expanded.
POLYSTYRENE (Expanded)	Pipe Covering Board	-40°C to 80°C -40°F to 175°F	.036	4°(40°)	
POLYURETHANE	Pipe Covering Sheet	-40°C to 107°C -40°F to 212°F	.025	4°(40°)	K-value may change as these materials age. Combustible.
POLYURETHANE	Pipe Covering Sheet Roll	-70°C to 100°C -94°C to 212°F	.036	10°(50°)	High flame spread and smoke.
POLYISOCYANURATE	Pipe Covering Sheet	-183°C to 140°C -297 F to 300 F	.025	4°(40°)	Lightweight, good workability. Check manufacturers' data. Some are treated for fire retardancy. K Values may change with age.

High Temperature range

15°C (60°F) through 315°C (600°F)

Type	Form	Temp. Range	K-Factor	Mean Temp. C (F)	Notes
CALCIUM SILICATE	Pipe Covering Block Segments Type I	to 649°C (1200°F)	.065	93°(200°)	High compression strength, good workability, water absorbent, non-combustible. High flexural strength. Resistant to abrasion. See manufacturers' data for shrinkage factors.
GLASS CELLULAR	Pipe Covering Block Segments	to 427°C (800°F)	.050 .063	24°(75°) 93°(200°)	Good strength, water and vapour resistant, non-combustible, poor abrasion resistance. Subject to thermal shock. For applications over 204°C (400°F) see manufacturers' specifications.

GLASS FIBER	Pipe Covering Board	to 455°C (850°F) to 538°C (1000°F)	.037 .033	24° (75°) 24° (75°)	Good workability, non-combustible, water absorbent. Low compression resistance.
GLASS FIBER	Blanket	to 538°C (1000°F)	.033	24° (75°)	General purpose material, many facings available.
MINERAL FIBER	Pipe Covering Block Board Blanket	to 649°C (1200°F) to 1035°C (1895°F) to 649°C (1200°F) to 649°C (1200°F)	.037 .037 .037 .048	24° (75°) 24° (75°) 24° (75°) 24° (75°)	Good workability, non-combustible. Water absorbent. Low compression resistance.
PERLITE (Expanded)	Pipe Covering Board	to 649°C (1200°F)	.076	93°(200°)	Good workability, non-combustible. Poor abrasion resistance. Special packaging required to protect materials. Corrosion inhibitor.
ELASTOMERIC FOAM	Pipe Covering-I Sheet-II Roll	-40°C to 105°C -40°F to 220°F	.043	24°(75°)	Closed cell, finish not required, good workability. May require UV protection. Flame spread/ smoke limited)
POLYSTYRENE (Extruded)	Pipe Covering Board	-183°C to 74°C -297°F to 165°F	.037	24°(75°)	Lightweight, excellent workability, combustible although some are treated for fire retardancy (check manufacturers' data sheet for properties) High flame spread/ smoke. Check manufacturers' data sheets for values. K value may change as these materials age.
POLYSTYRENE (Expanded)	Pipe Covering Board	-40°C to 80°C -40°F to 175°F	.039	24°(75°)	
POLYURETHANE	Pipe Covering Board	-40°C to 105°C -40°F to 225°F	.027	24°(75°)	
POLYETHYLENE	Pipe Covering Board	-70°C to 100°C -94°F to 212°F	.037	24°(75°)	
POLYISOCYANURATE	Pipe Covering Board	-183°C to 149°C -297°F to 300°F	.027	24°(75°)	

Acoustic Insulation (Fig 1)

Acoustic insulators are those materials that prevent sound transmission or absorb it. Sound is transmitted in form of pressure waves through the air where we can distinguish various voices as well as the noise. Sound travels also through solid objects. The continuous sounds surrounding mankind may lead to nervous tension and affect the behavior and action of people. Therefore, environmental engineering identified appropriate sound levels for living and working. Since, it is easy of sound transmission through concrete parts, thus, it should always control the design of the building and select the most appropriate soundproofing materials. The insulation of building prevents the transmission of sound outside or inside and from room to another.

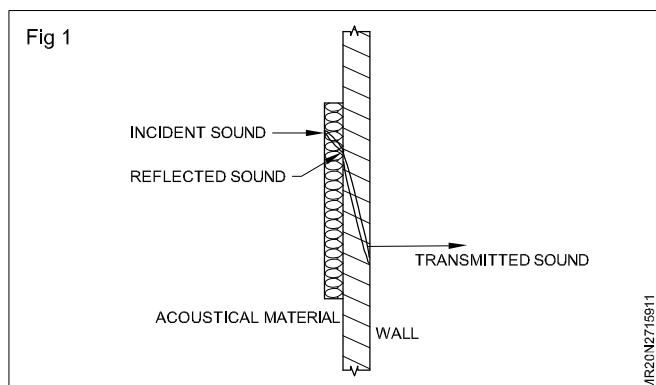
Objective of Acoustic Insulation:

- 1 Prevent transmission of sound from the outside.
- 2 Prevent transmission of sound between the rooms through walls and ceilings.
- 3 Prevent the transmission of sounds and vibrations of machines

Classification of Acoustic Insulators

The incident sound upon a surface could be distributed into three main parts. The first part is reflected from the surface, the second part is absorbed by the surface while the last part is transmitted across the surface to inside. So it could say that the sound-proofing materials are divided into:

- 1 Reflective materials
- 2 Absorbing material



Commercial Insulators

- 1 Acoustic tiles, these tiles have the capability of sound absorption, durability and ease of cleaning. Often, they are made of composite materials such as quartz mixed with granular resin, as well as the fiberglass, that results from the mixing of glass wool with epoxy. These tiles are used for the absorption of sounds of machines.
- 2 Glass wool or rock wool, they are characterized by the ability to absorb sound and thermal insulation, and can be mounted on the walls and ceiling. These could be used in commercial and industrial buildings.
- 3 Polyurethane foam which are available in the form of spray, layers and tiles.
- 4 Cellulose panels which are compressed and perforated face.
- 5 Gypsum boards with the addition of fibers to the surface.
- 6 Rubber in many forms natural rubber panels, industrial chloroprene (neoprene or polychloroprene) and layers of Mass Loaded Vinyl (MLV). These are available in panels and rolls and they have high sound absorption and they are used to cover the walls, as well as to absorb vibrations.
- 7 Natural cork or synthetic cork (EPS).
- 8 Plastic packaging sheets: these layers fit for ceilings in factories where large dimensions. These are resistant to dust as well as the moisture.
- 9 Perlite, a white color substance taken from the volcanic rocks, and it is a good insulator of sound and heat. It gives the surface a reliable fire-resistant. Perlite is used to insulate the ceiling, walls and floors.
- 10 Visco elastic damping compound (VDC), a viscous resin fast to dry, used in flooring damping, absorption of the noise as well as to absorb the vibrations of machinery and ducts.

11 Fabrics, leather, carpet and sponge materials.

12 Metallic panel, it is similar in work to the silencer where it dissipates the undesired sounds and then absorbs it by acoustic insulation inside (fiberglass).

Vapour Barrier

A vapour barrier is often used to refer to any material for preventing movement of moisture that resists diffusion of moisture through insulation, wall, ceiling and floor assemblies of building. Technically, many of these materials are only vapour retarders, as they have varying degrees of permeability.

Vapour diffusion retarders are normally available as coatings or membranes. The membranes are generally flexible and thin materials, but sometimes thicker sheet materials named as 'structural' vapour diffusion retarders are also used.

Steel/aluminium sheets, reinforced plastic sheets, etc. are of the rigid type and are efficient barriers, being impervious to vapour transmission. As they are rigid, they can be fastened to the walls and ceilings by screws and joints and the screw locations can easily be sealed.

Materials used as vapour retarders are:

- Aluminum foil
- Paper-backed aluminum
- Polyethylene plastic sheet 0.004 to 0.006 inches thick (0.10 or 0.15 mm)
- Advanced polyethylene vapour retarders
- Asphalt-coated Kraft paper, often attached to one side of fiberglass battens
- Metallised film
- Vapour retarder paints
- Extruded polystyrene or foil-faced foam board insulation.

Air Filters

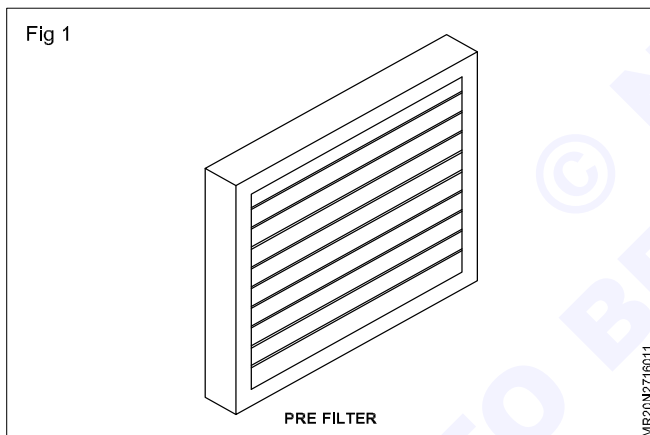
Objectives: At the end of this lesson you shall be able to

- importance of air filters
- types of air filters
- installation and servicing of air filters.

Importance of air filtration: The recirculated air within the air-conditioned area acts as a carrier 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 is passed through filters that remove the dust particles from air and ensure delivery of clean air to the conditioned space. The air filters interfere with performance of the air-conditioning system.

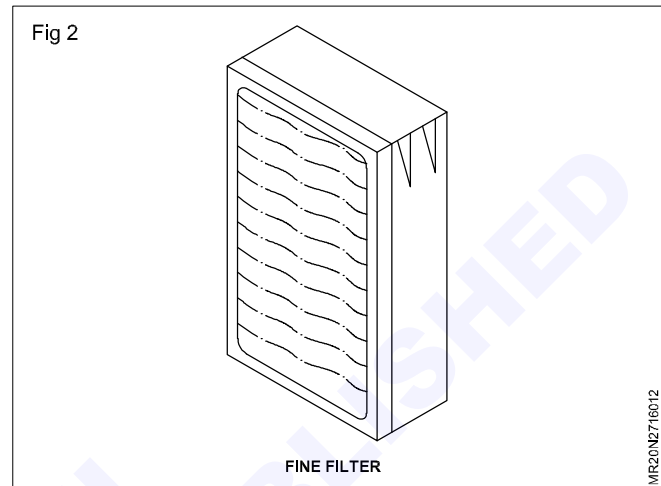
Prefilters: Present day filters used for general comfort application and as prefilters for clean room. Applications have the filtering media of synthetic material in the form of mesh, stitched and formed into deep folds and housed in mild steel or Aluminum frame. (Fig 1)



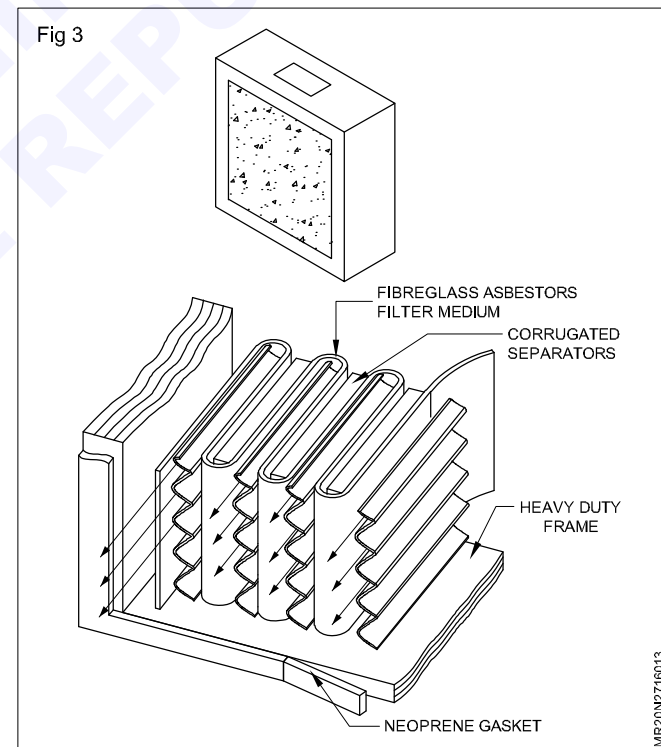
They arrest particles of sizes ranging from 10 to 20 micron with 90% efficiency. When the filters are clean the pressure drop is about 6mm (0.25") W.G. and have to be cleaned when the pressure drop reaches 15mm (6") W.G.

Fine filters: They are used where filtering is required down to 5 micron size. This filter has microlayer fibre glass and asbestos. Both of which have the advantage of fix resistance, moisture resistance, strength and good dust reduction capacity. They are of cleanable type. The pressure drop when the filters are clean is around 6mm W.G. and have to be cleaned when pressure drop exceeds 15mm W.G. They will have an efficiency of 99.9% down to fine microns and located on fan discharge side. (Fig 2)

Absolute filters or high efficiency particulate air (hepa) filters. In latest designs of Hepa filters the filtering media is a sheet of extremely fine glass fiber interwoven in diverse directions and mixed with resin. The media is accordingly pleated which increases the filtering surface



and at the same time minimizes the volume of the filter assembly. (Fig 3)



To maintain minimum and uniform distance between the various folds for uniform passage of air corrugated spacers are inserted in each fold. The direction of the channels of the corrugated spacers encourages laminar flow at the filter exit. They also stiffen the assembly. These filters also resist extreme temperature and humidity conditions corrosion etc. The filter medium is usually 1mm thick and resembles a white blotting paper. The fibre in the filter

medium usually have a diameter between 0.1 and to 10 microns and have the ability to capture sub-micron size particles. They offer low resistance to the air flow and can achieve 99.97% efficiency down to 0.3micron. The efficiency of arrest by interception increases with the diameter of the particles and also as the fibre diameter becomes finer. The maximum pressure drop is 50min (2") W.G. Once this pressure drop is reached, the filter has to be replaced as these filters are not cleanable by one of throw away type. The life of the H.E.P.A. filter depends on the amount of particulate matter been filtered and on the degree of prefiltering employed. Therefore incase H.E.P.A filters are used, prefilter (course and line filters) installation is a must prefilters should be well maintained to increase the life span of the H.E. P.A filters.

Fitting and maintenance of filters: The frames of the filter panels must tightly fit into fixing arrangement and no leakage /by pass should be allowed. Considering the role they play in protecting the system components acid by the desired clean (conditioned) air output, maintenance of filters should be given due importance.

Filters collect dust and if not cleaned or replaced in time the elements can give sway allowing the dust collection to spread to the conditioned space/cooling coil. Therefore the filters should be periodically cleaned without fail and care for just like any other mechanical equipment at the lay out design stage and particularly during installation it should be ensured that the filters are easily accessible for maintenance purposes sufficiently large inspection door and good lighting should be provided if the filters are fixed in an enclosed space (such as in supply air duct, plenum).

It is difficult stipulate the frequency of cleaning/replacement of the various type of filters course and fine filters must be cleaned or replaced when the air flow across them drops by 10% or when the air side resistance reaches two or three times the initial valve, (U) when the filters were cleaned.

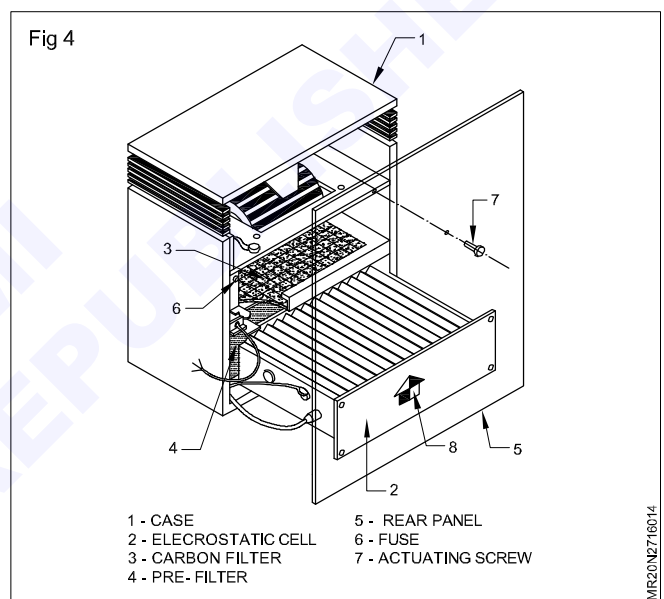
Washable filter elements should be washed with water of recommended temperature excessive temperature can effect the fibre bonding agent. If any element is hardened or has lost its elasticity it should sprunk or settle down should be replaced. In electronic should be periodically checked as inadequately charged or undercharged plates will not function properly. Broken discharge wires in the ionizing section should be replaced for an effective and uniform field of ionization.

Electronic air cleaners: In a number of applications very high efficiency air filters are needed, and even in comfort cooling work. Considerable economies can be secured by reducing the quantity of ventilation air which must be cooled to interval design conditions. Electronic air coolers are increasingly used for these purposes. Since they are efficient enough to enable tobacco smoke and odors for example, to be removed from air recirculated through them.

Operating principles can be followed with the help of Fig 4, contaminated air is drawn through the equipments by a centrifugal fan immediately air is drawn through the

equipment by a centrifugal fan immediately after entry. The air is prefiltered by a normal washable type metallic mesh filter. In their passes through an ionizing area. In which it is exposed to a high voltage positive electrical field. This positively charges all solids in the air stream which now passes between a series of parallel collecting plates which are alternatively positive and negatives charged. The positively charged particles in the air area attracted to and settle on the negatively charged collectors. The air them passes through a charcoal filter, which removes any odors, before being returned to the room.

The collecting plates are cleaned of accumulated solids by removing and washing them. In addition to removing dust. This type of filter effectively removes bacteria as small as 2 to 3 microns and is used to combat cross infection in hospital. It also has a number of industrial applications, including the removal and recovery of oil particles from mist or smoke generated in factories.



Function of air filter: In Air conditioning space the air moves from one place to another. During its movement dust and foreign materials come in contact with air. The dirty air is uncomfortable for human beings. So the dirty air must to clean before supplying in to the air conditioning space. The air filters are used for cleaning the air. The different air filters explained in the previous lesson.

Purpose of air filter servicing: Before supplying the air in the air conditioning space, the air is cleaned by air filters. Due to accumulation of dust and other foreign materials the air filter may be restricted. So the air filter should be cleaned periodically.

Installation of air filter

The air filter is fitted in front of the cooling coil. Before air reaching is to the evaporator, the dirty air should be cleaned. If the air is not cleaned, the dust will accumulate in the evaporator coil. By the accumulation the evaporation will reduce and reduce the cooling capacity. So the air filter is installed in front of the evaporator coil, to the clean air. After cleaning the air, it flows through the cooling coil.

Package AC (with Air Cooled Condensers)

- Objectives:** At the end of this lesson you shall be able to
- study the Package AC (with Air Cooled Condensers)
 - construction and working principle
 - electric circuit.

Introduction

Package air conditioner is a bigger version of the window and split air conditioners. The window and split air conditioners are usually used for the small air conditioning capacities ranging from 0.5 ton to 3 tons. The central air conditioning systems are used for where the cooling loads extend beyond 20 tons. The packaged air conditioners are used for the cooling capacities in between these two extremes. The packaged air conditioners are available in the nominal capacities of 3, 5, 7, 10 and 15 tons. (Fig 1)

The air cooled type which are self-contained are factory assembled, those split package types needs laying of refrigerant piping between Indoor and outdoor units, pressure testing, evacuation, charging, etc. and thus are not factory assembled as these workings have to be carried out in the field. (Fig 2)

Where there is scarcity of water, air-cooled units are favored, though their capacity will be less than that of the water-cooled units using the same compressor. For the evaporator side, centrifugal fans are provided, which can

develop a higher static pressure. So, air distribution ducts and grills can be connected to the unit.

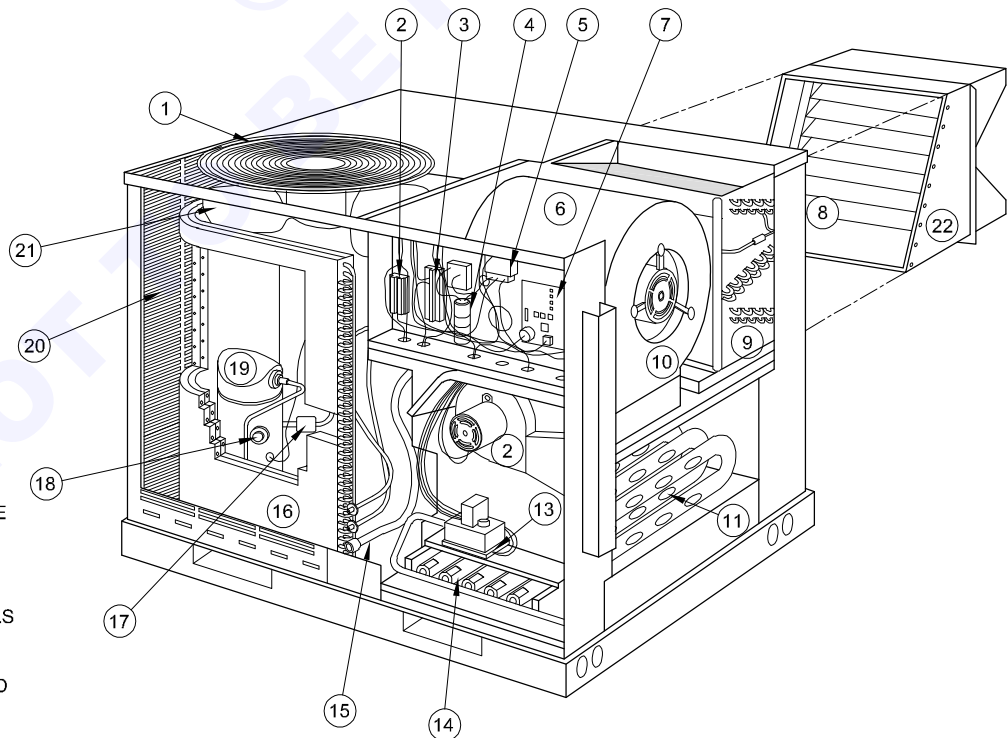
As the name implies, in the packaged air conditioners all the important components of the air conditioners are enclosed in a single casing like window AC. Thus the compressor, cooling coil, air handling unit and the air filter are all housed in a single casing and assembled at the factory location. These units are used commonly in places like restaurants, telephone exchanges, homes, small halls, etc

Protection devices such as High/Low pressure switch, overload relays for all motors, water flow and air flow switches are included in the units. The compressor have winding protection thermostat built into the winding to disconnect the circuit in the event of overheating.

There is an interlocking circuit with the evaporator fan motor starter to ensure that the compressor can only start if the fan motor is running.

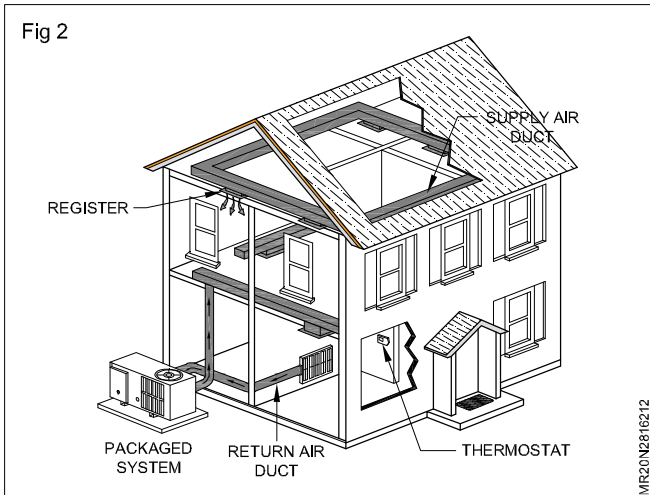
Fig 1

- 1 FAN GRILE/GUARD
- 2 CONTACTOR
- 3 TERMINAL BLOCK
- 4 CAPACITOR
- 5 TRANSFORMER
- 6 BLOWER
- 7 CONTROL BOARD
- 8 DATA PLATE
- 9 EVAPORATOR COIL
- 10 BLOWER MOTOR
- 11 HEAT EXCHANGER
- 12 INDUCER MOTOR
- 13 GAS CONTROL VALVE
- 14 BURNERS
- 15 CONDENSATE DRAIN LINE
- 16 CONDENSER COIL
- 17 FILTER DRIER
- 18 COMPRESSOR TERMINALS
- 19 COMPRESSOR
- 20 CONDENSER COIL GUARD
- 21 FAN BLADE
- 22 ECONOMIZER



GAS/ELECTRIC PACKAGED UNIT SCHEMATIC

MIR20N2816211



Components

This self contained unit is assembled in a casing where all the air conditioning components are housed. They include:

- Compressor usually hermetic or semi-hermetic type for operation on 380/400 Volts 3 Phase is used.
- Air-cooled condenser.
- Electrical Panel.
- Thermostatic Expansion Valve.
- Air Filter.
- Front Panel & Return Air Grill.
- Evaporator Coil.
- Evaporator Fan And Housing.
- Heating and Humidifying Components may be included in the unit. Dehumidification is needed for cooling mode during summer and Humidification for heating mode during winter.

Air-cooled package units are proving to be quite popular for central residential and small commercial units. They are compact and eliminate the need for cooling towers and water piping. They are very popular in areas which have hard water and the resulting condenser scaling problems.

Are designed to meet many different residential and commercial installation requirements. The unit can be installed in the attic or crawl space, through the wall or transom, suspended from ceiling, placed on a roof or on a concrete base next to the basement wall. they are completely weather proofed for outside or roof installations.

Constructions and working

These type of units consists of Hermetic or semi-hermetic compressors, suitable for operation on 380 to 400 volts three phase ac supply. In bigger capacity units (10 and 15 ton), compressors with capacity control are also used. These are units with two independent refrigeration

systems. In these units, though the cooling tubes of the coils are entwined, i.e. every alternate row is connected to from the evaporator of one circuit and other rows from the coil of the second circuit.

By providing two systems, 50% of capacity reduction can be obtained by cycling one refrigeration system through a thermostat. The air-cooled condensers can be entwined circuited as in the cooling coil, or two separate air-cooled condenser assemblies can be adopted.

A thermostat with its sensing bulb fixed on the air entry side of the cooling coil, is provided to cycle the compressor as per the desired setting. In units with two refrigeration systems, two stage thermostats can be provided. However it is a general practice to provide a single-stage thermostat to control one of the compressor only, the other compressor running all the time.

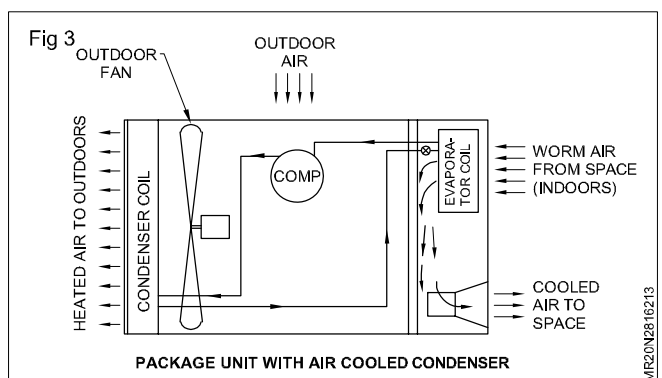
Forward curved fans are used in PAC, the width of the unit is kept low, so it occupies less floor area, allowing maximum conditioned floor area for beneficial use. The low unit width results in low area for the entry air to the fan and so higher air velocity, which reduces the air quantity handled by the fan and also increases the noise level. So, the design should ensure liberal air intake area to the fan, for smooth, less noisy air flow and efficient fan performance.

The air cooled condenser is supplied with a centrifugal condenser fan. The condenser air may be ducted to the air conditioner from outdoors.

Fig 3 shows a air cooled type package unit. The condenser is installed in shade towards outside where the cool air contacts with it. The refrigerant vaporised to absorb the heat inside the room which enters into condenser compressed by compressor and changed into liquid from.

Return air from the space is pulled through coil-1, called the indoor coil. It is cooled and dehumidified and discharge to the duct system by the indoor blower.

Coil-2 (the outdoor soil) is an air cooled condenser and rejects heat to the outdoor air which is moved over the coil by the outdoor fan. Passage of air across the motor compressor aids cooling the unit. The two compartments separating the indoor and outdoor sections are well insulated to avoid heat transfer.



Troubleshooting of air cooled PAC

Objectives: At the end of this lesson you shall be able to
 • possible problems and their remedies.

Problem and possible Cause	Remedy
Compressor Motor and Fan Do Not Start	
1 Circuit breaker off or fuse bad	1 Reset breaker or check fuses.
2 Thermostat set too high	2 Reset thermostat to lower temperature.
3 Bad thermostat switch or wiring. thermostat	3 Short between Y,R and G; if unit starts, the must be replaced.
4 Loose connections.	4 Check wire terminals and tighten.
5 Bad transformer.	5 Check primary voltage (110/220), if power is there but on voltage on secondary wires (24 VAC), replace transformer.
6 Bad compressor and /or fan.	6 Check and repair/replace as necessary
7 Bad relay in control panel.	7 Check or replace as necessary.
8 High-pressure switch open	8 Check for dirty, lined, or obstructed condenser, bad condenser fan relay or motor, or bad high-pressure switch.
9 Low-pressure switch open.	9 Check for poor airflow through evaporator, bad low- pressure switch, low freon or pressure, dirty filter.
10 Contactor winding shorted	10 Check continuity in winding; replace contactor if necessary
11 Bad wall thermostat	11 Check or replace as necessary.

Compressor Stops Before Thermostat is Satisfied

1 Condenser dirty	1 Clean condenser coil and fins.
2 Low voltage	2 Check for required voltage
3 Condenser fan speed too slow	3 Check for loose blower wheel
4 Dirty filter (S).	4 Clean or replace
5 Defective run capacitor.	5 Check and replace if necessary.
6 Defective compressor motor.	6 Check for proper voltage. Allow enough time for overload to reset. If condenser pressure is normal, but compressor draws more than rated amperage, compressor is defective.
7 High-or low-pressure control switch inoperative	7 Check control switches,

Unit Does Not Cool Sufficiently

1 Thermostat set too high	1 Adjust to desired temperature.
2 Thermostat improperly located	2 Relocated thermostat away from drafts, out of direct sunlight, etc.
3 Compressor and/or condenser fan not running.	3 Check cause.
4 Dirty condenser and/or evaporator.	4 Clean condenser and/or evaporator.
5 Dirty filter(s).	5 Clean or replace
6 Blower wheel slips on shaft.	6 Check and tighten screw
7 Refrigerant low as shown by low amperage, evaporator not cold, or large portion of condenser cool.	7 Recharge after checking for restriction in capillary tube, strainers, TEV and filter-drier. Amperage should not be lower than FLA shown on condensing unit nameplate.

8 lack of insulation on ducts.	8 Replace loose or missing insulation.
9 Air leaks in ducts.	9 Check and repair.
10 Insufficient air from evaporator.	10 Make sure duct dampers are open, duct runs are not too long or too small. Adjust blower speed.

Evaporator Has Excessive Frost Buildup

1 outside temperature below 70°F.	1 Advise customer unit not designed to operate at low ambient temperature
2 Sensing element improperly located	2 See number 6 above
3 Faulty thermostat	3 Check thermostat; see that temperature is not set too low
4 Insufficient airflow	4 Check for dirty filter, condenser, or blower wheel loose fan or wheel or exhaust door open.
5 Faulty unit.	5 Check for loss of refrigerant or restriction in sealed system.
6 Fan running too slow.	6 Advise customer to run fan at higher speed; check for low voltage. Check for binding blower wheel or shaft, wrong motor, or blower wheel.

Circuit Breaker Tripping or Fuses Blowing

1 Faulty wiring.	1 Check condition of wiring and connections, look for short-circuiting, and repair as necessary.
2 Restarting too soon.	2 Advise customer to wait two to three minutes before attempting restart.
3 Wrong fuses or circuit breaker.	3 Check fuse for proper type and time delay; check circuit breaker size for adequate amperage.
4 Incorrect voltage.	4 Check power source for voltage no more than 10% \pm of that on nameplate.
Problem and Possible Cause	Remedy
5 Faulty component.	5 Check capacitors, thermostats, overload protector, relays, switches, fan, and compressor motor, etc.

Moisture Drips Inside of Room

1 Unit improperly leveled.	1 Unit should be one-fourth inch lower to allow moisture to run outside.
2 Drain hole(s) clogged	2 Clean drain hole(s) of debris.
3 High humidity.	3 Reduce door openings, repair or improve sealing around unit, and advise customer of any abnormal operating conditions.

Unit Does Not Work

1 No power.	1 Check power supply at wall receptacle, check plug and service cord, circuit breaker, or fuse; make sure circuit is not overloaded with appliances.
2 Faulty wiring.	2 Be sure unit is wired according to its wiring diagram; check electrical components for correct wiring and operation. If all is in proper working order and unit still does not run, check for faulty compressor.
3 Bad start relay	3 Check start relay on compressor as instructed in section on relays.
4 Humidity control. (When used; also called a continuity humidistat.)	4 Unplug unit, set control on dry and check for across the plug prongs. If there is no continuity, the control is bad and needs to be replaced. Next, turn control toward wet until you hear a click; then check again for continuity. If there is continuity, replace the control. (Relative humidity in room must be between 20% and 80% the extremes in average control knob settings.)

5 Defective defrost bimetal. (If equipped).	5 Check function of bimetal switch as you would on any refrigerator.
6 Defective pressure control switch. (If equipped)	6 Unplug unit, bypass pressure control switch with jumper wire, connect power, and if unit start, replace switch

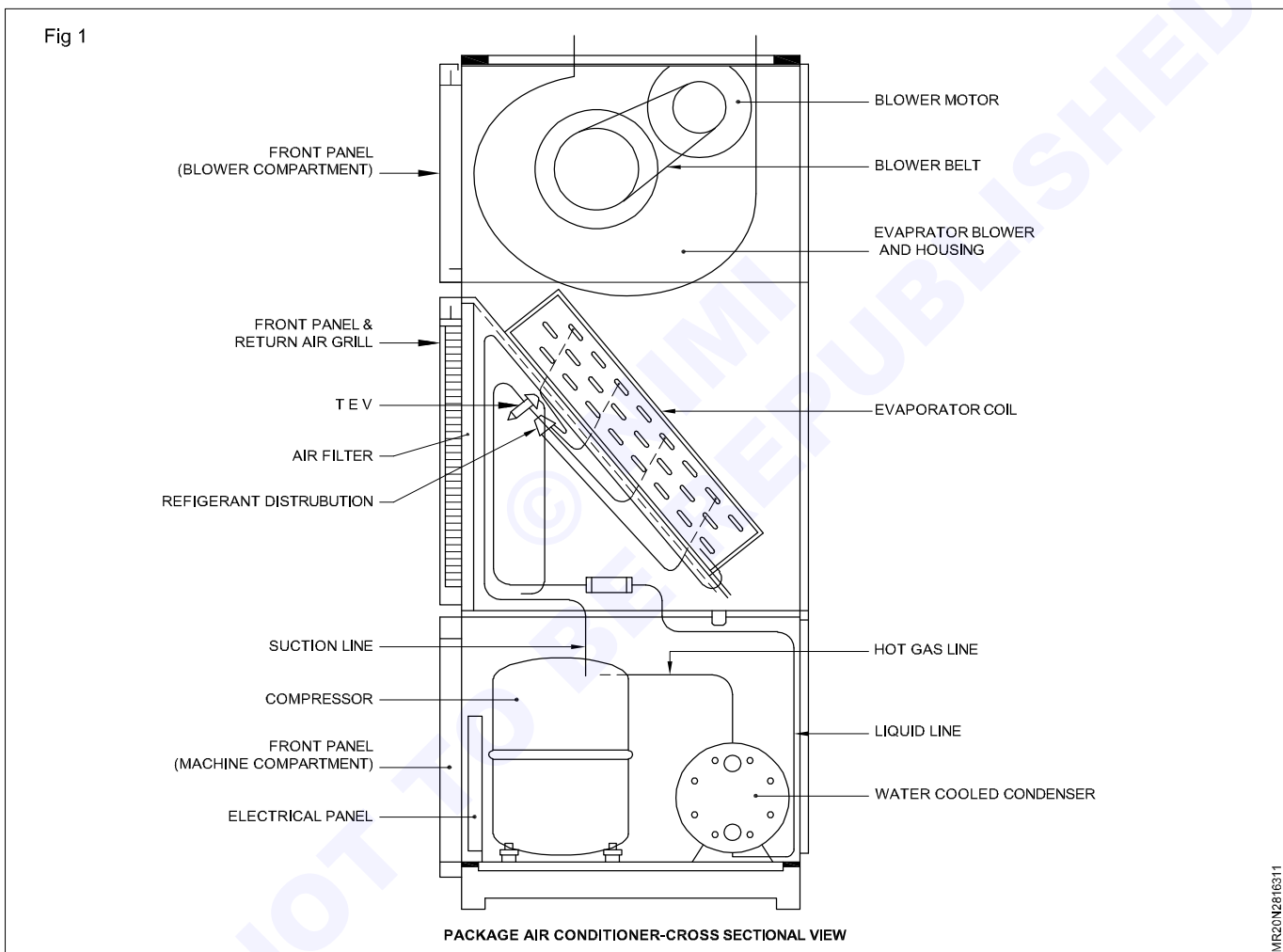
Construction and working principle of package AC with water cooled condenser

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

- construction of PAC with water cooled condenser
- working Principle of PAC
- components used in this system.

In package air-conditioners, all components are mounted in a cabinet (Fig 1). They vary in capacity available in 3, 4, 7, 10 and 15TR. These units are normally used in small

commercial areas such as restaurants, supermarkets, banks, telephone exchanges and control rooms.



Package unit may have either water cooled or air-cooled condensing units. Air cooled models are needed for some areas because of water restriction. Air ducts must lead to the outdoors for condenser cooling. In split type units there is no need of ducts for condensing units (outdoor unit) condensing unit in outdoor, evaporator unit (cooling unit) in indoor. Laying of the refrigerant piping between the indoor and outdoor unit.

Hermetic or semi hermetic compressors are operated on three phase A.C. supply (440V) for higher capacity units (7.5 to 15 tonnes) compressors with capacitor control are

also used. There are two independent refrigeration systems in these unit. The cooling coils of the two systems are independent. The coils have common tube fins and supporting frame work. The tubes of the coils in alternate row is connected, from the evaporator of one circuit and other rows from the coil of the second circuit. By providing two systems, 50% capacity conduction can be obtained by cycling one refrigeration system through a thermostat. Two separate water cooled condensers or one condenser shell with leak tight internal partition to from two independent condensers are used, the water side is common to both the independent condenser portions.

A thermostat with its sensing bulb fixed on the air entry side of the cooling coil (before the suction filter) is provided to cycle the compressor as per the setting desired. In unit with two refrigeration systems, two stage thermostat can be provided to equalize the wear and tear of the two compressors, a changeover manual switch is provided in the electrical control circuit. This switch changes over the electrical connections of the thermostat from one of the other compressor. Periodically the position of the changeover switch is changed, so that both the compressors have equal hours of operation.

Safety controls: High pressure cut out, low pressure cutout, overload relays for compressor, thermostat, water flow switches are provided in the unit. All the controls are connected series with the hold-on coil of the starter of the compressor motor (Fig 2)

This circuit is interlocked with the evaporator fan motor starter, to ensure that the compressor can start and run only if the Fan motor/Blower motor is running.

The function of components

Compressor: Suck low pressure, low temperature refrigerant -compress and discharge high pressure high temperature vapour to condenser.

Condenser: Reject heat from refrigerant vapour and turning it to liquid.

Expansion valve: Refrigerant throttling device. It needs the liquid refrigerant to the evaporator.

Evaporator: It picks up heat from return air (load).

Blower: Blow the cool air to the duct.

High pressure cut out: It is to turn off the compressor, if the high side pressure is high. It is a manual reset device.

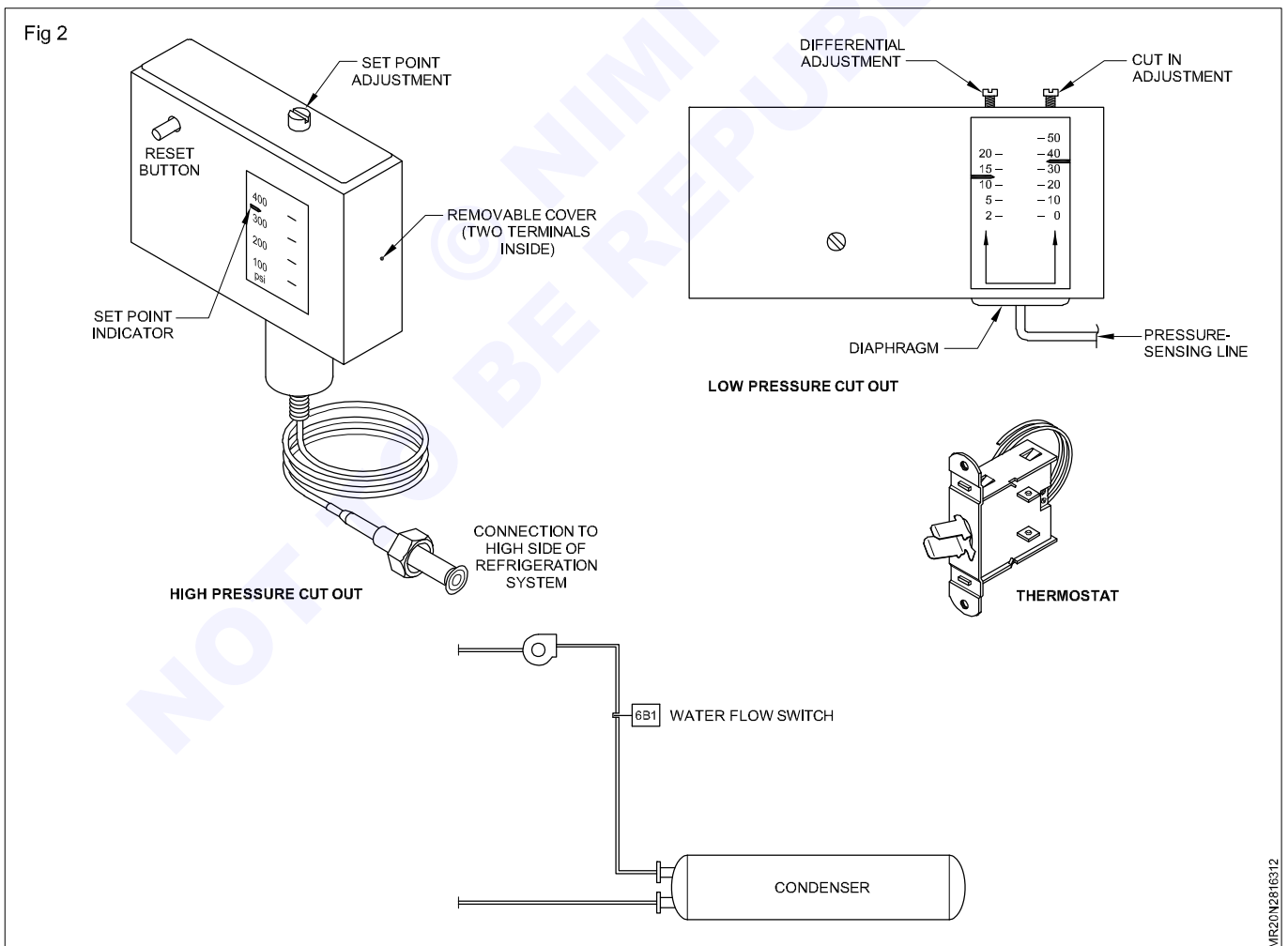
(Automatic reset model also available for both HP and LP cut outs).

Low pressure cut out: It will trip the compressor when low side pressure falls. It is an automatic reset device.

Over load relay: It is actuated by a temperature sensor. It makes the control circuit on a temperature rise, or breaks it on a temperature fall.

Water flow switch: It is to turn off the compressor if the water flow is low (water cooled condenser).

Air-filter: Return air purifier and prevent chocking of cooling air.



Specifications

Technical data for packaged air-conditioners air-cooled

Model No	-0.5A	-06A	-7.5A	-10A
Nominal capacity	5TR	6TR	7.5TR	10TR
Compressor make				
Rating	6.7KW	3.7KW Each	5KW	6.7KW Each
Nos.	1	2	2	2
Refrigerant	R-22	R-22	R-22	R-22
Bare-weight-kg	42	38 (each)	40(each)	42(each)
Evaporator type	ALUMINIUM FIN BONDED TO COPPER TUBES			
Face Area Sq.M.	0.4	0.45	0.6	0.8
No of rows	4	4	4	4
Fins/cm.	5	5	5	5
Blower air Qty. (M3/HR)	3400	4080	5100	6800
Blower size(mm)	300*300-1No.	300*300-1No.	300*300-1No.	300*300-2No
Motor rating	0.75KW	1.5KW	1.5KW	1.5KW
Condenser type	ALUMINIUM FIN BONDED TO COPPER TUBES			
Face area sq.mt.	0.84	1.20	1.60	1.70
No.of rows	4	4	4	4
Fins 1 cm.	5	5	5	5
Nominal air qty.	6800	8000	10200	13600
Eva. Unit dimensions length (mm)	1200	1200	1200	1200
Depth(mm)	750	750	750	750
Height(mm)	1800	1800	1800	1800

Water cooled

Model No	-0.5A	-06A	-7.5A	-10A
Nominal capacity	5TR	6TR	7.5TR	10TR
Compressor make				
Rating	6.7KW	3.7KW Each	5KW	6.7KW Each
Nos.	1	2	2	2
Refrigerant	R-22	R-22	R-22	R-22
Bare-weight-kg	42	38 (each)	40(each)	42(each)
Evaporator type	ALUMINIUM FIN BONDED TO COPPER TUBES			
Face Area Sq.M.	0.4	0.45	0.6	0.8
No of rows	4	4	4	4
Fins/cm.	5	5	5	5
Blower air Qty. (M3/HR)	3400	4080	5100	6800
Blower size(mm)	300*300-1No.	300*300-1No.	300*300-1No.	300*300-2No
Motor rating	0.75KW	1.5KW	1.5KW	1.5KW
Condenser type	SHELL AND TUBE			
Tube material	19mm OD INTEGRALLY FINNED COPPER TUBE 19 TPI			
No.	1	2	2	2
No. of Tubes	36	16(each)	18(each)	36(each)
Overall size MM	220D*790	150D*1120	150D*1200	220D*790
Water-in out	11/4"BSP	11/4"BSP*2	11/4"BSP*2	11/4"BSP*2
Unit dimensions length (mm)	1200	1200	1200	1200
Depth(mm)	750	750	750	750
Height(mm)	1800	1800	1800	1800

Duct system and AHU

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

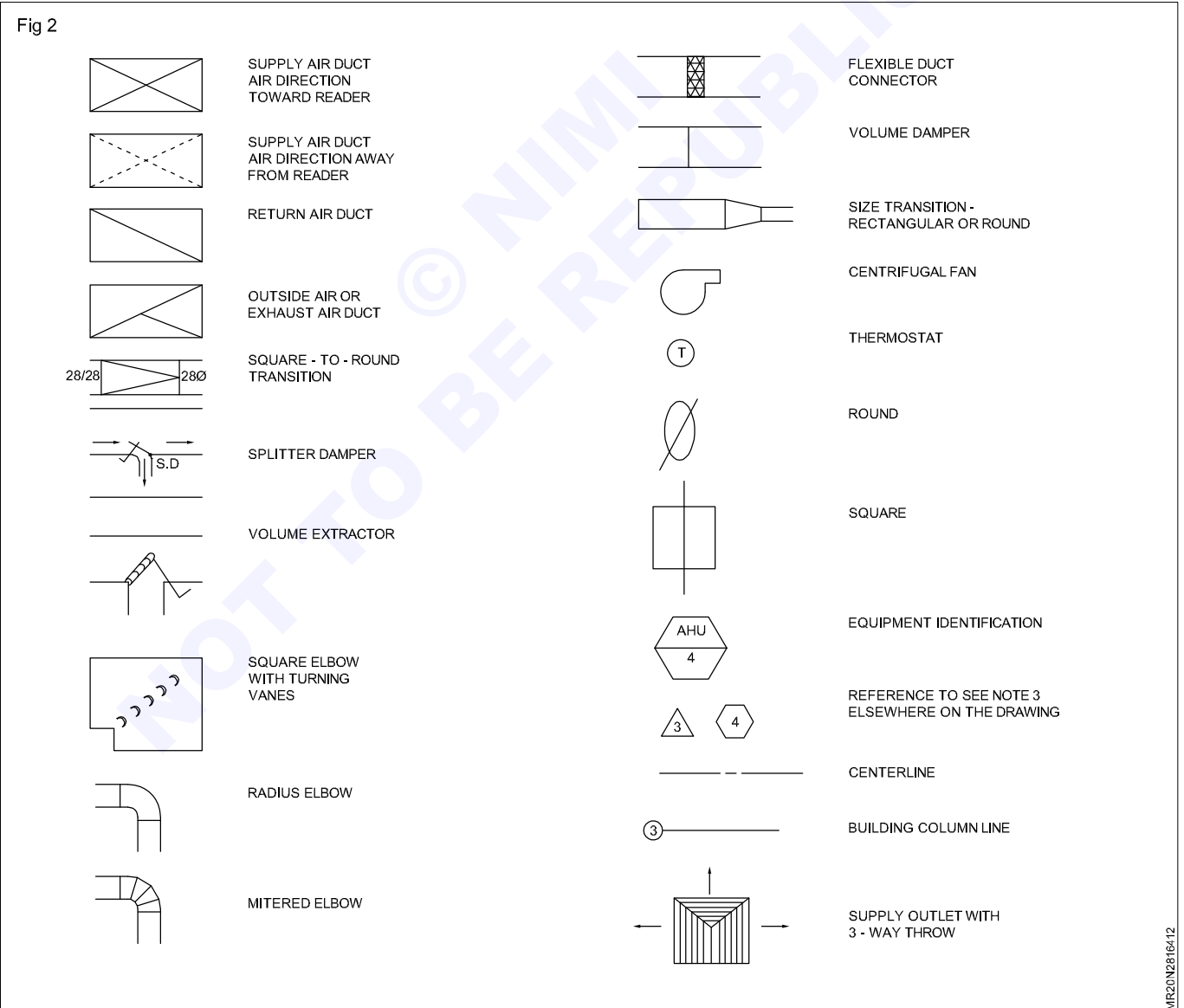
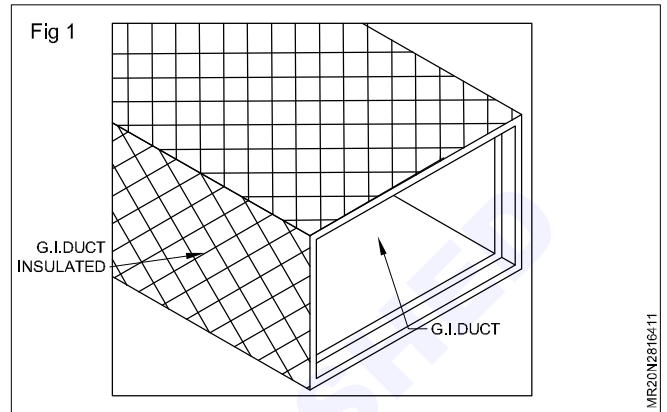
- duct system
- AHU.

Duct materials, standards, symbols, joints

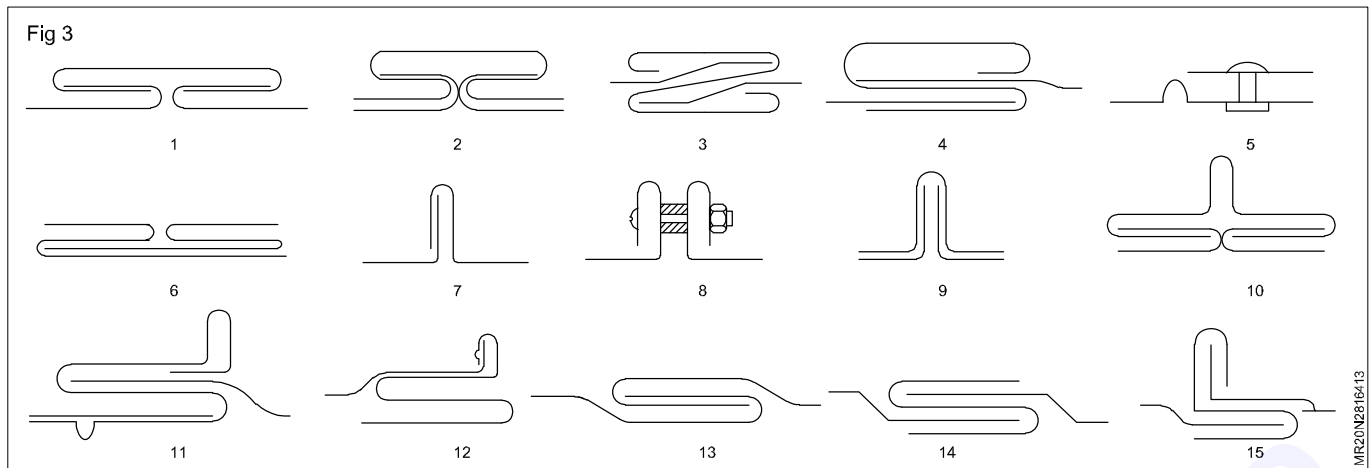
Comfort cooling ducts are commonly fabricated out of galvanized iron, Aluminium or Fiber glass reinforced plastic (FRP) Fig 1.

For industrial purpose depending on the process. Ducts may be fabricated from mild steel with apoxy coating, or even masonry duct, for 1/2" or 10" wg positive and negative pressure.

Duct drawing symbols (Fig 2)



Duct joint/symbols (Fig 3)



Ducts, grilles and diffusers

Ducts: Ducts are usually galvanised sheet steel or Aluminium sheets into rectangular boxes or round tubes. They are used to distribute the cool air from the Air Handling Unit (A.H.U.) or Air Washer (A/W), uniformly through out the building to be air-conditioned. They start at the A.H.U or A/W, and travel to the spaces to be conditioned carrying the cool air. (Fig 4)

Diffusers and grilles: The conditioned supply 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 attached to the false ceiling and a variety of diffusers are available for different air spreading needs. For well distributed cooling an air flow pattern needs to be created in the conditioned space.

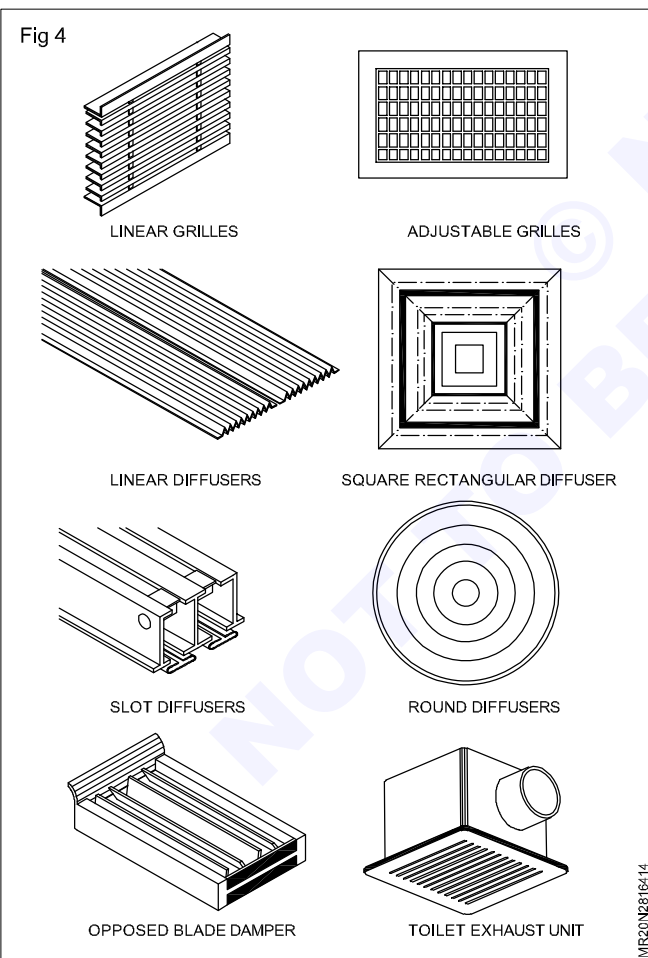
The supply air diffusers and the return air grilles, should be carefully separated to prevent short circuiting of the air.

Return air usually flows into the plenum or return air box through grilles placed in the false ceiling.

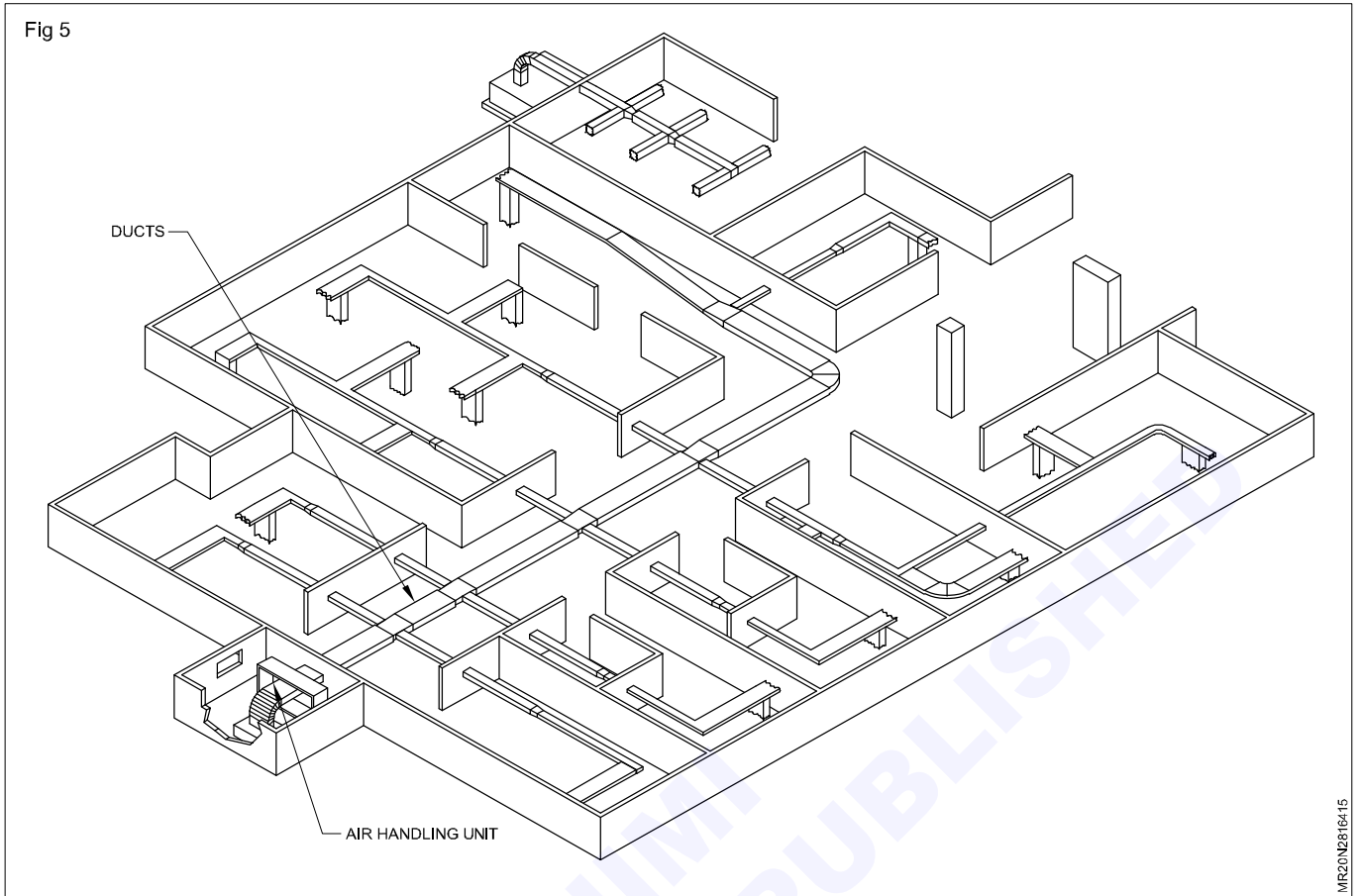
Return air: Since a substantial amount of energy goes into cooling the air in the first place it is a practice to recycle the air. The air is therefore brought back to the A.H.U. or H/W, using return air, ducts, it is common to route the return air through the gap between the false ceiling and the main ceiling, a space referred to as a plenum, it is desirable whenever possible to pass the supply air duct through the return air plenum, because this works like a heat exchanger, there by improving the efficiency of the plant.

Sometimes a separate system of return air ducts, boxing is employed to carry the return air instead of using the plenum. Where the supply air ducts do not pass through the plenum. They are usually insulated. So that cool air do not pick up heat from the warmer surroundings.

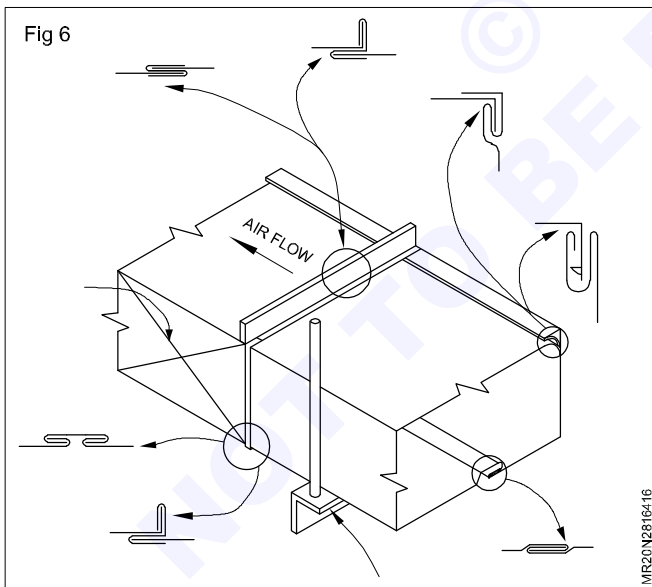
Duct joints: Several types of joints have been developed. See Fig 3 and 5, 6, 7. The joint should be air tight and strong. Many of the joints are also sealed with special duct tape to make them leak proof. Sealants are put in the duct seam for the same purpose.



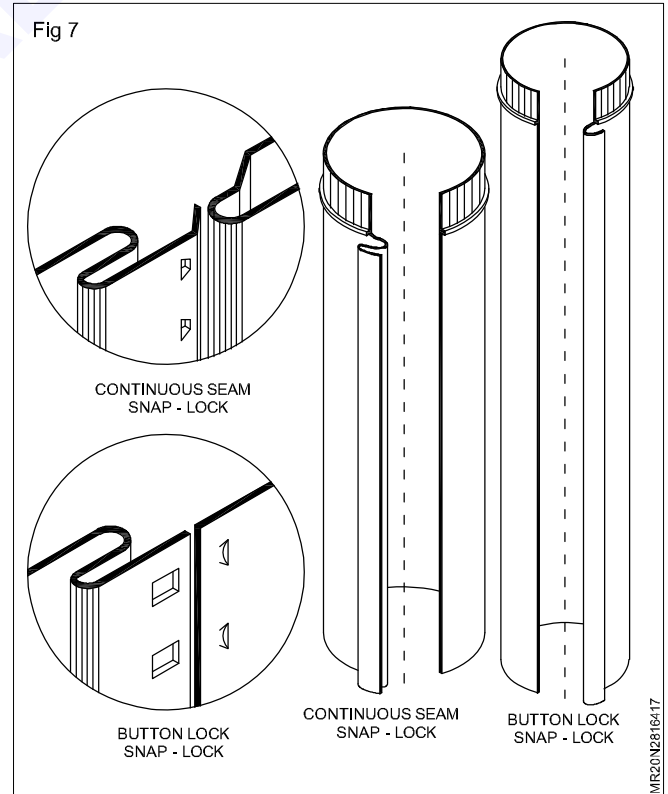
A typical duct layout (Fig 5)



Duct joint/symbols (Fig 6)



Two seam lock methods (Fig 7)



Function of duct

Ducts are used to carry air from air conditioning room to fan coil unit (FCU) and returned to air conditioning room with the help of blower in air conditioning system. There are two types of air transmission system adopted for air conditioning systems. One is low velocity and other is high velocity systems. The low velocity is with 760m/min. The high velocity is above 760m/min. The low velocity system is adopted for comfort AC systems with the range of 360 to 600m/min.

Types of duct

The ducts are classified in to three types with respect to the function.

- 1 Supply duct
- 2 Return duct
- 3 Fresh air duct

Supply duct

This duct carry the conditioned air from AHU and supply into the air conditioned room.

Return duct

This duct carry the used air from the air conditioned room and supply it to the AHU.

Fresh air duct

This duct serves the function of carrying out side fresh air into AMU room.

According to the shape, the ducts may be of three types.

- 1 Round duct
- 2 Square /Rectangular duct
- 3 Flexible duct

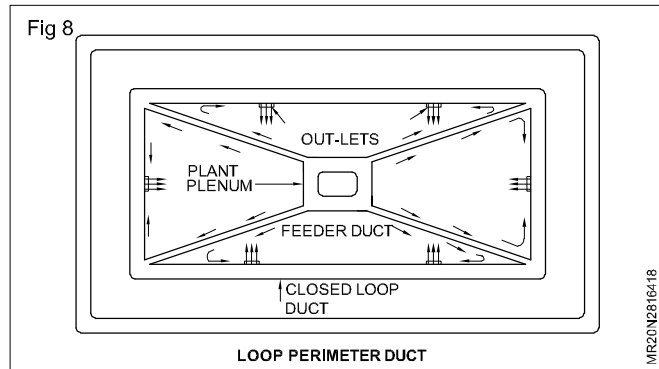
The round duct is made of G.I sheet or aluminum sheet in the shape of a round pipe. Air can pass through it very easily. It is easy in making. The square or rectangular duct is in the shape of square or rectangular form and made up of G.I or aluminum material. This duct more popular than round duct. The flexible duct is generally made of wire of spring steel is the shape of round. This duct is more flexible and can be adjusted in the different direction.

According to the fitting, the ducts may again classified in to three types.

1. Loop perimeter duct
2. Radial perimeter duct
3. Extended plenum duct

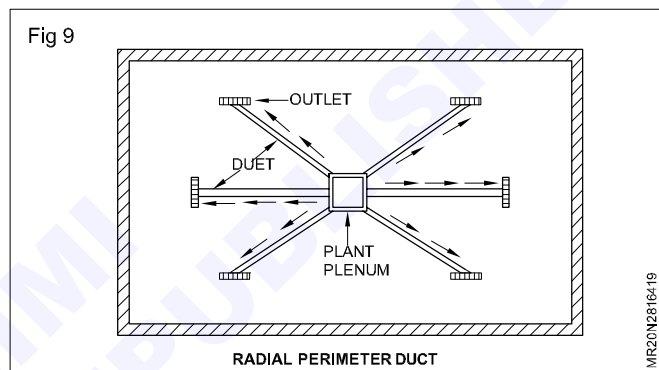
Loop perimeter duct (Fig 8)

In loop perimeter duct the conditioned air is taken from the AHU through a joint duct to the space to be air conditioned. So the conditioned air is evenly distributed through several branch ducts running from the plenum to the perimeter of the building to be air conditioned.



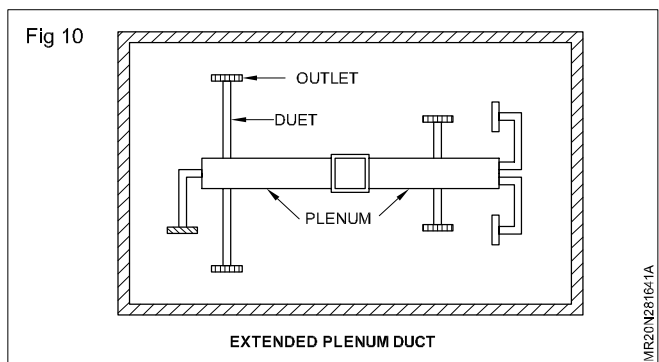
Radial perimeter duct (Fig 9)

In radial perimeter duct, the conditioned air is taken from the AHU through a joint duct to the air conditioned room to be air conditioned. So the conditioned air is equally distributed in all directions through several branch ducts fitted around the radius of the joint duct.



Extended plenum duct (Fig 10)

In this type of duct conditioned air is brought from the AHU - through a joint duct and extended along the centre beam of the air-conditioned room to be air-conditioned. The conditioned air is equally distributed in all directions through several parallel branch ducts running from the joint duct to each outlet.



Servicing of duct system

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

- **state the purpose of servicing the duct.**
-

Duct cleaning has become popular in recent years, with commercial cleaning services popping up everywhere. But is the service worth it, or is it a scam? Here's some information to help you decide whether or not your home might benefit from having the HVAC ducts in your house cleaned.

Duct cleaning services

Professional duct cleaning services use specialized blowers, vacuums, and brushes to clean out the supply, intake, and return ducts throughout your home. Duct cleaning should also involve a thorough cleaning of the air handler, registers, grilles, fans, motors, housings, and coils of the HVAC system.

There's no research at present proving that routine duct cleaning improves the air quality or reduces dust in your home. There is, however, evidence that dirty heating and cooling coils, motors, and air handling units can make your HVAC unit less efficient.

While duct cleaning alone doesn't seem that necessary, there are cases where cleaning the HVAC unit and ductwork could be useful.

Should I have ducts cleaned?

Due to growing concerns about indoor air quality, it's easy to convince homeowners that their ducts need cleaning. But unless ducts are really dirty, there's no reason to clean them. The EPA takes a similar stance on the issue, recommending cleaning only if the ducts and HVAC unit are contaminated.

If done properly, duct cleaning doesn't hurt; but it's not something that needs to be on your regular home maintenance list. You probably don't need to have your ducts and HVAC system cleaned unless.

- **Renovation:** If your home has been remodeled—especially if there was asbestos abatement, lead paint removal, or significant dust—your ductwork may need to be cleaned. Ducts should be sealed off during renovations; but if they weren't, dangerous dust and debris may become lodged inside the ductwork.
- There are two key components to HVAC cleaning: breaking contaminants loose, and collection of contaminants.
- **Breaking Contaminants Loose.**
- Properly cleaning HVAC systems requires removing the sources of contamination. Source removal begins with use of one or more agitation devices designed to loosen contaminants from the surfaces within the heating and air-conditioning system. Examples of agitation devices include brushes, air whips, and compressed air nozzles or "skipper balls." Agitation can also be achieved through hand-brushing or contact vacuuming.
- **Collection of contaminants**
- During cleaning, the entire HVAC system is placed under continuous negative pressure (vacuum) to prevent the spread of contaminants. Continuous negative pressure allows very fine particles to be removed from the system as they become airborne, ensuring that these particles are not released into the living space when the system is turned on after cleaning. This negative pressure also serves to extract the loosened contaminants, which are collected and removed from your home.

Central AC Plant

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

- identify various components
- study of construction and working principle.
- explain mechanical parts used in central AC plant
- explain electrical parts used in central AC plant.

Mechanical parts

Vapour compression refrigerator cycle is used in central air conditioning plant. The main components are compressor, condenser, liquid processor, drier, expansion valve, evaporator and accumulator.

Compressor

Compressor is the heart part of the vapour compression cycle in central air conditioning. Generally open type reciprocating or sealed type. Another compressor is screw 2 type is used in air conditioning systems. Now a day scroll type compressor is using in air conditioning. The centrifugal compressor is used in commercial central air conditioning plant.

Condenser

Water cooled condenser is generally used in central air conditioning plant. But some small central air conditioning system using air cooled condenser. In water cooled condenser, cooling tower is required to cool the condensing water. The water cooled condenser are shell and tube type, shell and coil type and plate heat exchanger type.

Liquid receiver

Liquid receiver is fitted at the out let of the condenser. The function of liquid receiver is collect liquid refrigerant coming from condenser and supply to the expansion valve. Pump down process can done in liquid receiver.

Drier strainer

It is located in the liquid line to prevent moisture and dust particles.

Expansion valve

For reducing the pressure and amount of liquid refrigerant into the evaporator a refrigerant control device is located at the in let of the evaporator coil. The expansion valve

using in central air conditioning plants are thermostatic expansion valve, electronic expansion valve and float valve controls.

Evaporator

Evaporator coil is fitted at the outlet of the expansion valve. The evaporator coil are direct or indirect type.

Air Handling Unit (AHU)

AHU is the part of central air conditioning plant. It consists of air filter, blower, cooling coil inlet and outlet air flow.

Ducts

Ducts are used to carry air from one place to another place. The different ducts in air conditioning systems are supply duct, return ducted fresh air duct.

Electrical parts

The main electrical parts used in central air conditioning plant are as follows:

- 1 Motor 3 phase for operating compressor
- 2 Motor for cooling tower fan
- 3 Motor condenser water pump
- 4 Motor for blower
- 5 Low pressure cut out
- 6 High pressure cut out
- 7 Oil pressure cut out
- 8 Crank cast oil heater
- 9 Thermostat switch
- 10 Solenoid valve
- 11 Starter for motor
- 12 Over load protector
- 13 Single phase preventer

Central / Industrial airconditioning system

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

- describe about air conditioning system & central airconditioning
- air conditioning principle
- types of A.C. system, chiller
- describe about AHU, humidification, & de-humidification
- air washer.

Central air conditioning system & industrial air conditioning system is large plant & machineries. It is different than

domestic freezer and air conditioner. As though the principle & working are similar to the small plant. Basically

the plant room is separate, normally it is in basement or ground floor of the multistoried building. All the major components like compressor, condenser, chiller, water pumps, and controlling devices installed at plant room except the air handling unit & cooling towers. A.H.V. placed in every floor of the buildings in suitable position. The chilled water through insulated pipe line circulated to A.H.V. by centrifugal pump.

In case of die system the refrigerant circulates directly to weather maker (AHU) through refrigerant control from the liquid line of condenser.

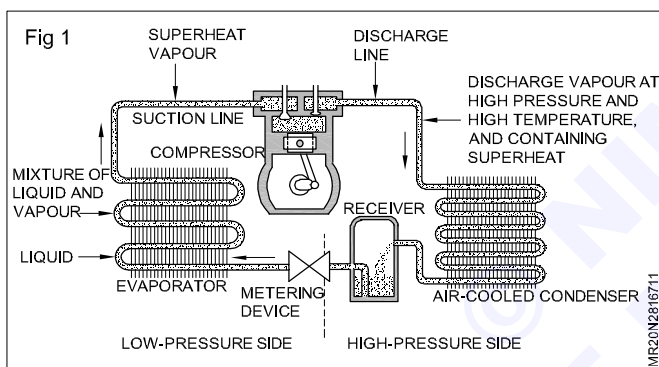
The chilled air circulated from air handler to conditioned space through insulated air duct.

The cooling tower generally provides at the roof or any open airy space. The pipe line provides from condenser to cooling tower to circulate the water.

Central / Industrial A.C. system

What is airconditioning? (Fig 1)

Air conditioning is defined as a process which cools (or heats), cleans, circulates, freshens air and controls its moisture content simultaneously.



Most often airconditioning is about removing heat. Now that we have defined airconditioning let us get us know the nature of 'Heat'. There are two types of 'Heat': Sensible Heat and Latent Heat.

'Sensible Heat' is any heat that raises the temperature but not the moisture content of the substance. This is our regular and familiar every day heat. Because it raises the temperature it can be detected by the senses, and this in fact, is why it is called Sensible Heat.

'Latent Heat' is the tricky one. When we talk of Latent Heat we mean 'Latent Heat of Vaporisation'. It is that heat required to transform a liquid to vapour. Take water for example. Water can be heated to its boiling point of 100 °C. If more heat is added at this point the temperature of the water does not increase. The water continues to boil and becomes steam. So where does all the heat go? Well, the heat goes into changing the water into steam. The latent heat of vaporisation in this instance is the heat required to change water from liquid at 100 °C to vapour at the same temperature.

Latent heat plays an important part in refrigeration and air conditioning. It explains the principle of refrigeration and also is a component of Heat Load, of which we will learn

more along the way. Human beings generate latent heat by way of moisture (perspiration) on their skin. The perspiration requires to be dried, therefore a change of its state from liquid to vapour is required. Fresh air which is added into the air system, very often brings in plenty of moisture with it. Removal of this additional moisture also involves latent heat removal.

A portion of the airconditioning heat load is therefore in the form of latent heat. For example in an office 10% of the airconditioning heat load could be in the form of latent heat. This goes up to around 25% in a restaurant and around 33% in a movie theatre.

How is cooling made possible?

Now that we have discussed "Heat" let us talk about the principle at work in airconditioning. The core concept to understand is Evaporation. Remember how could you skin felt when dabbed by liquid spirit at a doctor's clinic before an injection? It felt could because the spirit evaporated (changed from liquid state to the vapour state) very rapidly. And when it evaporated it needed heat to change its state. Where did this heat come from? It came from the liquid itself, and your skin, with which it was in contact.

In the refrigeration cycle this principle is put to work by causing a liquid Refrigerant* to evaporate in a cooling coil (evaporator). This refrigerant is a specially chosen substance which has the property of evaporation at a very low temperatures. (For example, the commonly used refrigerant, R-22, would start evaporating at *40 °C even under normal atmospheric pressure). The cooling coil, in which the refrigerant evaporates, is in contact with the air (or water in chilled water systems) surrounding it, thereby cooling that as well. Once this air (or water) is then directed to the spaces which require cooling.

A refrigerant is a gas with special characteristics that make it suitable for Refrigeration. It is possible to liquefy it even in ambient temperatures when the pressure is raised. R-22 is the most commonly used refrigerant in airconditioning. Recent studies indicate that Refrigerants when leaked into the atmosphere cause damage to the ozone layer. By international consensus today's refrigerants may be replaced by new ozone friendly refrigerants over the next three or four decades.

Equipment used to produce cooling

Now that we have seen the process by which cooling takes places, and examined the nature of heat and humidity, let us briefly look at the main equipment used to produce the effects we require.

The compressor: Under atmospheric temperature and pressure the refrigerant is in gaseous form. We learnt that cooling takes places when liquids evaporate to become gas. Therefore we must first transform the refrigerant gas into liquid form. Most gases can be made into the liquid form by raising its pressure (and cooling it, which is handled by the condenser). The equipment that increases the pressure of the gas by compressing it, is called the Compressor.

The condenser: During compression however the refrigerant becomes hot. This is because of two reasons:

- Because of the work done on it (remember how warm the hand pump became when pumping air into your bicycle tyres?) and
- Because the refrigerant is converted from gas to liquid releasing its latent heat.

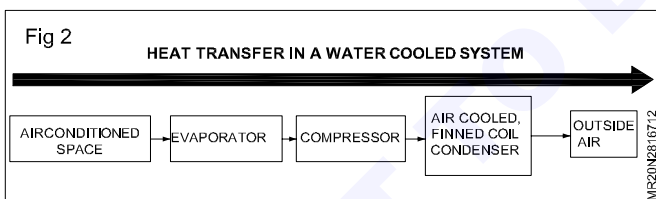
This heat has to be removed to enable the gas to condense into a liquid easily. The equipment that removes the heat is called the Condenser.

The evaporator ('Cooling Coil' to most of us): From the condenser we now have the liquid refrigerant ready to go to work. This refrigerant can remove heat from the space when it starts evaporating. The liquid refrigerant from the condenser is injected through a metering device* called the capillary or expansion valve into the cooling coil which is bundle of tubes.

Inside the cooling coil the pressure is low because of the metering / throttling device on one side and the compressor suction on the other side. In the low pressure, the liquid refrigerant starts evaporating rapidly. While evaporating needs sensible heat to transform itself from the liquid to the gas state. So it soaks up heat from the surrounding tubes, and from the air, with which the tubes are in contact. This is what causes the cooling. (Fig 2)

End of cycle and beginning of the next one: Having done this, the refrigerant is back into the gaseous form. It is sucked into the compressor where it will be compressor again for the next refrigeration cycle.

In the water cooled systems, the heat from the conditioned area is transferred to the cold refrigerant warming it up. This warm refrigerant transfers the heat to water in the Water Cooled Condenser thereby warming the water. This warm water in turn transfers the heat to the atmosphere through the cooling tower.



Types of airconditioning systems

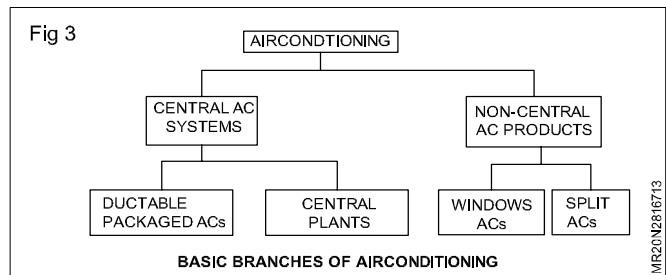
Over the years, Airconditioning Systems have evolved to suit different needs. The emergence of new technologies, environmental conditions and the availability of space have all played a part in shaping the airconditioning systems of today. Though many types of airconditioning systems are available it is convenient to first classify them broadly as follows:

Basic branches of airconditioning (Fig 3)

The basic branches of airconditioning are Central AC systems and Non-Central AC products. Central AC systems can then be divided into Ductable Packaged Airconditioners and Central Plants, while Non-Central AC

products can be divided into Window ACs and Split ACs. Further subdivisions appear in subsequent pages.

Airconditioning falls into two broad segments.



Central AC systems and non-central AC products

By Non-Central AC Products we mean those airconditioners that do not use any air ducting to cool the conditioned space. Window mounted 'Room Airconditioners' and the 'Non-Ducted Split Airconditioners' fall into this category. These products are suitable where air throw is limited to around 4 metres (13 feet) and small spaces are involved. Where large spaces are involved, multiple units are used to distribute the air.

Alternatively in order to distribute the air uniformly using less units, **Central AC systems** are preferred.

Central AC systems can be further subdivided into **Ductable Packaged Airconditioners** and **Central Plants**. The term 'Ductable' implies an airconditioning system suitable for ducting. The design engineers may prefer to minimise ducting by employing Fan Coil Units instead.

Humidification and Dehumidification method

AHU & FCU.

Always wear goggles, rubber gloves and safety shoes, when you are working on acid circulation while de-scaling.

In air-washer the sediments and dust may be collected at the bottom of the basin. After de-scaling the pipes, nozzles, drain the water fully, then scrape the bottom of the basin with G.I. sheets, gather the dust and sediments, remove from there, clean the basin thoroughly with wire brush and put bleaching powder and wash with fresh water.

The arrangement of AHU in air-conditioning plant

The Air-Handling Unit is a centrifugal type blower or the fan is usually located in the air-handler / chilled water coil cabinet. Its purpose is to create a pressure differential, so that the air from the conditioned space is drawn to the unit.

The air is passed through filter first, to remove dust particles and then over the cooling coils or chilled water tubes, where the heat is rejected. The cooled and dehumidified air is, then drawn in to the suction side of the fan and discharged. In the suction side of the AHU is kept a little open to draw in fresh air.

The joints of the panels and sections are well gasketed and bolted. The equipment has leveled as to ensure free flow of condensate water from the cooling coil tray to fan section tray and the drain points.

The drain line, being connected to the fan section tray, is on suction side of the fan and so the surrounding air gets sucked in through the drain pipe along with the outside foul smells.

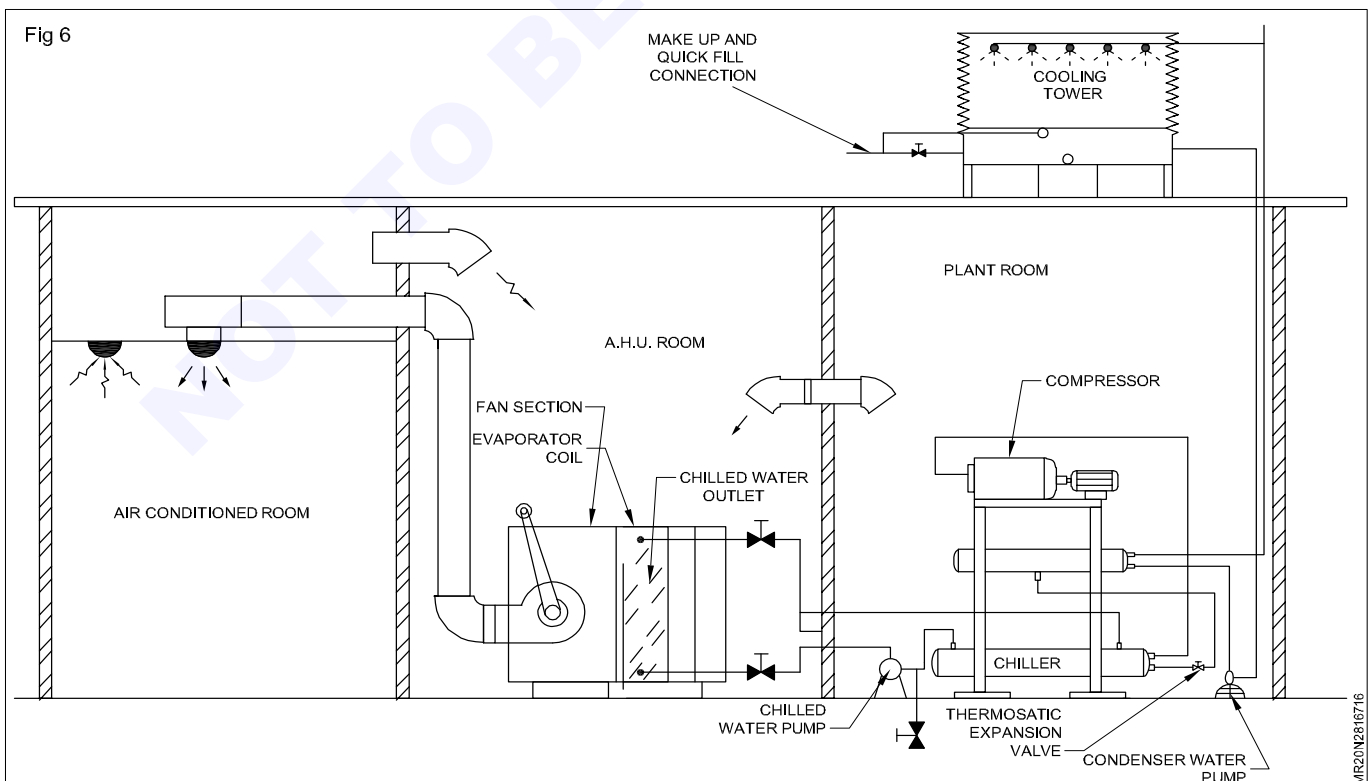
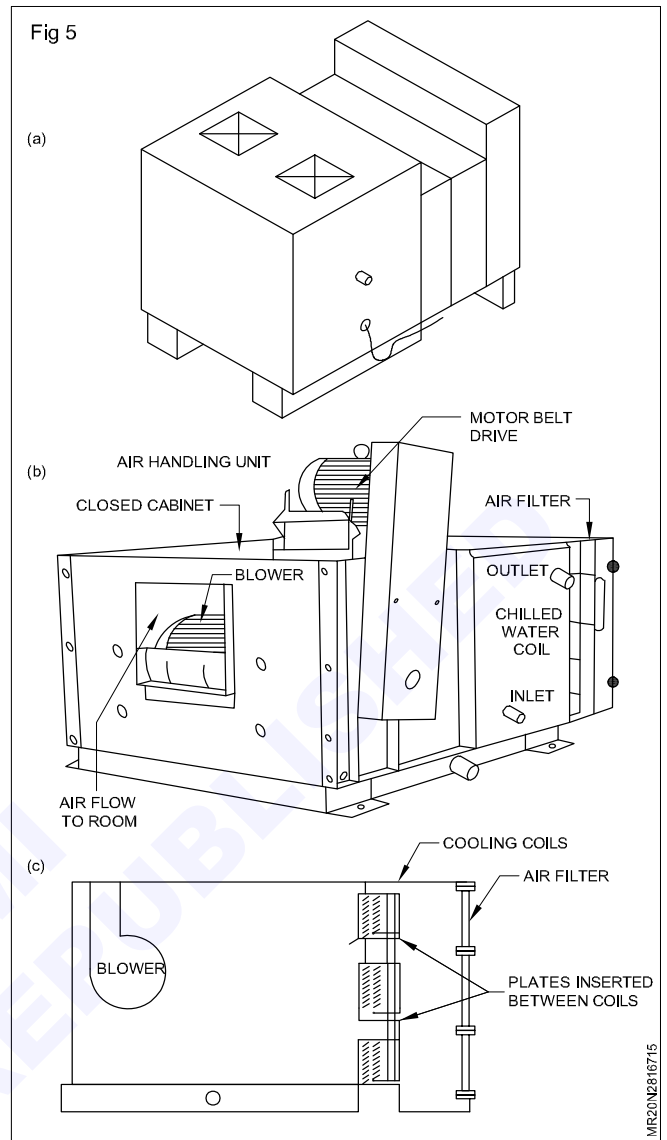
It will prevent the free flow of the condensate water to drain also. To avoid this provided a 'U' trap in the condensate drain line. The height of the 'U' trap should be more than the negative pressure, create, by the fan in the fan chamber.

The gap between the coil ends and coil section panel are blocked and formed as a sealed cabinet. If not a lot of return air-will by-pass the cooling coil, effecting the capacity of the plant. Fig 1a,b,c.

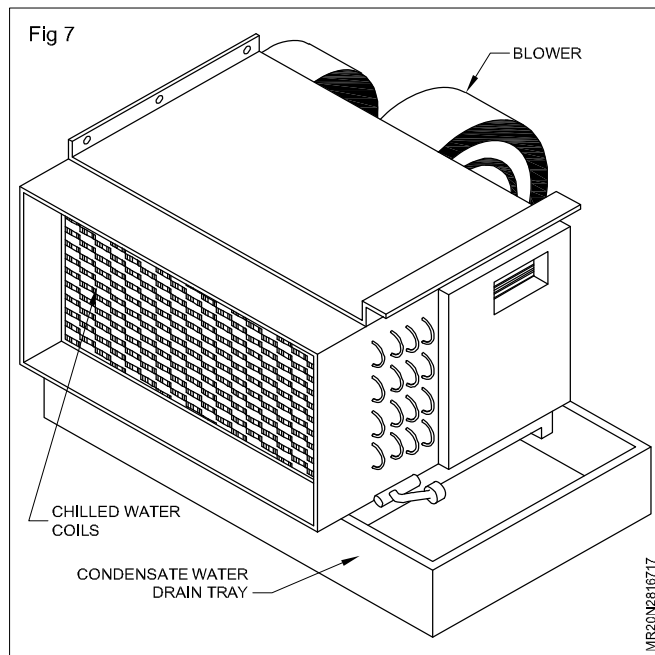
In case of there is two or more section of cooling coil, on the vertical plans, a thin galvanized from (G.I.) plates between the coil sections will be provided. This arrangement will avoid the top coils dust with condensate water blocking the down coil, and each plate will have separate drain linked to the common drain point.

A flexible canvass connection will be provided between the AHU fan outlet and the supply duct to prevent transmission of vibration from the AHU to ducts. The AHU connected with the plant arrangement. Fig 2.

Fan Coil Units: The Fan Coil Unit (FCU) is a sheet metal cabinet. the houses a chilled water coil, a blower with motor and an air filter. These are generally used, where multiply storeys buildings of cold storage plants, or multiple storeys buildings of cold storage plants, or multiple area like big Hotel's rooms are to be cooled independently using central air conditioning plant. Fig 3.



The water is chilled centrally and pumped to various parts of the buildings through insulated pipes. The chilled water enters to FCU, Where heat exchange takes place between the room air and the chilled water in the coil. Air is forced by the blower, passed over the coils. The air speed can be controlled by the closing the fan speed by selected switch.



The thermostat controls the solenoid valve that closes the chilled water flow, when the room attains the desired temperatures while the temperatures raises it allows the chilled water into the coil.

Air-washer's applications in air-conditioning plant

Air-washers are similar to AHU, but the main difference is the chilled water will be sprayed through nozzles in a closed chamber and the air passes through get cooled. Heat transferring will be more faster, when compare to AHU. These chilled water sprays finds principles application in industrial process, assembly halls, theatres and sports arenas, where large flow rates or air are required.

For the comfort cooling purpose the eliminators avoid the water carry over with the cooled air, and the heating coils (steam) de-humidify the air according to our need.

Industrial air-conditioning system using air-washer.

Descaling in AHU

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

- necessity of descaling
- descaling in AHU.

Necessity of de-scaling in chilled water coil: As the chilled water passes through the coils, the chemicals mixed with the chilled water and the tendency of water forms as a coating or sediments inside the coils. These will reduce the heat transferring efficiency of the cooling coil, and it results poor cooling effect, so it is necessary to do, de-scaling into the chilled water coils periodically.

It is safest to use prepared chemicals from a good company, carefully balanced cleaners, such as inhibited muriatic acid or diluted hydrochloric acid, do good job without damage to the cooling coil. After cleaning it should be rinsed thoroughly.

Descaling in AHU & Air-washers: the de-scaling of chilled water coils in AHU or Air-washer can be cleaned by forced circulation system. The pump is designed for acid circulation, the barrel or container which used is made of acid-resisting materials and the pipe lines are PVC materials.

The arrangement of acid circulation AHU is shown in Fig 1.

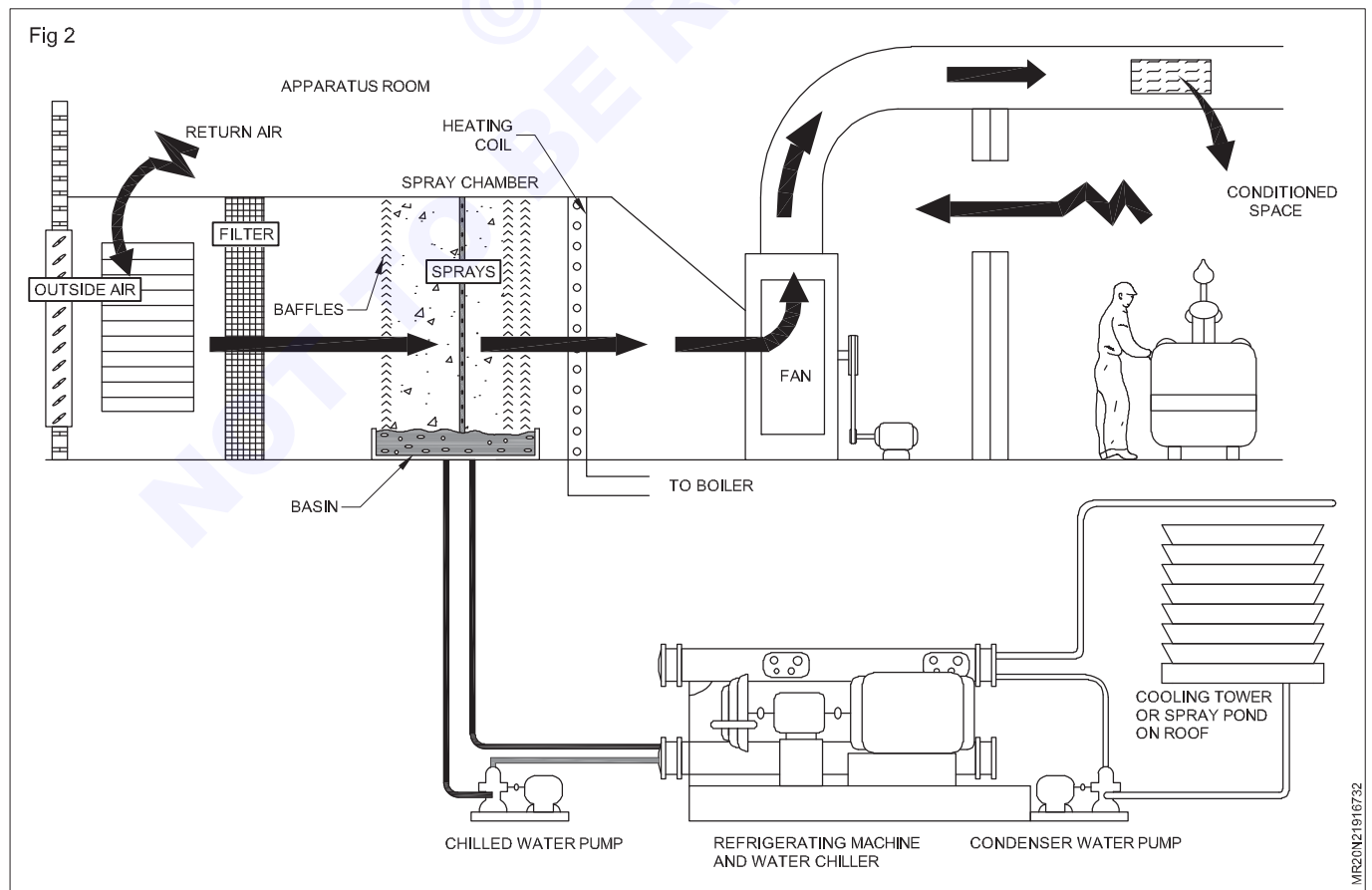
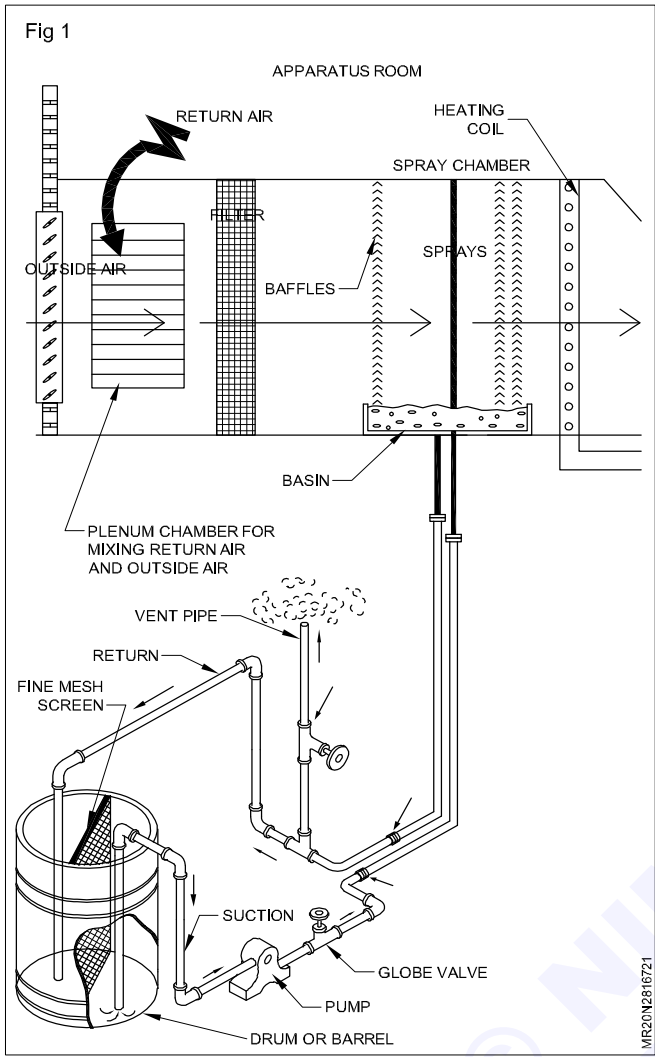
The arrangement of acid circulation method of descaling at air-washer is shown in Fig 2. It is important to check after de-scaling and rinsing the coil hence some particles of acid solution may be stuck in between the coils. If may cause any chemical reaction and simulate corrosive actions to the coils.

So the final rinsing water should take for sample and test with litmus paper. The sample water pH, should be 7 to 7.5, till that result, the coils has to be rinsed repeatedly.

Always wear goggles, rubber gloves and safety shoes, when you are working on acid circulation while de-scaling.

In air-washer the sediments and dust amy be collected at the bottom of the basin. After de-scaling the pipes, nozzles, drain the water fully, then scrape the bottom of the basin with G.I. Sheets, gather the dust and sediments, remove from there, clean the basin thoroughly with wire brush and put bleaching powder and wash with fresh water.

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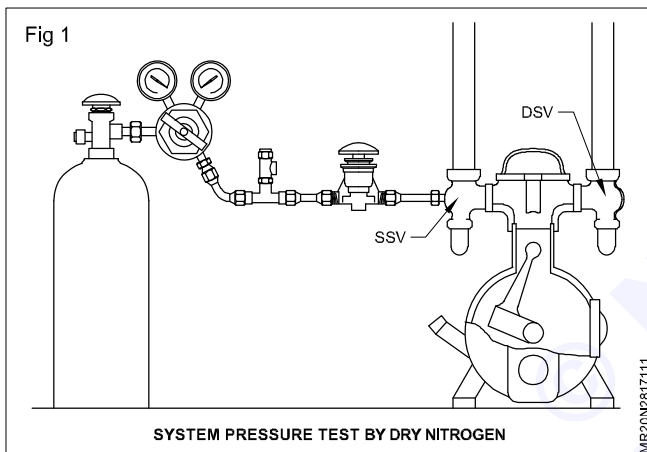
Pump down, Pressure test, Leak arrest

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

- pump down the unit and pressure test with dry nitrogen
- trace the leak and arrest the leak.

Pump down the unit and pressure test with dry nitrogen (Fig 1)

- Pump down the system and recover the refrigerant in the cylinders or in the standby receiver.
- Remove any controls or relief valves in the system, which could get damage while pressurizing the unit.
- Connect the dry nitrogen cylinder with pressure regulating valve to compressor Suction Service Valves (SSV) port. (Check the nitrogen cylinder is having cylinder pressure gauge and regulator pressure gauge)



- Keep the Suction Service Valve (SSV) in back seat crack position and (DSV) Discharge Service Valve in back seat (open) position. Then open the nitrogen cylinder valve slowly and set the recommended (50% of) pressure.

- Leave the nitrogen to enter in the system gradually till the suction line pressure gauge shows the required pressure (10 kg/cm² approx.)
- Keep the liquid line shut off valve fully open and reset the pressure reducing valve at nitrogen cylinder up to the 100% of recommended pressure (20kg/cm² Approx.)

Trace the leak and arrest the leak

- Close the nitrogen cylinder valve and isolate the cylinder.
- Apply the soap solution by brush on the possible joints (screw, flanges, brazing) and all the gauge connecting joints, carefully observe if there is any leak, and mark the correct spot.
- Release the nitrogen pressure inside the system slowly to atmosphere.
- Arrest the leaks with suitable methods.
- Again pressurize the system and hold it for 24hrs. and check is there any pressure drop.
- 6 Finally release the pressure in the system through, service valve gauge port, to atmosphere slowly. Assure the machine room is well ventilated.

(Caution: No attempt should be made to repair the leaks, while the system is under pressure).

Evacuate, Charge or topup the gas

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

- evacuate and charge the gas & top up the gas
- check up the condition of the unit after charge of gas.

- Close the nitrogen cylinder valve and isolate the cylinder.
- Apply the soap solution by brush on the possible joints (screw, flanges, brazing) and all the gauge connecting joints, carefully observe if there is any leak, and mark the correct spot.
- Release the nitrogen pressure inside the system slowly to atmosphere.
- Arrest the leaks with suitable methods.
- Again pressurize the system and hold it for 24hrs. and check is there any pressure drop.

- Finally release the pressure in the system through, service valve gauge port, to atmosphere slowly. Assure the machine room is well ventilated.

(Caution: No attempt should be made to repair the leaks, while the system is under pressure).

- Re-connect all the controls and relief valves.
- Connect the vacuum pump to the suction service valve.
- Check that all the systems cycle, valves are open and the solenoids are also open.

- Run the vacuum pump around 12 hours and check the reading in the compound gauge. If it reaches to the recommended vacuum pressure (760 mm of Hg approx.) close the charging hose hand shut off valve, allow the system to stand under vacuum for 24 hours, after stop the vacuum pump.
- Check the vacuum reading, confirm there is no leak in the system.
- Disconnect the vacuum pump and charging line after back seat the suction service valve.
- Connect a drier with the charging line to recovered gas in cylinder, purge the line before connecting to suction service valve.
- Check up all the parameters, safety devices to the system properly, keep compressor oil level perfect,
- Check the fan, motor bearings, supply water line to condenser, lubricate the pumps, and other normal maintenance checkups.
- Slowly open the cylinder valve and back seat crack the suction service valve.
- Keep the gas cylinder in slanting position and allow the liquid refrigerant to charge in the system.
- Continue charging till the gas rushing into system (feed the charging line) when the flow reduce, lift the cylinder carefully upside down.
- After complete idle charging close the cylinder valve, lift the cylinder make it to stand in normal position as the valve side up.
- Start the compressor and record the pressure & temperature.
- If the recovered gas is not sufficient to get the required evaporative temperature and suction pressure, connect a new cylinder and top up only gas (not liquid) to the required amount.
- After complete charge, close the charging line valve, cylinder valve disconnect and cover with valve cap. Close the service port also with the seal cap.
- Check and record suction and discharge pressure.
- Check the AC plant evaporator temperature and record it.

Record sheet

Table 1
Air conditioning plant

Capacity	Type of condenser	Type of evaporator	Details of Humidifier (if any)

Vacuum pulled up to =

Vacuum remains after 12 hrs =

Table 2

	Suction Pressure	Discharge Pressure	Evaporator Temperature	Relative Humidity
Initial reading before pump down				
Final reading after gas charge				

Gas leak arrested details :

Remarks:

Instructor:

Trainee:

Pressure test, oil change evacuation & gas charge in central A.C. system (DX Direct Expansion system)

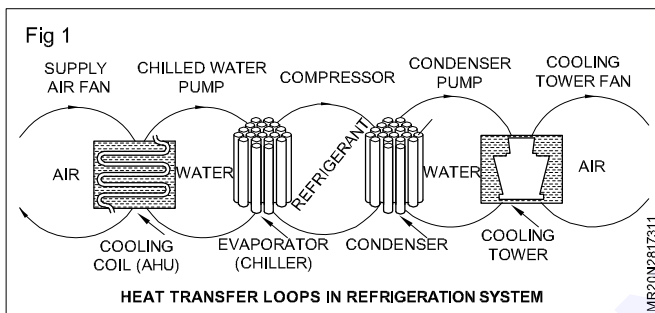
Objectives : At the end of this lesson you shall be able to

- describe about DX system, chiller system & other system
- top up of oil & gas in central A.C. system
- operation maintenance & trouble shooting of control A.C. system included preventive maintenance.

Refrigeration deals with the transfer of heat from a low temperature level at heat source to a high temperature level at the heat sink by using a low boiling refrigerant.

There are several heat transfer loops in refrigeration system as described below:

In the Fig 1 thermal energy moves from left to right as it is extracted from the space and expelled into the outdoors through five loops of heat transfer.



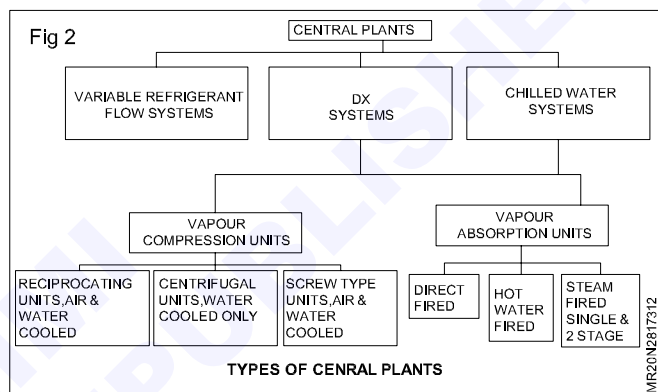
- Indoor air loop. In the leftmost loop, indoor air is driven by the supply air fan through a cooling coil, where it transfers its heat to chilled water. The cool air then cools the building space.
- Chilled water loop. Driven by the chilled water pump, water returns from the cooling coil to the chiller's evaporator to be re-cooled.
- Refrigerant loop. Using a phase-change refrigerant, the chiller's compressor pumps heat from the chilled water to the condenser water.
- Condenser water loop. Water absorbs heat from the chiller's condenser, and the condenser water pump sends it to the cooling tower.
- Cooling tower loop. The cooling tower's fan drives air across an open flow of the hot condenser water, transferring the heat to the outdoors.

Central plants

Direct expansion, chilled water and VRF systems (Fig 2)

Central plants are usually large air conditioning plants assembled at the site. These plants are used for big buildings such as hotels, theatres, hospitals, large office complexes and factories. They are designed for accurate control of all the parameters of comfort. As the name implies the Central Plant is housed in a central location, usually in the plant room. This plant room could be in a basement or adjacent to the building to be airconditioned.

Though the Central Plant can look quite complex with large compressors, pumps, gauges, miles of piping, ducts and cables, the basic components are the same as smaller plants. Central Plants comprise compressors, condensers, Air-handling units, water chillers and cooling towers.



As we see in the tree diagram for Central Plants, the main divisions are those that use **Direct Expansion (DX)** and those that use **Chilled Water**. **Variable Refrigerant Flow** systems are a third revolutionary category of Central plants.

Direct expansion (DX) systems: In this system, air is cooled and conditioned in the plant room. This treated air is then circulates to various parts of the building. The air returning from the airconditioned area is sucked through a coil-fin arrangement by a fan. Refrigerant inside the coil picks up heat from this air and evaporates. The cold air then circulate back to the airconditioned space. In DX plants the space where this heat exchange takes place is called an Air Handling Unit (AHU). This type of system typically uses ducting passing through the structure to various parts of the building to be conditioned.

Chilled water system: Where refrigerant and water interaction takes place the system is called a chilled water system. The refrigerant in the shell (or tube, depending on the design) of a **shell & tube heat exchanger**, evaporates by picking up the heat from the water which is in the other portion of the heat exchanger. This chilled water is then circulated to various water-air heat exchangers called **Fan Coil Units/Air Handling Units**. The system is also preferred where multiple zones are to be cooled like a hotel or hospital.

Maintenance of Central AC

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

- various process of maintaining Central AC
- checking types of dampers
- checking air flow
- explain the important checks and starting procedures
- describe about the planned maintenance
- explain evaporating the plant at design efficiency.

Important checks and starting procedures

Pre start-up checks: Confirm that all fans are tight on shafts, rotate easily and turn in the correct direction. Check the alignment of all drive kits, and that pulleys etc. are light on shafts. Check belt's tension. Make sure that all bearings etc. are clean and properly lubricated. Use the control circuit current and verify the sequence of operation of all motor starters, controls and safety devices with reference to detailed wiring diagram.

Post start-up checks: Starting and running amperage of all motors, suction & discharge pressures / temperatures, oil pressure. Air-temperatures, chilled water temperature (if applicable) condenser air or water temperatures. Dry-bulb, wet-bulb temperatures of the ambient air and conditioned place. And abnormal noise or vibration, whether the conditioned, space is free from draughts or stagnant air pockets, stratification etc. all ancillary equipments and complete control circuits functioning correctly. Finally check the log sheets & remarks.

Log sheets: It is desirable that all main operating characteristic, pressure & temperatures to be recorded at set times. The information should be kept on well protected loose-leaf, log sheets or in bound books.

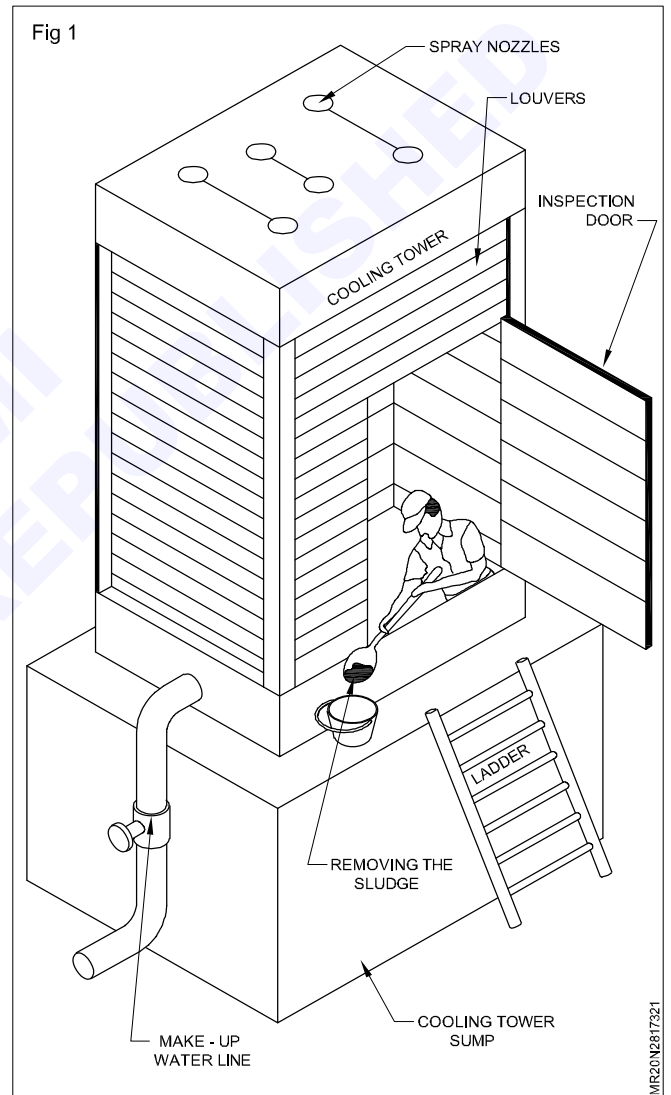
These should contain columns for time, switched 'on', time switched 'off' and progressive totals of hours run by each compressor or pump with stand-by/changeover facilities. A remarks column to record unusual events such as power failures, and action taken & normal maintenance. The sheet size and lay-out must be suitable to the equipment.

Starting procedure: Always follow the detailed instructions provided by equipment manufacturers or system designers. In general - start all motors manually in the correct sequence. Make certain that compressor suction & discharge, liquid line valves are opened, then start the compressor. Start the cooling tower fans and circulating water pumps before starting the compressor. Test the operating and safety controls in condensing unit after starting the compressor. Check evaporator fans & any accessories, air side operating and safety controls. Check and balance systems operating pressure & temperature, check the operating of all operating safety controls.

Planned maintenance (Fig 1)

Daily: Check that all equipments are free from noise and vibration. Check operational suction discharge and all pressure, check the air-water, refrigerants temperature whenever possible.

Weekly: Check the liquid line sight glass, check/clean/replace air-filters if necessary. Check condensate drums are free from blockage, check running amperage of all most motors. Check if the condensing temperature, inlet & outlet are normal.



Monthly: Lubricate the fan and motor bearings as necessary. (Follow the manufacturer's lubricant specification and bearing - care instruction). Check all belts for condition tension and alignment. Tighten all fan sheaves and pulleys if it is loose; check the conditions of the cooling tower sump's strainer screens, clean all water filters, refrigerant liquid line strainers. Check the condition of the duct work and test balancing, service electrical contacts of starters and controls.

Quarterly: Check water cooled condensers for levels of chemical treatment, of the condensing temperature is

high check, if it need de-scaling. If the heat exchangers provided with fins check the surface for freedom from blockages. Lubricate the fans and bearings as necessary, leak test refrigeration system. Inspect humidifiers if necessary clean the sensors of the thermostat.

Yearly: Examine all motors/fans/shaft bearings. Clean all water strainers drain, clean & repair cooling tower, clean or replace spray nozzles, while cooling tower maintenance. Remove the sludge gathered inside the cooling tower sump Fig. 1. Cooling tower & condenser water lines surfaces exposed to sun should be cleaned and painted, check all operating all safety controls for correct setting &

operation. Maintain a schedule maintenance board and tick the works completed with date.

Operating plant at design efficiency: If we are not given proper attention, it may lead to faulty operation, in results in the long run any major problem may occur and it works out to be quite costly, for example, a partially clogged water filter or cooling tower spray nozzles increase the discharge pressure of the compressor, contributing to increased power consumption for much less cooling effect.

As an example increase of a 15 TR plant is given in table below:

Condition	Suction Temperature in °C	Condensing Temperature in °C	Ton of Refrigeration	BHP	Percentage reduction in capacity	Percentage increased in BHP
Normal	7.2	40.6	17	0.93	-	-
High condensing pressure	7.2	46.1	15.6	1.12	8.2	20

Hence we have generalised the important of preventive maintenance & service.

- 1 Maintain an effective planned schedule to keep the heat transfer surfaces, air filtering and air-handling equipments clean, free of dust, scale and corrosion.
- 2 Lubrication of moving parts at the right time, with quality and correct quantity of lubricants.
- 3 Checking operation of safety and operating controls periodically.

- 4 Periodical checking of the system for refrigerant leak.
- 5 Check for abnormal vibration and noise.
- 6 Maintenance of a properly recorded log of readings of the plant.
- 7 It is important to carry out seasonal, periodical, overhaul of components as recommended by manufacturer.

Preventive maintenance of central A.C. plant

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

- explain preventive maintenance.

Preventive maintenance

In central air-conditioning plant needs maintenance. Preventive maintenance and service assume greater importance to improve the efficiency of the system and prevent damage. In energy crises and material shortage, proper and timely preventive service can result in a considerable amount of savings in power and material. Good maintenance and service is only possible if the plant is properly erected and commissioned. The preventive maintenance can help in three ways.

- 1 To anticipate faults
- 2 To improve efficiency
- 3 To save energy

The preventive maintenance schedule as follows:

- 1 For improve system performance and decrease power consumption, clean the air filter, clean AHU, lubricate blower motor.
- 2 Check the operation of safety controls periodically.

- 3 Check the refrigerant leak, maintain properly.
- 4 Check vibration and rectify vibration.
- 5 Maintain log back properly.

Reasons for increase in discharge pressure

- 1 Fouling of tubes in water cooled condenser.
- 2 Scale formation in condenser water tubes.
- 3 Pressure of non-condensable in the system.
- 4 Overcharge of refrigerant in the system.

Preventive steps for increase of discharge pressure

- 1 De scale condenser water tubes periodically.
- 2 Clean the cooling tower.
- 3 Purge the non-condensable gases.
- 4 Remove excess refrigerant.

Reasons for suction pressure reduction

- 1 Fouling of the evaporator surface

- 2 Wrong adjustment of throttling devices.
- 3 Reduction of air quantity over cooling coils.
- 4 Clogging suction filters of high capacity compressors.
- 5 Shortage of refrigerant.
- 6 Clogged liquid line strainers.

Preventive steps for reduction in suction pressure

- 1 Clean the cooling coil periodically.
- 2 Adjust the throttling device correctly.
- 3 Check the damper position, if it is open the plant will have a low suction pressure and will not deliver full capacity when it is required. Therefore, there dampers should be checked for proper fixture and free movement.
- 4 Clean suction filter.
- 5 Check the leakage, rectify leak, add refrigerant.
- 6 Clean liquid line strainer.

Three-way valves (Fig 1): These are traditionally used in constant-flow pumping system, where the unused water is bypassed at the coil. They are also used in variable-flow pumping systems. In special cases, several may be installed at the end of the longest piping runs. The sum of their flow equals the minimum flow the pump can produce in stably. This also allows the piping system to stay at the temperature set point in case another air handler requires immediate chilled or heating water.

Introduction 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. The adjustment handle which helps the opening and closing of the damper. 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.

Three types of duct air-flow controls are:

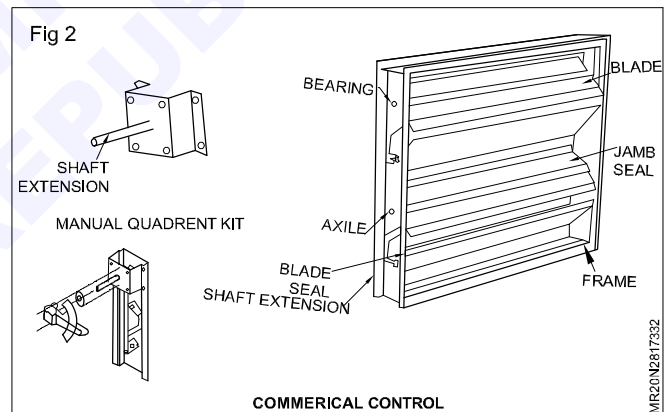
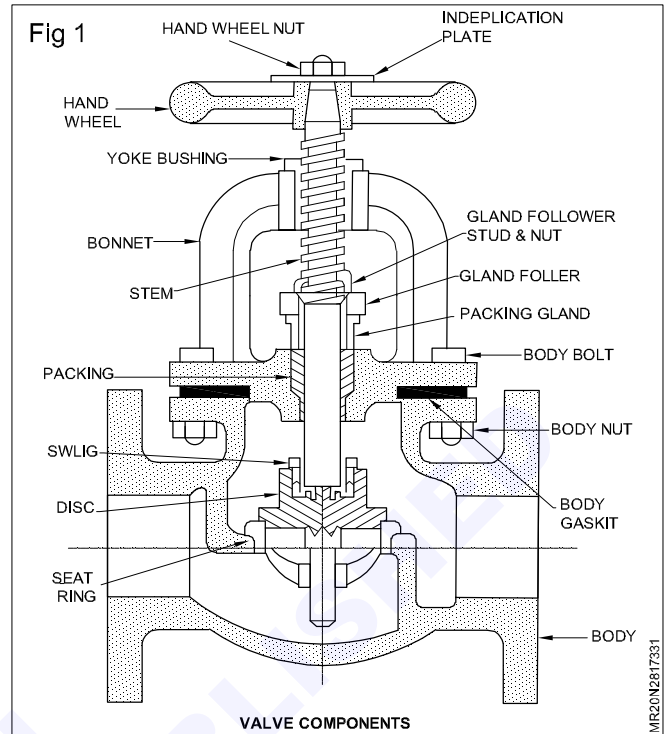
- 1 Butterfly damper
- 2 Multiple vane damper
- 3 Splitter damper

Commercial control (Fig 2)

Commercial control dampers regulate the flow of air in the same manner as manual balancing dampers, in addition, they can be used as a positive shutoff or for automatic control. There are three types of commercial control dampers available:

- Volume control - VCD series

- Insulated control - ICD series
- Air measuring control - AMD series



Variable symmetric blade design (VSB)

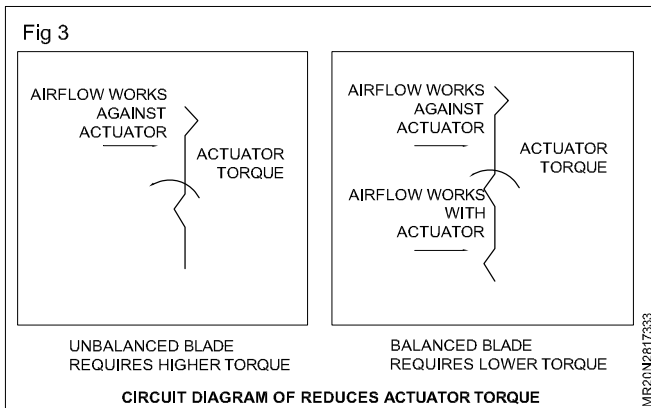
Variable Symmetric Blade design (VSB), uses two principles to increase damper performance. First, all damper blades are symmetric about their axis. Second, any combination of 4,5,6 and 7in. (102,127,152, and 178mm) blade widths are used in a single damper. These two features are part of standard construction and provide the following advantages.

Increase mounting flexibility: Symmetrical blades have identical operating characteristics regardless of airflow direction. This allows a control damper to be mounted in either direction of flow, an advantage when installing with space constraints.

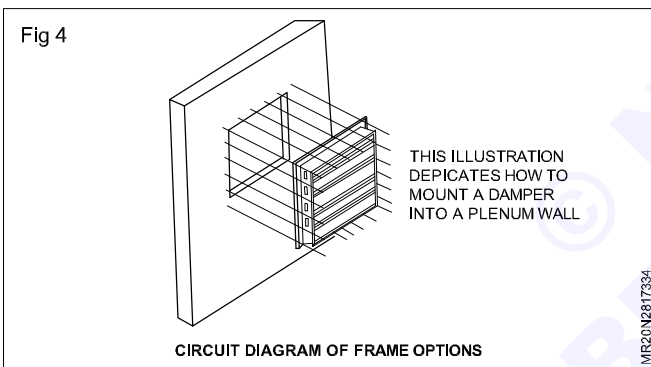
Increases free area: Traditional damper designs with a single blade width require oversized blade stops, limiting free area when the blades are open is able to reduce height or eliminate blade stops, which maximizes free area and increases damper performance.

Reduces actuator torque: If an unsymmetrical blade closes against air flow, a large amount of torque is needed

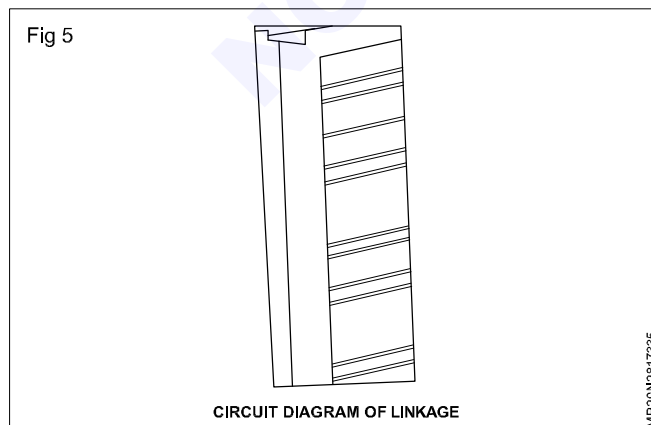
because the air distribution is unbalanced. VSB design balances airflow on each side of a symmetrical blade, reducing the torque required to operate the damper. The use of symmetrical blades allows to reduce the size and quantity of actuators used on dampers. (Fig 3)



Frame options: The channel frame style allows a damper to be insert mounted into an opening without being concerned about the linkage sticking out past the frame. The single and single flange frame can be insert mounted or directly mounted to the wall, mating surface or bulkhead. The quick connect frame design is extruded to match up to a TDC, TDF, or Duct mate connection to allow the damper to be cleared to the ductwork. (Fig 4)

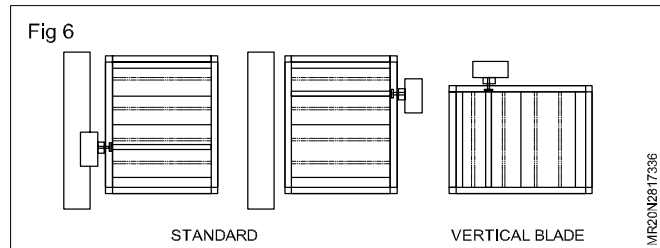


Linkage: Traditional damper linkages are found in the airstream, adding to the pressure drop of the damper blades and frame. Control dampers have blade linkages concealed in the frame to prevent additional pressure drop and unwanted noise. With standard plated steel construction (stainless steel optional), the linkage is engineered to accurately control each and very blade without need for adjustment. (Fig 5)



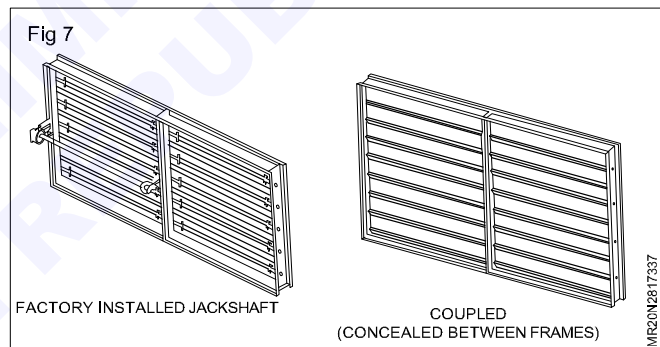
No top or bottom (Fig 6)

Standard control dampers are designed for installation in any position with the blades horizontal. The damper can be turned over so the actuator is on the left or right side. Optional vertical blade models can be turned with the actuator at the top or bottom.



Multi-section dampers (Fig 7)

Each of VCD control dampers have a maximum size for a single damper section or panel. These sections vary from 48 in. wide x 60 in. high (1219 mm x 1524mm) to 60 in. wide x 74 in. high (1524mm x 1880mm). Dampers larger than a single section will be made up of equal size sections which, depending upon model and size, may be shipped as a single complete assembly or as separate sections for field assembly. Multi-section damper assemblies are supplied with a coupler or factory installed jackshaft so all sections operate together.



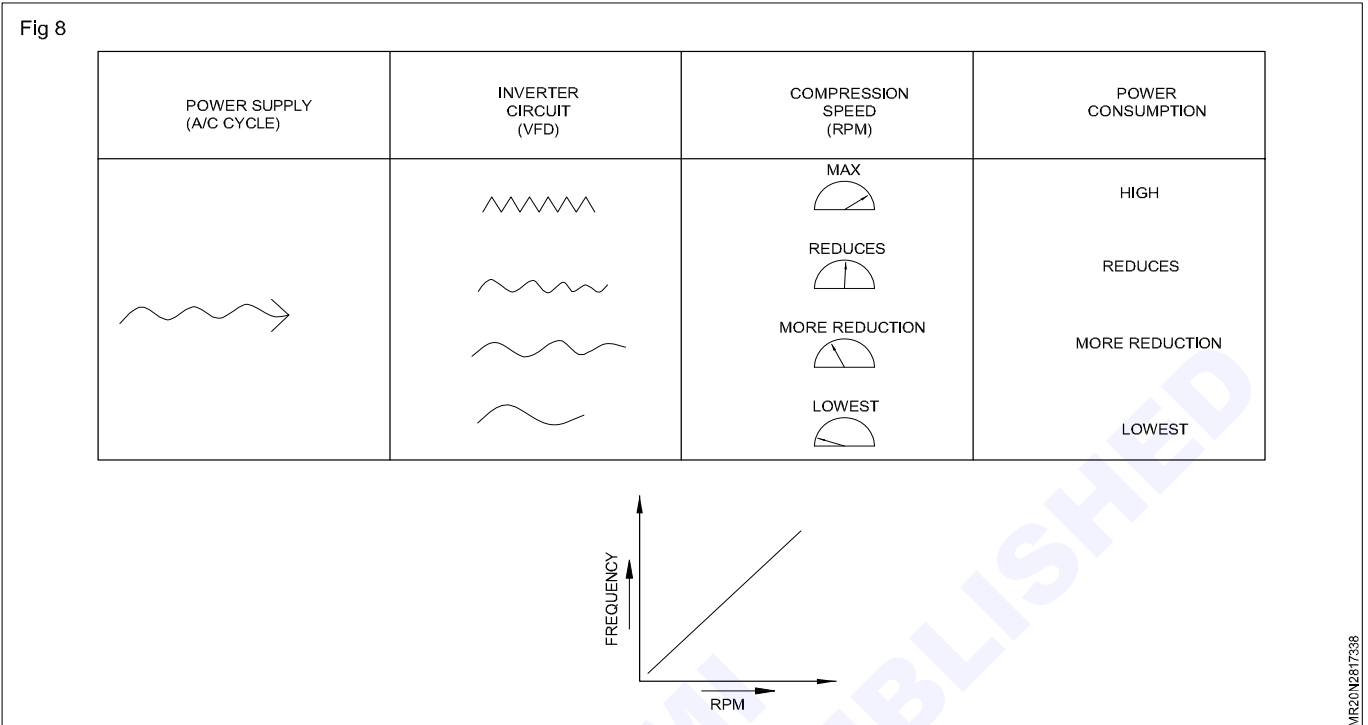
Accumulator: Accumulator is used installed in the function line of the system, so as to prevent the entry of liquid refrigerant into the compressor. When the liquid - vapour mixture fluids through the function line due to identify differentiate gets stored at the bottom of accumulator but vapour rises the 'U' loop invention line as shown in the fig. showing due to increase in temp during gets sucked by the compressor.

Inverter compressor (Fig 8)

Inverter compressor is the latest compressor type different from the old compressor and its main function is to control the rpm of compressor and volumetric ratio in respect to heat load of space. In this type of compressor, a VFD (Variable frequently drives) is used which can vary the frequency of input current of the compressor. The VFD gets signal through a communication cable (MPU-microprocessor unit) about the variation of load. And the variation of used is since by a transmitted in VFO gets the signal and these increases the frequency of A/C supply intern increases the rpm of compression and the opposite is also true. The normal frequency of India is 50 Hz and also decreases the frequency from 50-100 hz. Thus is this

process power consumption also varies. The same function is absent in the normal compressor. When the next load decreases too much, the compressor does not

cut off, but it continues power. In normal compressor after reaching the desired temperature compressor gets cut off desired temperature, compressor current during the starting of compressor.



In the refrigeration circle of VFV the lowest temperature and pressure liquid vapour mixture, returns from evaporator through suction line. And the liquid gets deposited at the bottom of the accumulator, whereas the vapour is sucked through the 'U-loop' into the compressor. The compressor compresses the refrigerant into high pressure and high temperature refrigerant and discharges it through discharge line, in this process lubricating oil gets out with the refrigerant. If the oil is not separated, it will choke the evaporator coil or EEV port. So, oil separators remain connected after discharge line. Which will separate the oil from refrigerant and send back it into the compressor. The high temp, high pressure refrigerant reaches the common condenser and reaches to the common condenser and condenser rejects its heat and turns the refrigerant. The refrigerant reaches the EEV (Electronic expansion valve) which remains connected to all the evaporators, which helps to vary the volume of refrigerant in the evaporators. A thermistor is there which continuously senses the heat load of spaces and sends signal to EEV

and MPU in the outdoor through communication cable. Thus, if load is more the EEV will open more to allow large volume of refrigerant to enter the evaporator coil and if load is low the EEV will open less and allow less volume of refrigerant to enter the evaporator coil. The thermistor senses the load of the space and sends signal to MPU in the ODU through communication cable. Again the MPU sends signal to VFD of the compressor thus varying the speed of the compressor as and when required. Each and every evaporator is connected with EEV and thermistors, accordingly to load in each and every evaporator EEV allows refrigerant to enter the individual evaporators and thus maintains the heat load of different spaces. So the name VRV/VRF. After reaching evaporators the evaporators evaporate the refrigerant taking heat from space and the vapour refrigerant moves through suction line to the compressor via accumulator.

Function of different parts according to Refrigerant Circuit of VRV/VRF

Objectives: At the end of this lesson you shall be able to
 • function of different parts according to refrigerant circuit.

Function of different parts according to Refrigerant Circuit (Fig 1)

In the earlier Exercise we have learned about the basic of VRV/VRF, their types and functions of their various types. In the practical situations there are many complex and

various parts are remaining in the VRV system. In this section we will try to learn the functions of various parts used in ODU of VRV/VRF system according to Refrigerant Circuit:

Outdoor Unit:

No. in piping diagram	Name	Major function
(1)	Inverter compressor	Inverter compressor is operated on frequencies between 52 Hz to 210 Hz by using the inverter.
(2)	Inverter fan	the fan is operated at step rotation speed by using the inverter.
(3)	Electronic expansion valve (Heat exchanger upper)	While in heating, PI control is applied to keep the outlet superheated degree of air heat exchanger constant.
(4)	Electronic expansion valve	PI control is applied to keep the outlet superheated degree (Sub cooling heat exchanger) of sub cooling heat exchanger constant.
(5)	Electronic expansion valve (Heat exchanger lower)	While in heating, PI control is applied to keep the outlet superheated degree of air heat exchanger constant.
(6)	Electronic expansion valve (Receiver gas purge)	Used to collect the refrigerant to receiver.
(7)	Electronic expansion valve (Refrigerant cooling)	Used to control the refrigerant amount to cool the diode bridge and power module of the inverter PCB.
(8)	Electronic expansion valve (Leak detection)	Used to detect refrigerant leakage.
(9)	Solenoid valve (OS oil return)	Used to return oil from the oil separator to the compressor.
(10)	Solenoid valve (Liquid shutoff)	Used to return oil from the accumulator to the compressor.
(11)	Four way valve (HP/LP gas)	Used to switch dual pressure gas pipe to high pressure or low pressure.
(12)	Four way valve (Heat exchanger lower)	Used to switch outdoor heat exchanger to evaporator or condenser.
(13)	Four way valve (Heat exchanger upper)	
(14)	High pressure sensor	Used to detect the high pressure.
(15)	Low pressure sensor	Used to detect the low pressure.
(16)	High pressure switch (For M1C)	This functions when pressure increases to stop operation and avoid high pressure increase in the fault operation.
(17)	Pressure regulating valve (Liquid pipe)	This is used when pressure increases, to prevent any damage on components caused by pressure increase in transport or storage.
(18)	Sub cooling heat exchanger	Apply sub cooling to liquid refrigerant.
(19)	Capillary tube	Used to return the refrigerating oil separated through the oil separator to the M1C compressor.

(20)	Thermistor (Outdoor air)	Used to detect outdoor air temperature, correct discharge pipe temperature and others.
(21)	Thermistor (M1C discharge)	Used to detect discharge pipe temperature.
(22)	Thermistor (Receiver inlet)	Used to detect liquid pipe temperature of receiver inlet.
(23)	Thermistor (Heat exchanger liquid upper)	This detects temperature of liquid pipe for air heat exchanger.
(24)	Thermistor (Heat exchanger liquid lower)	
(25)	Thermistor (Sub cooling gas)	Used to detect outdoor air temperature, correct discharge pipe temperature and others.
(26)	Thermistor (Sub cooling liquid)	This detects temperature of liquid pipe for sub cooling heat exchanger.
(27)	Thermistor	This detects temperature of gas pipe for air heat exchanger. (Heat exchanger gas upper)
(28)	Thermistor (Heat exchanger gas lower)	
(29)	Thermistor (Suction)	Used to detect suction pipe temperature.
(30)	Thermistor (Deicer)	Used to detect liquid pipe temperature of air heat exchanger. Used to make judgements on defrost operation.
(31)	Thermistor (Compressor suction)	Used to detect suction pipe temperature of compressor.
(32)	Thermistor (Receiver gas purge)	Used to detect gas pipe temperature of receiver gas purge piping.
(33)	Thermistor (M1C body)	Detects compressor surface temperature, this switch is activated at surface temperature of 120°C (248°F) or more to stop the compressor.
(34)	Thermistor (Leak detection)	The thermistor detects refrigerant leakage.

This refrigerant circuit showing system with two inverter compressors (Fig 2)

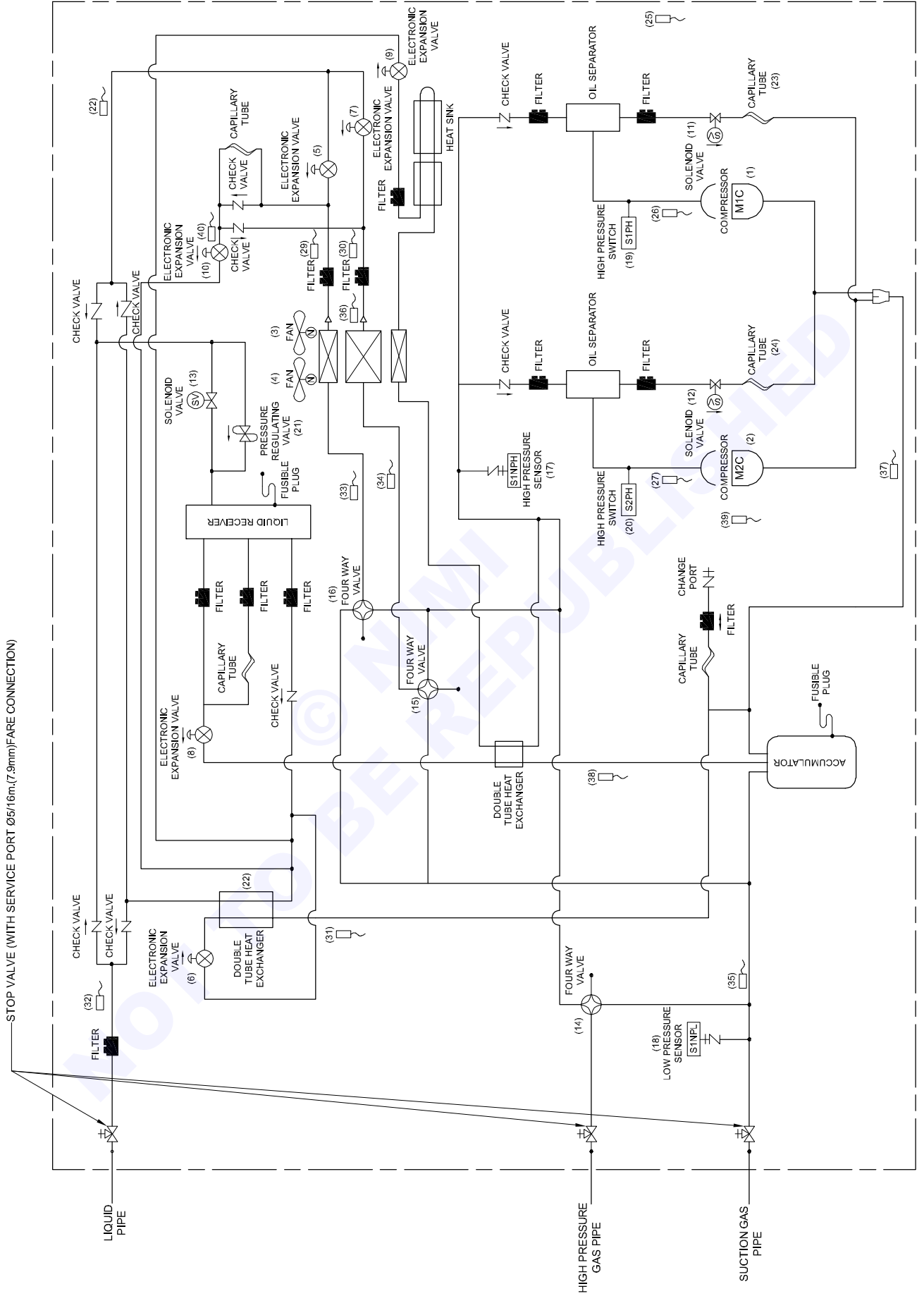
No. in piping diagram	Name	Major function
(1)	Inverter compressor	Inverter compressor is operated on frequencies between 52 Hz to 210 Hz by using the inverter. Compressor operation steps: Refer to page 66~
(2)	Inverter compressor	
(3) (4)	Inverter fan	Because the system is an air heat exchange type, the fan is operated at 9-step rotation speed by using the inverter.
(5)	Electronic expansion valve (Heat exchanger upper)	While in heating, PI control is applied to keep the outlet superheated degree of air heat exchanger constant.
(6)	Electronic expansion valve	PI control is applied to keep the outlet superheated degree (Sub cooling heat exchanger) of sub cooling heat exchanger constant.
(7)	Electronic expansion valve (Heat exchanger lower)	While in heating, PI control is applied to keep the outlet superheated degree of air heat exchanger constant.
(8)	Electronic expansion valve (Receiver gas purge)	Used to collect the refrigerant to receiver.
(9)	Electronic expansion valve (Refrigerant cooling)	Used to control the refrigerant amount to cool the diode bridge and power module of the inverter PCB.
(10)	Electronic expansion valve (Leak detection)	Used to detect refrigerant leakage.
(11)	Solenoid valve (OS oil return 1)	Used to return oil from the oil separator to the compressor (M1C).
(12)	Solenoid valve (OS oil return 2)	Used to return oil from the oil separator to the compressor (M2C).
(13)	Solenoid valve (Liquid shutoff)	Used to return oil from the accumulator to the compressor.
(14)	Four way valve (HP/LP gas) low pressure.	Used to switch dual pressure gas pipe to high pressure or low pressure.
(15)	Four way valve (Heat exchanger lower)	Used to switch outdoor heat exchanger to evaporator or condenser.
(16)	Four way valve (Heat exchanger upper)	
(17)	High pressure sensor	Used to detect the high pressure.
(18)	Low pressure sensor	Used to detect the low pressure.
(19)	High pressure switch (For M1C)	This functions when pressure increases to stop operation and avoid high pressure increase in the fault operation.
(20)	High pressure switch (For M2C)	
(21)	Pressure regulating valve (Liquid pipe)	This is used when pressure increases, to prevent any damage on components caused by pressure increase in transport or storage.
(22)	Sub cooling heat exchanger	Apply sub cooling to liquid refrigerant.
(23)	Capillary tube	Used to return the refrigerating oil separated through the oil separator to the M1C compressor.
(24)	Capillary tube	Used to return the refrigerating oil separated through the oil separator to the M2C compressor.
(25)	Thermistor (Outdoor air) pipe temperature and others.	Used to detect outdoor air temperature, correct discharge

(26)	Thermistor (M1C discharge)	Used to detect discharge pipe temperature.
(27)	Thermistor (M2C discharge)	
(28)	Thermistor (Receiver inlet)	Used to detect liquid pipe temperature of receiver inlet.
(29)	Thermistor (Heat exchanger liquid upper)	This detects temperature of liquid pipe for air heat exchanger.
(30)	Thermistor (Heat exchanger liquid lower)	
(31)	Thermistor (Sub cooling gas)	Used to detect gas pipe temperature on the evaporating side of subcooling heat exchanger. Used to Exercise: the constant control of superheated degree at the outlet of sub cooling heat exchanger.
(32)	Thermistor (Sub cooling liquid)	This detects temperature of liquid pipe for sub cooling heat exchanger.
(33)	Thermistor (Heat exchanger gas upper)	This detects temperature of gas pipe for air heat exchanger.
(34)	Thermistor (Heat exchanger gas lower)	
(35)	Thermistor (Suction)	Used to detect suction pipe temperature.
(36)	Thermistor (Deicer)	Used to detect liquid pipe temperature of air heat exchanger. Used to make judgements on defrost operation.
(37)	Thermistor (Compressor suction)	Used to detect suction pipe temperature of compressor.
(38)	Thermistor	Used to detect gas pipe temperature of receiver gas purge (Receiver gas purge) piping.
(39)	Thermistor (M2C body)	Detects compressor surface temperature, this switch is activated at surface temperature of 120°C (248°F) or more to stop the compressor. (144/168 class models only)
(40)	Thermistor (Leak detection)	The thermistor detects refrigerant leakage.

Indoor Unit (Fig 3 to 6)

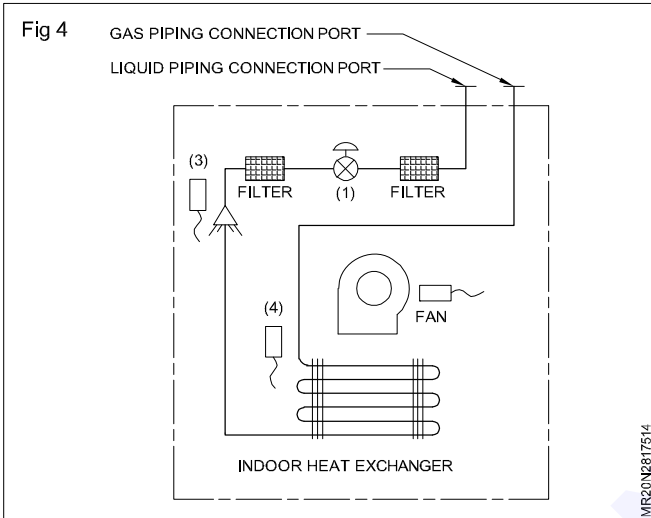
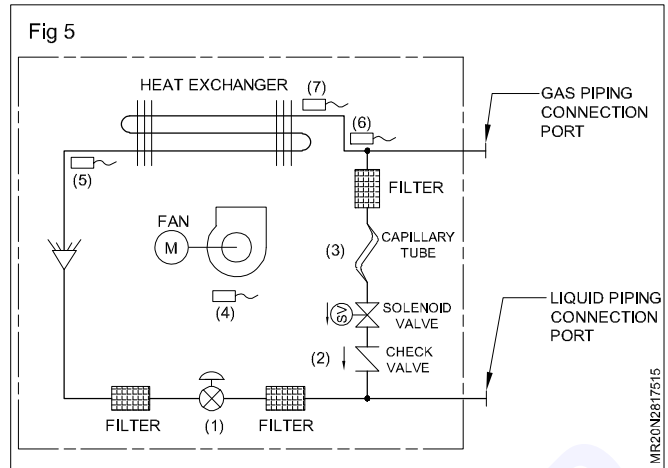
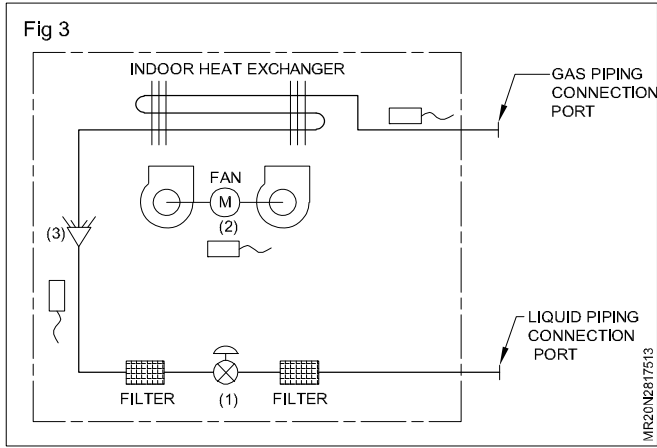
No. in piping diagram	Name	Function
(1)	Electronic expansion valve	Used for gas superheated degree control while in cooling or subcooled degree control while in heating.
(2)	Suction air thermistor	Used for thermostat control.
(3)	Liquid pipe thermistor	Used for gas superheated degree control while in cooling or subcooled degree control while in heating.
(4)	Gas pipe thermistor	Used for gas superheated degree control while in cooling.
(5)	Discharge air thermistor	Used for discharge air temperature control.

Fig 2



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Outdoor-Air Processing Unit



No. in piping diagram	Name	Function
(1)	Electronic expansion valve	Used to control the flow rate of refrigerant, and make the SH control (1) while in cooling.
(2)	Solenoid valve	Used to bypass hot gas while in heating with thermostat OFF. Closed while in cooling.
(3)	Capillary tube	Used to reduce pressure from high to low in bypassing hot gas.
(4)	Suction air thermistor	Used to turn ON or OFF the thermostat.
(5)	Liquid pipe thermistor	Used to control the opening degree of electronic expansion valve under the Sub Cooling control of heat exchanger outlet.
(6)	Gas pipe thermistor	Used to control the opening degree of electronic expansion valve under the Super-Heated control of heat exchanger outlet.
(7)	Discharge air thermistor	Used to control the electronic expansion valve opening and thermostat ON/OFF so as to keep the discharge air temperature at the set temperature.

Piping and design layout of VRV/VRF

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

- piping of VRV/VRF
- design layout of VRV/VRF.

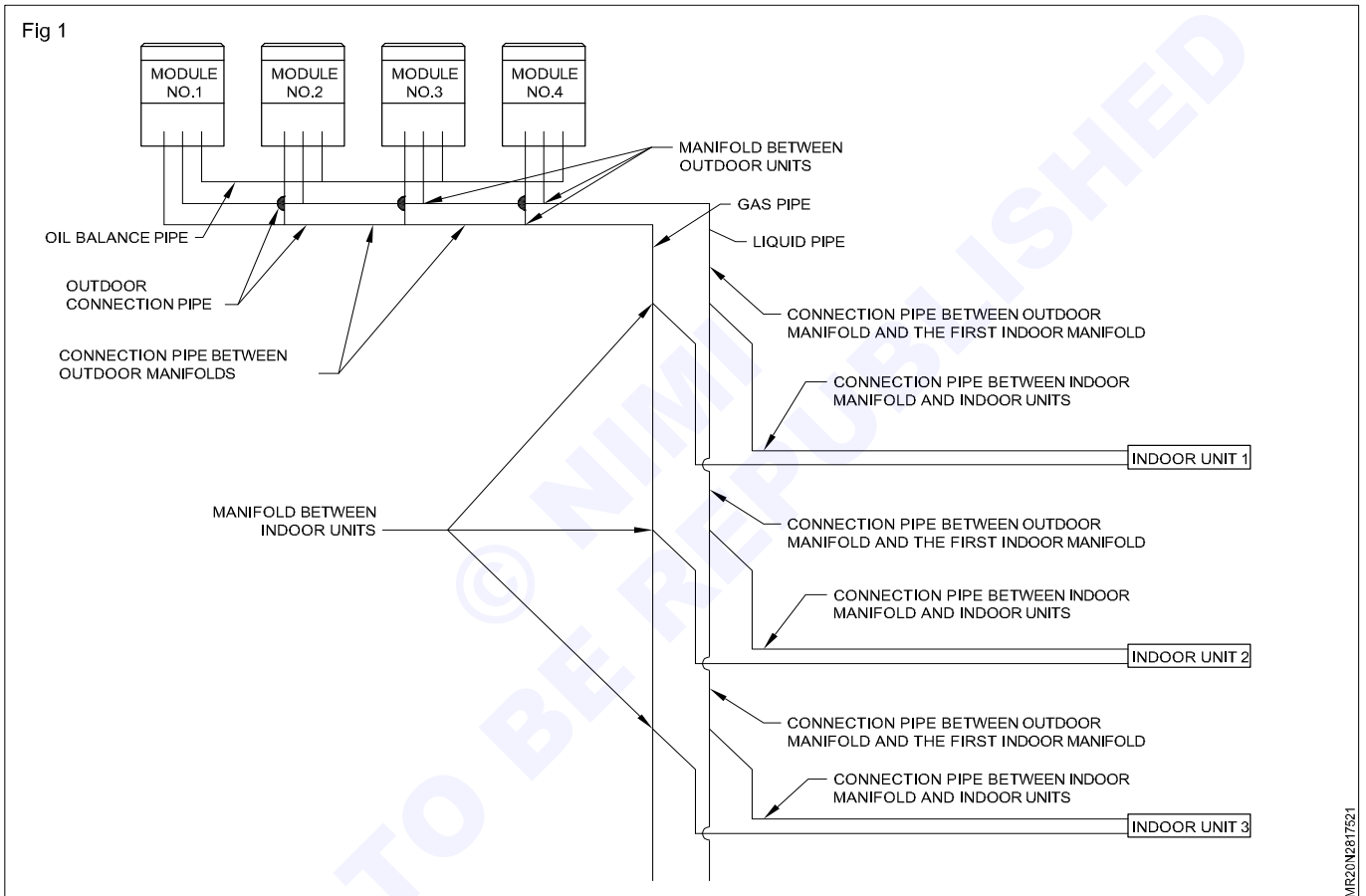
Piping of VRV/VRF (Figs 1 to 4)

Layout of refrigerant piping and design selection, if not done properly, results in operational problems. The design Engineer is responsible for selection and designing of the piping layout. The field personnel also should be well conversant with the selection and proper installation methods, to avoid any operational problems. Once the plant is commissioned, it becomes difficult, costly and

time-consuming to carry out any alterations. The important factors in the selection of pipe sizes are:

- 1 The gas velocity through the pipes should be low enough to avoid excessive pressure drop, but
- 2 At the same time it must be sufficiently high enough to return oil to the compressor.

Schematic Diagram of Piping Connection

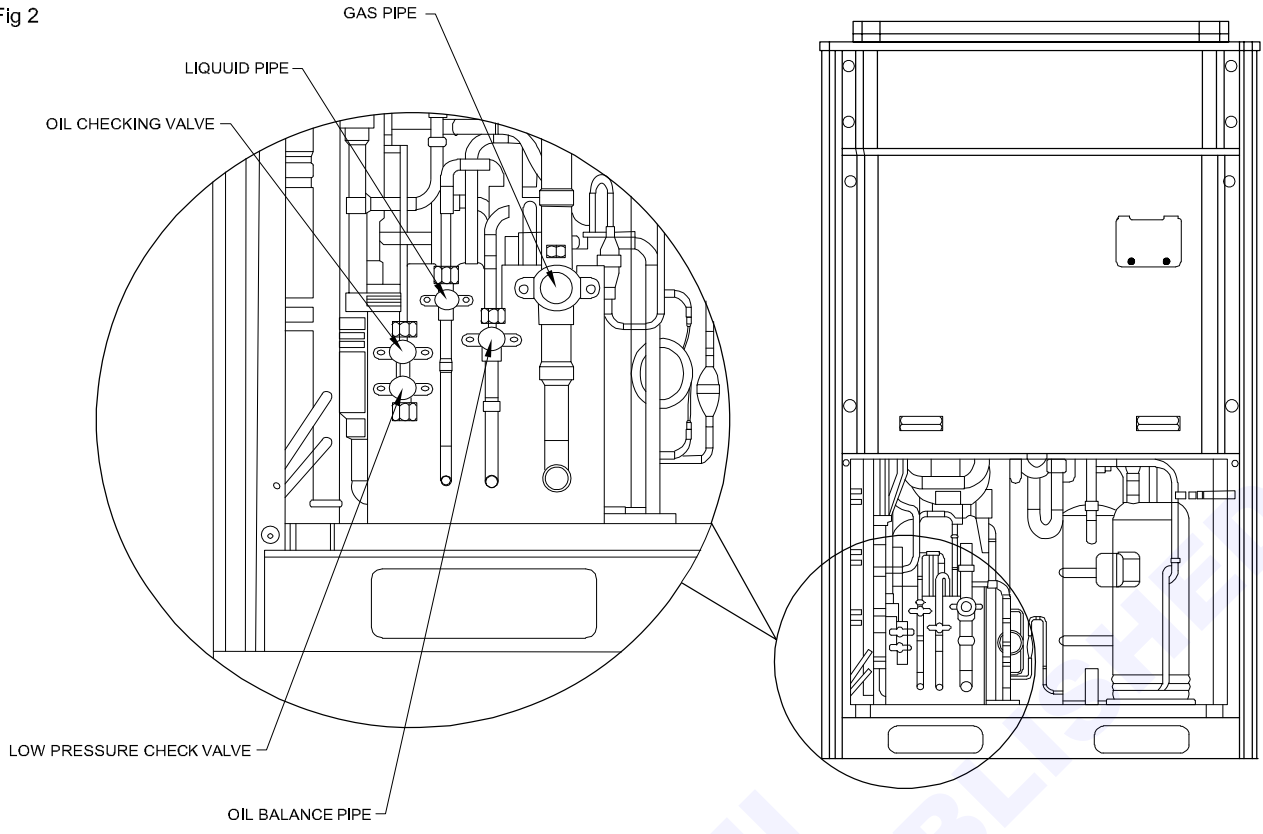


Basic Requirement for Pipe Connection

Outdoor units adopt the modular combination design of individual cooling system, that is, units are connected by

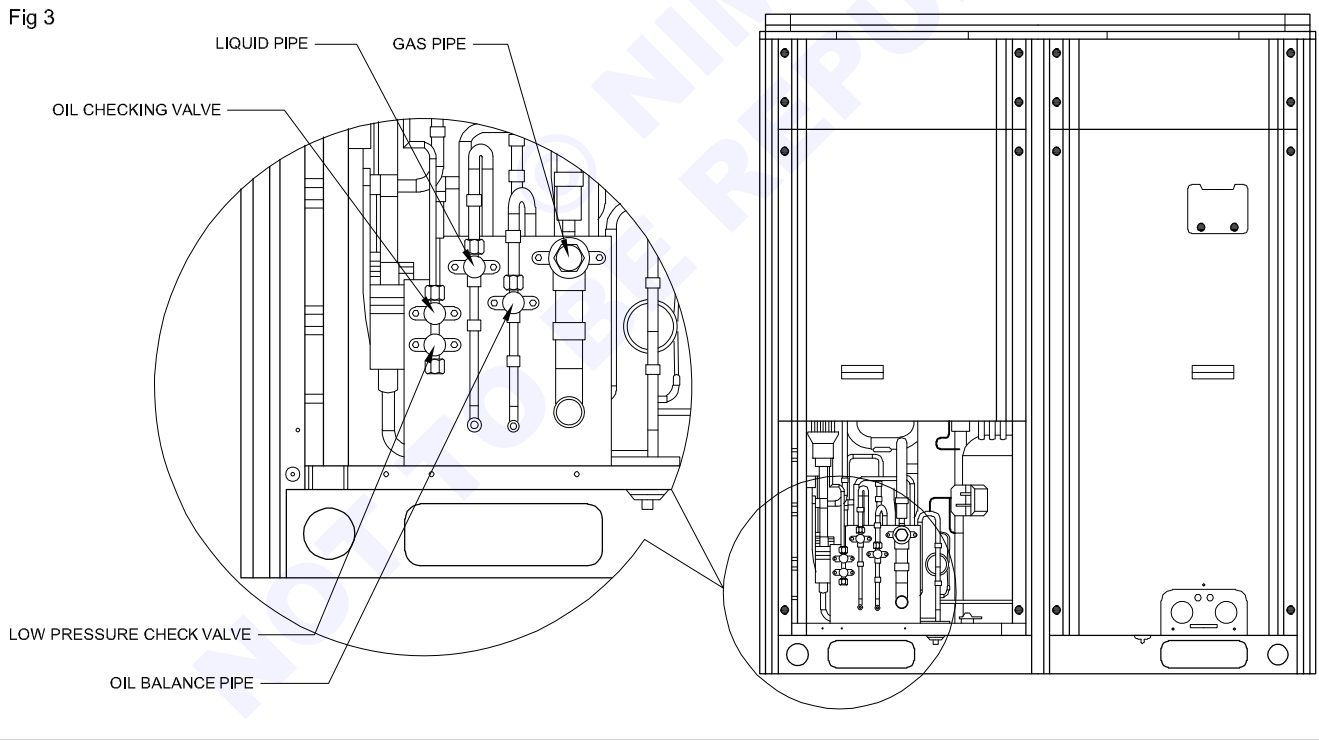
using pipes in parallel during installation. The tubing system used among modules includes air pipes, liquid pipes and oil equalizing pipes.

Fig 2



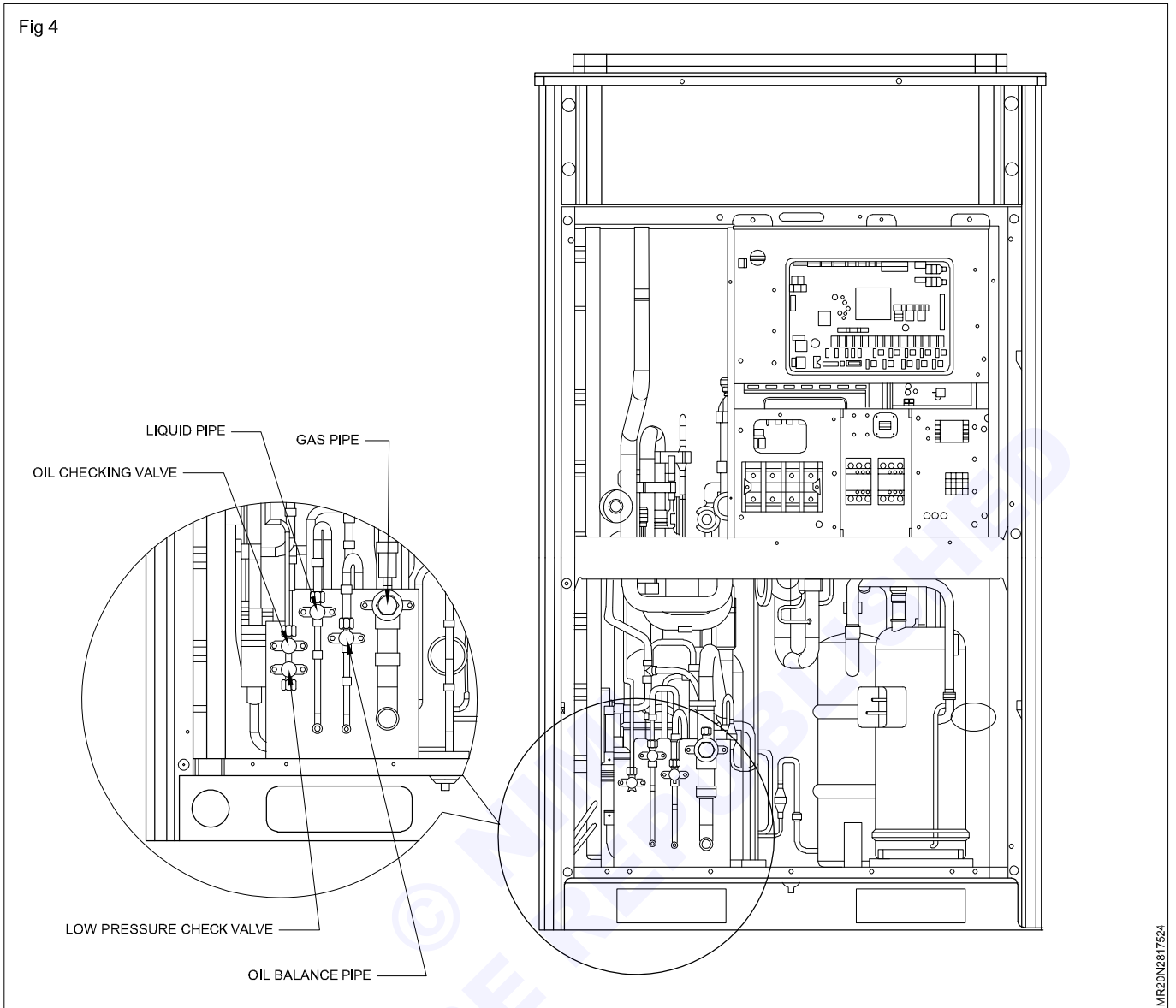
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Fig 3



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Fig 4



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Functions of oil check valve: During after-sale maintenance, the oil check valve can be used to extract lubricating oil samples, which are further detected to analyze the oil quality in the system. The oil check valve can also serve as the inlet for lubricating oil charging. Stop the system for at least 12 hours before the extracting of lubricating oil from the system; otherwise, overheat oil may burn the operator.

Functions of low-pressure check valve: It is mainly used for low pressure detection of the system and refrigerant charging during after-sale maintenance.

Pipe connection diagram of outdoor modules

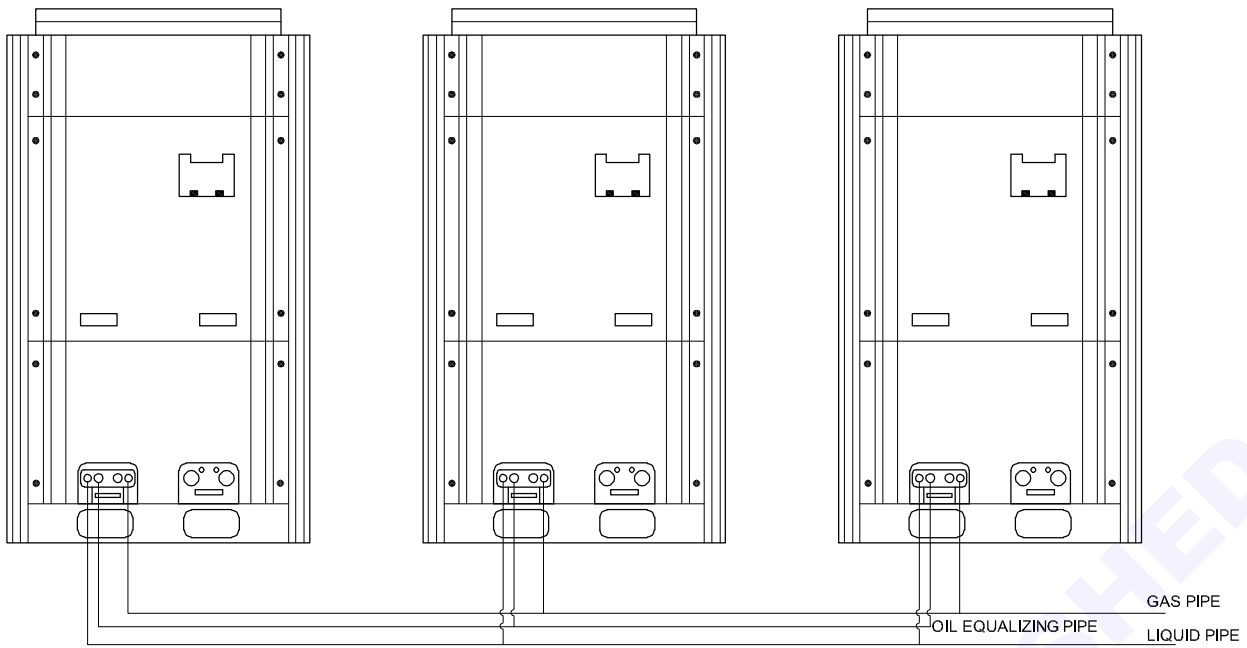
Each ODU system can be connected to multiple IDUs depending upon the capacity.

Refrigerant piping (Fig 5)

- Install the refrigerant pipe securely during the installation work before operating the air conditioner. If the compressor is operated with the valve open and without refrigerant pipe, the compressor sucks air and the refrigeration cycles is over pressurized, which may cause a injury.

- Tighten the flare nut with a torque wrench in the specified manner. Excessive tighten of the flare nut may cause a crack in the flare nut after a long period, which may result in refrigerant leakage.
- Ventilate the air if the refrigerant gas leaks during installation. If the leaked refrigerant gas comes into contact with fire, toxic gas may be produced.
- After the installation work, confirm that refrigerant gas does not leak. If refrigerant gas leaks into the room and flows near a fire source, such as a cooking range, noxious gas may be generated.
- When the air conditioner has been installed or relocated, follow the instructions in the Installation Manual and purge the air completely so that no gases other than the refrigerant will be mixed in the refrigerating cycle. Failure to purge the air completely may cause the air conditioner to malfunction.
- Nitrogen gas must be used for the airtight test.
- The charge hose must be connected in such a way that it is not slack.

Fig 5



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If refrigerant gas has leaked during the installation work, ventilate the room immediately. If the leaked refrigerant gas comes in contact with fire, toxic gas may be generated

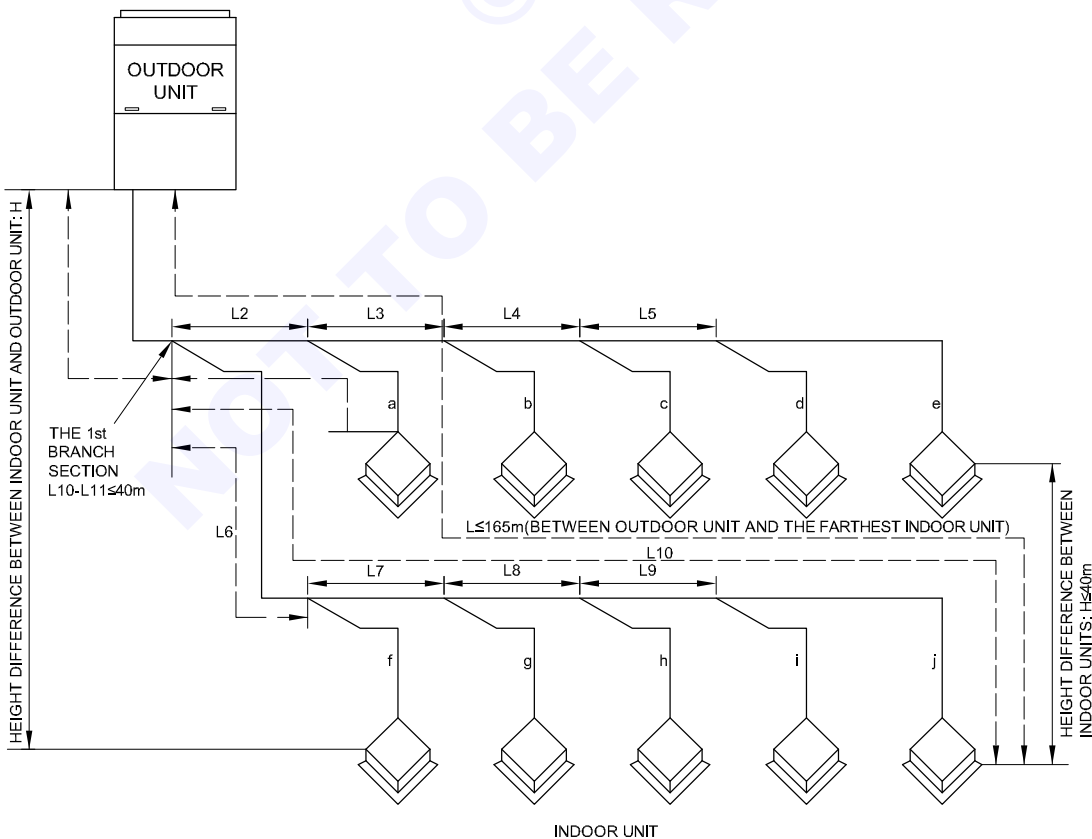
Allowable pipe length and drop height among indoor and outdoor units (Fig 6)

Y type branch joint is adopted to connected indoor and outdoor units. Connecting method is shown in the figure

below. Equivalent length of one Y-type manifold is about 0.5m.

L10: Length from the first branch to the farthest IDU; L11: Length from the first branch to the nearest IDU; Equivalent length of branch of IDU is 0.5m.

Fig 6



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R410A Refrigerant System		Allowable Value	Fitting Pipe
Total length (actual length) of fitting pipe		≤ 1000	$L1+L2+L3+L4+\dots+L9+a+b+\dots+i+j$
Length of farthest fitting pipe(m)	Actual length	≤ 165	$L1+L6+L7+L8+L9+j$
	Equivalent length	≤ 190	
Difference between the pipe length from the first branch of IDU to the farthest IDU and the pipe length from the first branch of IDU to the nearest IDU		≤ 40	$L10-L11$
Equivalent length from the first branch to the furthest piping (1)		≤ 40	$L6+L7+L8+L9+j$
Height difference between outdoor unit and indoor	Outdoor unit at upper(4)	≤ 90	-----
	Outdoor unit at lower(4)	≤ 90	-----
Height difference between indoor units (m)		≤ 30	-----
Maximum length of Main pipe(2)		≤ 90	L1
From IDU to its nearest branch (3)		≤ 40	a,b,c,d,e,f,g,h,i,j

Normally, the pipe length from the first branch of IDU to the farthest IDU is 40m. When those three conditions as below are satisfied, the length can reach 90m.

- 1 Actual length of pipe in total:
 $L1+L2x2+L3x2+L4x2+\dots+L9x2+a+b+\dots+i+j \leq 1000m$;
- 2 Length between each IDU and its nearest branch a, b, c, d, e, f, g, h, i, j $\leq 40m$;
- 3 Difference between the pipe length from the first branch of IDU to the farthest IDU and the pipe length from the first branch of IDU to the nearest IDU: $L10-L11 \leq 40m$.

When the maximum length of the main pipe from ODU to the first branch of IDU is $\geq 90m$, then adjust the pipe size of the gas pipe and liquid pipe of main pipe according to the following table. If the length between an IDU and its nearest branch is above 10m, then increase the size of the liquid pipe of IDU (only for the pipe size that is $\geq 6.35mm$). If the height difference between indoor and outdoor units exceeds 90m, please consult the manufacturer for specific technical requirements.

Connection Pipe among Outdoor Modules (Fig 7&8)

Note: When the distance between outdoor units exceeds 2m, U-type oil trap should be added at low-pressure gas pipe. $A+B \leq 10m$.

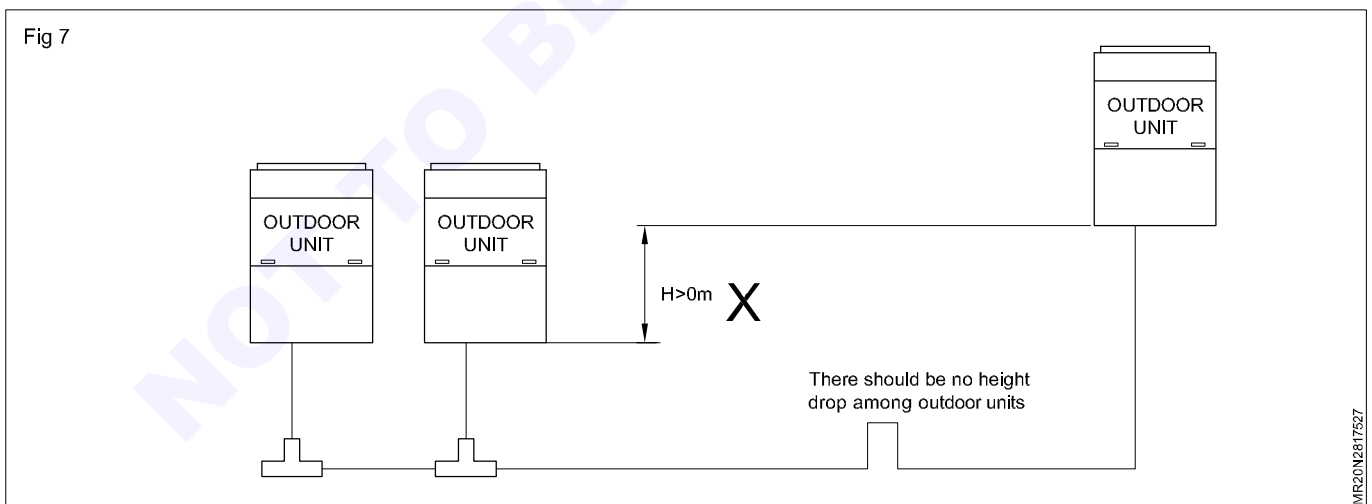
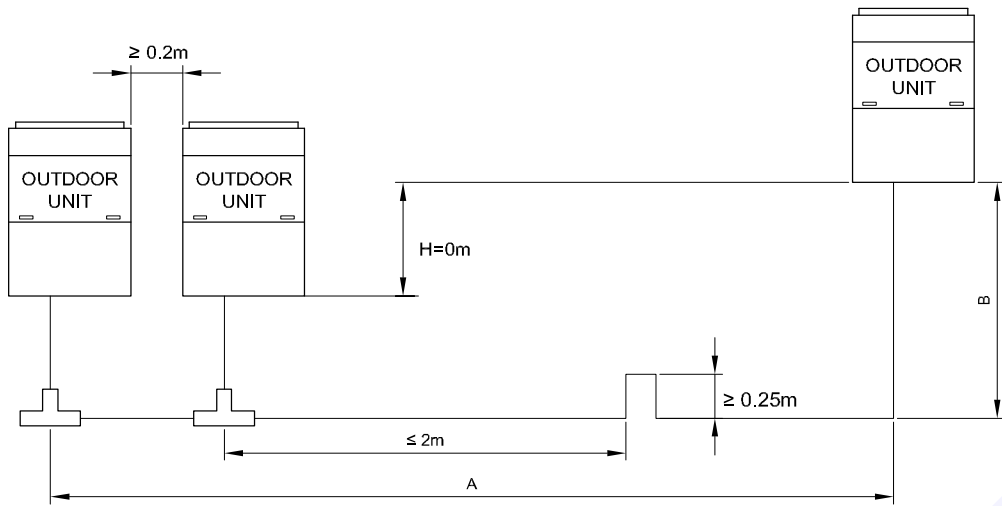


Fig 8



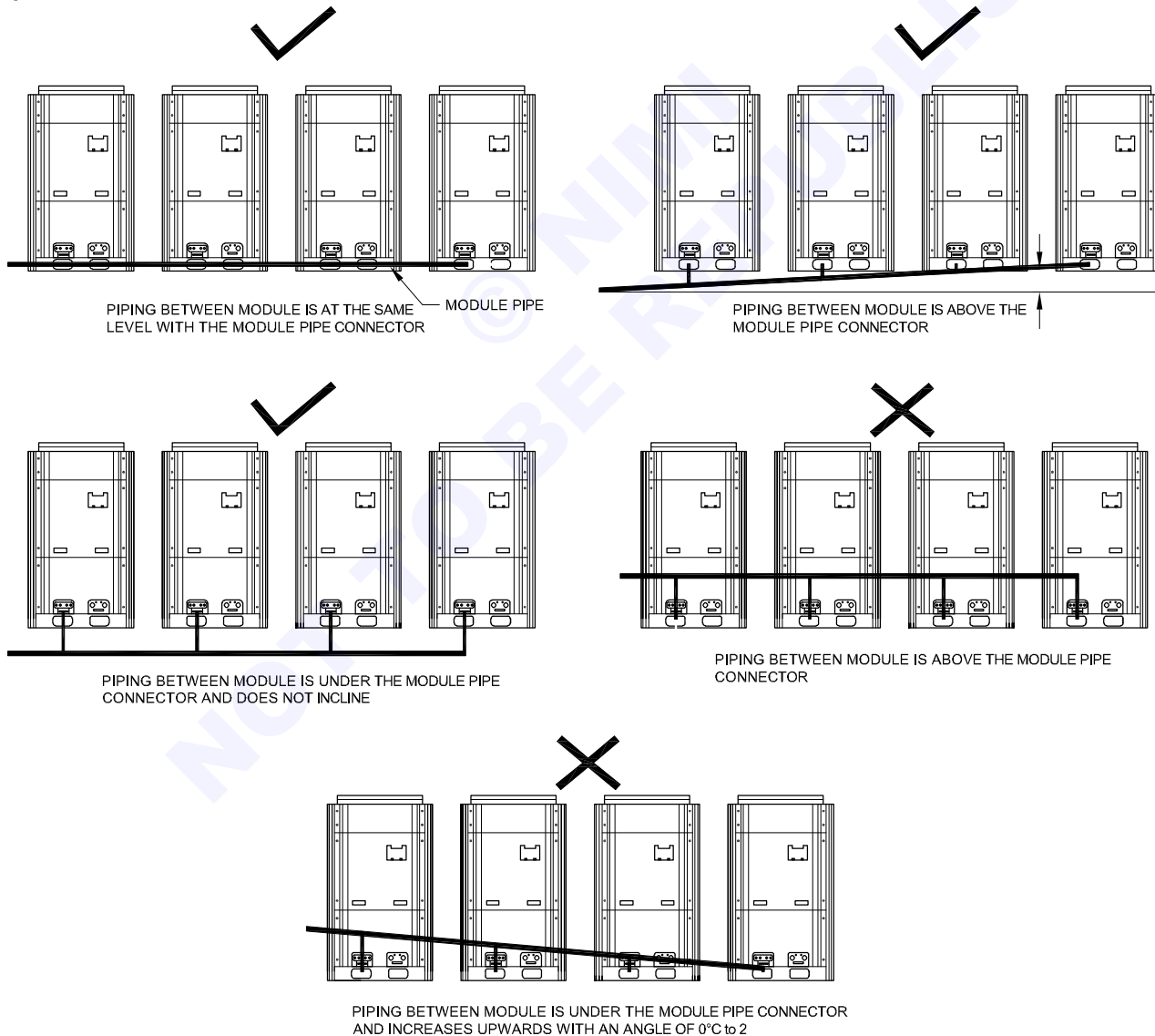
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Pipe connection among ODU's must meet the following requirements (Fig 9 & 10)

For single module system, pipe size (between outdoor unit and the first manifold) is determined by that of outdoor unit.

Fitting pipe between Outdoor Unit and the First Manifold

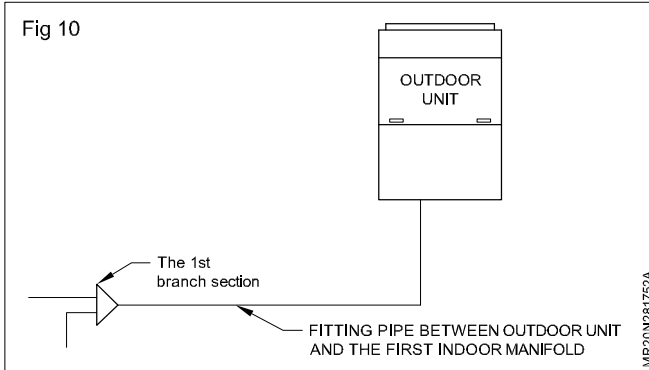
Fig 9



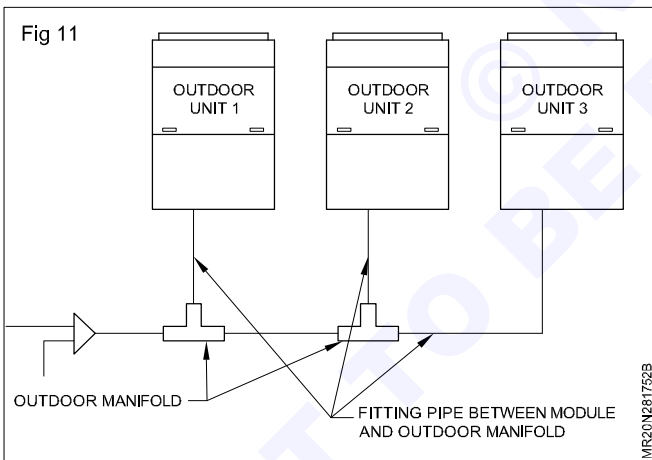
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Pipe size of basic outdoor module is shown as follows:

Pipe between ODU and the first branch of IDU	
Gas Pipe(mm)	Liquid Pipe(mm)
φ19.05	φ9.52
φ22.2	φ9.52
φ25.4	φ12.7
φ25.4	φ12.7
φ28.6	φ12.7
φ28.6	φ15.9
φ28.6	φ15.9
φ28.6	φ15.9



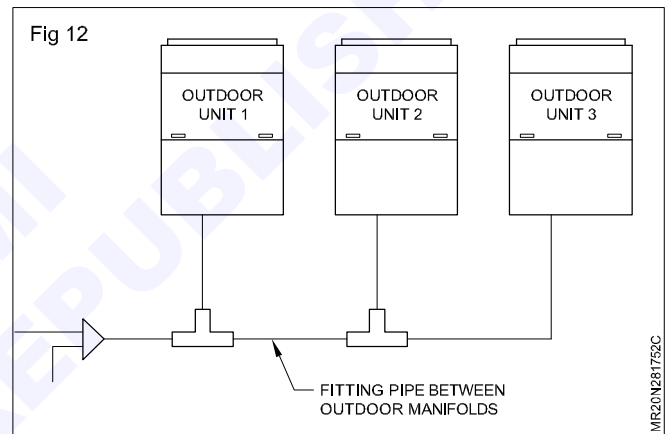
For multi-module unit, select appropriate manifold connected to outdoor module as per the pipe size of basic module. Pipe size of basic outdoor module is shown as follows (Fig 11)



Pipe between module and branch of ODU	
Gas Pipe(mm)	Liquid Pipe(mm)
φ19.05	φ9.52
φ22.2	φ9.52
φ25.4	φ12.7
φ25.4	φ12.7
φ28.6	φ12.7
φ28.6	φ15.9
φ28.6	φ15.9
φ28.6	φ15.9

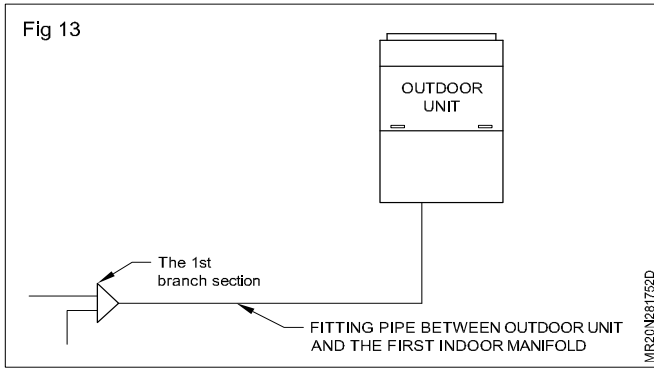
Fitting pipe between two manifolds from basic modules (Fig 12)

Pipe size (between two manifolds from basic modules) is based on the total capacity of upstream modules.



Total capacity of upstream modules (kW)	Pipe size between manifolds	
	Gas Pipe(mm)	Liquid Pipe(mm)
$22.4 \geq Q$	φ19.05	φ9.52
$28.0 \geq Q > 22.4$	φ22.2	φ9.52
$40.0 \geq Q > 28.0$	φ25.4	φ12.7
$45.0 \geq Q > 40.0$	φ28.6	φ12.7
$68.0 \geq Q > 45.0$	φ28.6	φ15.9
$96.0 \geq Q > 68.0$	φ31.8	φ19.05
$135.0 \geq Q > 96.0$	φ38.1	φ19.05
$186.0 > Q > 135.0$	φ41.3	φ19.05
$Q \geq 186.0$	φ44.5	φ22.2

Fitting pipe between the first manifold from indoor unit and the end manifold from outdoor unit (Fig 13)

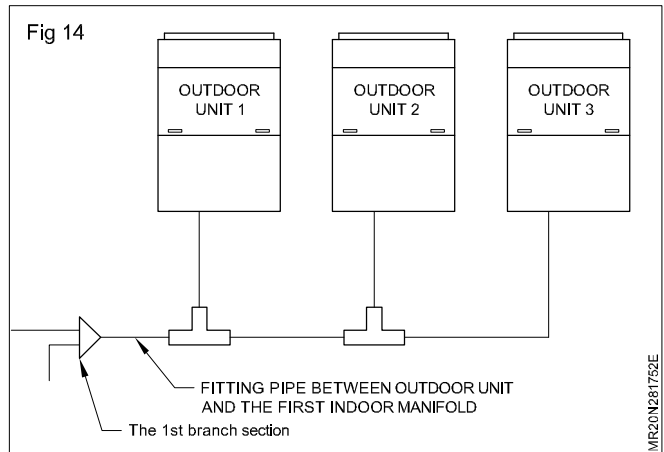


Pipe between ODU and the first branch of IDU

Gas Pipe(mm)	Liquid Pipe(mm)
φ19.05	φ9.52
φ22.2	φ9.52
φ25.4	φ12.7
φ25.4	φ12.7
φ28.6	φ12.7
φ28.6	φ15.9
φ28.6	φ15.9
φ28.6	φ15.9

Single module unit

For multiple modules, the piping from ODU to the first branch of IDU is based on the total rated capacity of outdoor modules. (Fig 14)

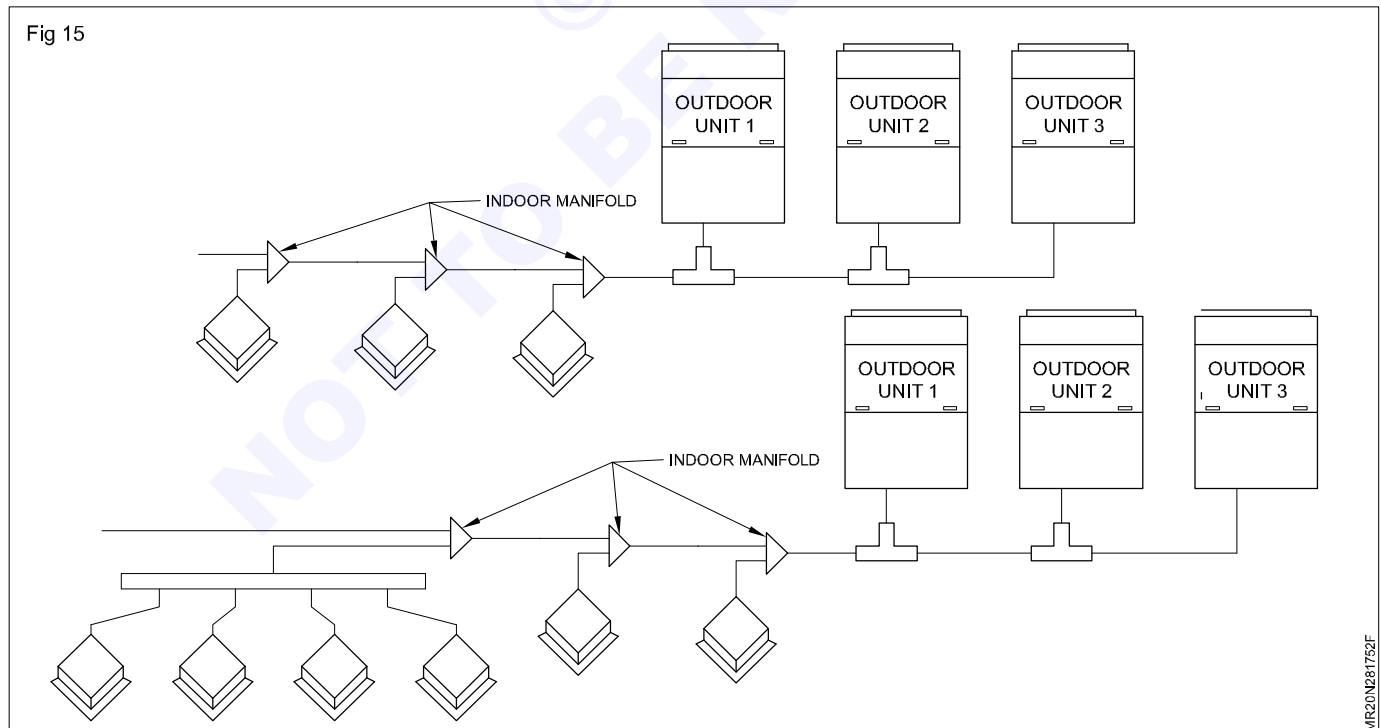


Pipe between ODU and the first branch of IDU

Gas Pipe(mm)	Liquid Pipe(mm)
φ28.6	φ15.9
φ31.8	φ19.05
φ38.1	φ19.05
φ41.3	φ19.05
φ44.5	φ22.2

Manifold at indoor unit side (Fig 15)

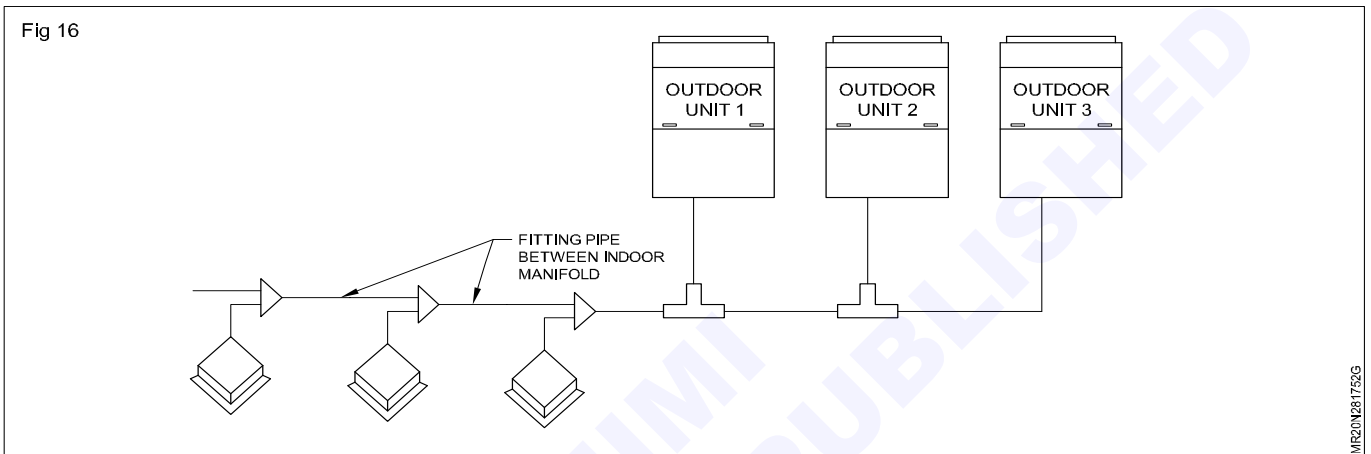
Manifold at indoor unit side can be selected as per total capacity of downstream indoor unit(s). Refer to the following table.



R410A Refrigerant system	Total capacity of downstream indoor unit (s) C(kW)
Y-type Manifold	$C \leq 20.0$
	$20.0 \leq C < 30.0$
	$30.0 \leq C < 70.0$
	$70.0 \leq C < 135$
	$135.0 \leq C$
T-type Manifold	$C \leq 40.0$
	$40.0 \leq C < 68.0$
	$68.0 \leq C$

Fitting pipe between manifolds (Fig 16)

Pipe size (between two manifolds at indoor unit side) is based on the total capacity of upstream indoor unit(s).



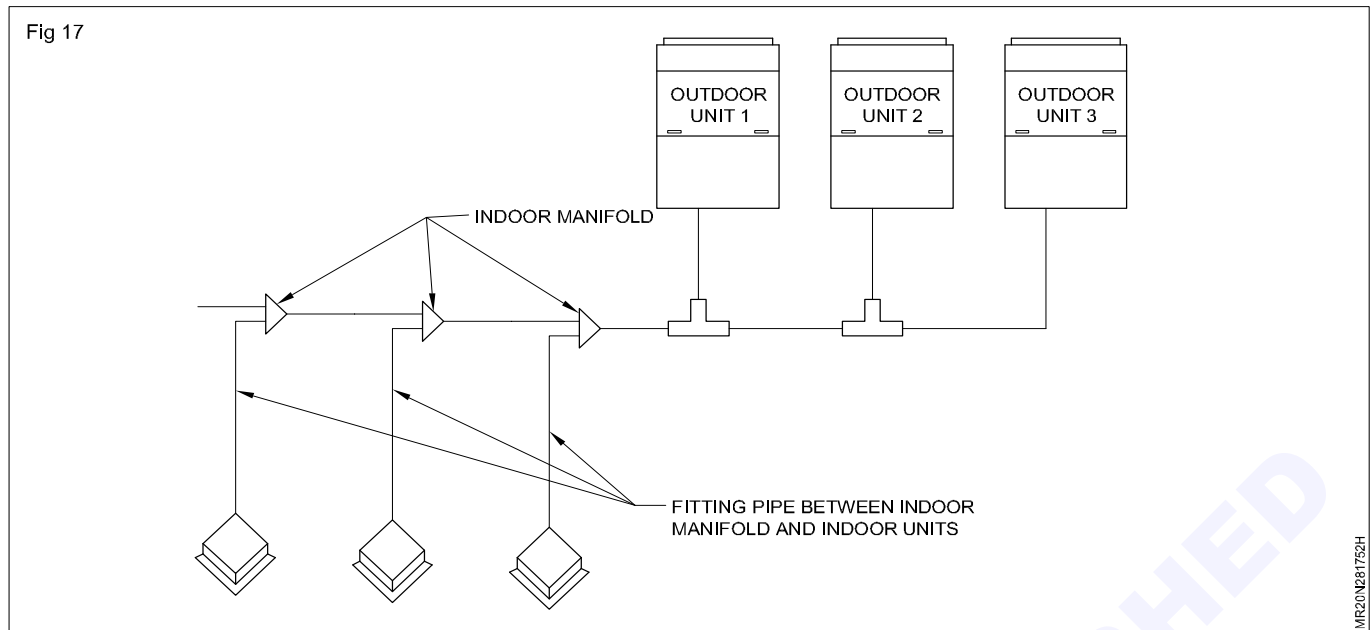
Total Rated Capacity X(kW) of Downstream Indoor Units	Fitting Pipe Size between Indoor Manifolds	
	Gas Pipe (mm)	Liquid Pipe (mm)
$C \leq 5.6$	$\phi 12.7$	$\phi 6.35$
$5.6 \leq C < 14.2$	$\phi 15.9$	$\phi 9.52$
$14.2 \leq C < 22.4$	$\phi 19.05$	$\phi 9.52$
$22.4 \leq C < 28.0$	$\phi 22.2$	$\phi 9.52$
$28.0 \leq C < 40.0$	$\phi 25.4$	$\phi 12.7$
$40.0 \leq C < 45.0$	$\phi 28.6$	$\phi 12.7$
$45.0 \leq C < 68.0$	$\phi 28.6$	$\phi 15.9$
$68.0 \leq C < 96.0$	$\phi 31.8$	$\phi 19.05$
$96.0 \leq C < 135.0$	$\phi 38.1$	$\phi 19.05$
$135.0 \leq C < 186.0$	$\phi 41.3$	$\phi 19.05$
$186.0 \leq C$	$\phi 44.5$	$\phi 22.2$

5.5.1 Fitting pipe between indoor unit and manifold

Manifold should be matched with fitting pipe of indoor unit.

Rated capacity of indoor unit C(kW)	Pipe between indoor branch and IDU	
	Gas Pipe(mm)	Liquid Pipe(mm)
$C \leq 2.8$	$\phi 9.52$	$\phi 6.35$
$2.8 \leq C < 5.0$	$\phi 12.7$	$\phi 6.35$
$5.0 \leq C < 14.2$	$\phi 15.9$	$\phi 9.52$
$14.2 \leq C < 22.4$	$\phi 19.05$	$\phi 9.52$
$22.4 \leq C < 28.0$	$\phi 22.2$	$\phi 9.52$

Pipe Installation and Insulation (Fig 17&18)

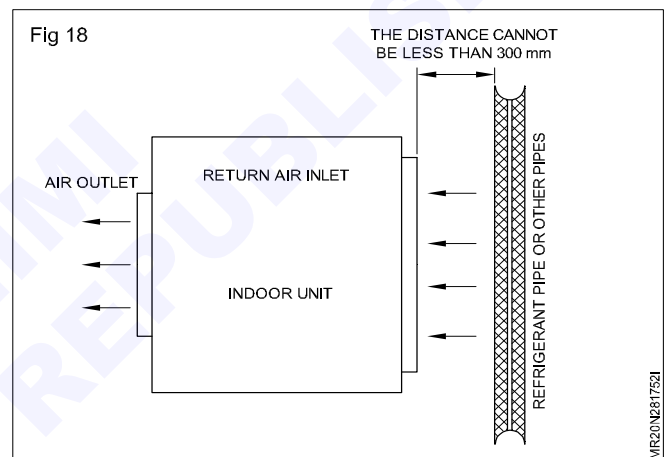


Pipe Installation for the Cooling System

Precautions on Pipe Direction Design

Refrigerant pipe layout must be designed in accordance with the following principles:

- 1 The air conditioning installation should not damage the bearing structure or the decorative style. Air conditioning pipes should be laid out along the bottom of beam as possible. If pipes meet one another at the same elevation, process based on the following principles:
Drain pipes enjoy the highest priority. Air ducts and pressure pipes should leave places for gravity pipes.
Air ducts and small pipes should leave places for major pipes.
- 2 The refrigerant pipe layout must be optimal in actual engineering with minimum pipe length and bends. In this way, the performance of the unit can be maximized.
- 3 The refrigerant pipe cannot affect air discharge and return of internal units. The minimum distance between the refrigerant pipe with an insulation layer and the air return box is 300 mm. If the air return or manhole is at the right lower part of the unit, the minimum distance is 150 mm. When the refrigerant pipe needs to be laid at the air outlet side, avoid laying the pipe at the front of the air outlet. The refrigerant pipe cannot connect to any part of the unit except the joint points. If the preceding principles are not followed, performance of the unit will be affected and running noises will be increased.
- 4 The refrigerant pipe must be laid away from the manhole of the unit so that sufficient space can be reserved for maintenance.
- 5 The riser should be installed in the air conditioning tube well, and the horizontal pipe should be placed in the ceiling, if possible.



Processing to Refrigerant Pipes

Cut-off and Burring

Use a special-purpose pipe cutter to cut copper pipes instead of using a hacksaw. Cut the pipes gently to ensure that the copper pipe does not deform.

After cutting the pipes, use a slicker to grater bur the pipes with the pipe opening inclining downward so that the copper scales do not fall into the pipe.

Allowable deviation: Skewness of the cross section cannot exceed 1% of the copper pipe caliber.

If the copper pipe is not used immediately after cut-off, cover it with a sealing cap or adhesive tape.

Pipe Cleaning: Cleaning with a piece of silk cloth: Wrap a thin steel wire with a piece of clean silk cloth. Crumple the cloth into a lump with diameter larger than the pipe caliber. Apply several drops of chlorylene to the cloth. Push the cloth in from one end of the pipe and pull out from the other end. Every time the cloth is pulled out, remove the dust and sundries with chlorylene. Wash repeatedly until the pipe is clean. This method applies to straight pipes.

Cleaning with nitrogen: Blow off all dust and sundries in the pipe with nitrogen. This method applies to coils.

After cleaning, cover the both ends of the pipe with a sealing cap or adhesive tape.

Pipe Bending Processing methods

Manual bending: applies to thin copper pipes ($\phi 6.35$ mm to $\phi 12.7$ mm) Mechanical bending: applicable range ($\phi 6.35$ mm to $\phi 54.1$ mm) Requirements:

The radius of the bending pipe must exceed 3.5D. The ratio of the short diameter after bending to the original diameter must exceed 2/3.

Precautions

During bending, there must be no corrugation or deformation inside the pipe.

The welding point of the pipe should not be at the bending part. The distance between the nozzle welding joint and the bending part should be less than 100 mm.

Pipe Expanding

Pipe expanding is used to provide a welding point for pipe connection. Requirements on pipe expanding are as follows:

- All burrs and sundries inside the pipe must be cleared after cut-off.
- Before pipe expanding, apply appropriate amount of lubricant on the surface of the pipe. (The lubricant must meet the refrigerant system's requirements.)
- Pipe expanding length must be in accordance with the insertion depth of the caliper.
- To avoid leakage due to straight lines at the expanding point, turn round the copper pipe and then make corrections.
- Apply appropriate force during pipe expanding to avoid crack.

Flaring

Another mode of pipe connection is flare opening connection, which requires pipe flaring before connection. Before pipe flaring, apply appropriate amount of lubricant on the surface of the opening to ensure smooth pass of flaring nuts and avoid pipe distortion. (The lubricant must meet the refrigerant system's requirements.) The concentricity must be ensured after pipe flaring. The sealing face must be intact without any burr, crack, or wrinkle.

Requirements on pipe flaring are as follows:

- End faces of the copper pipe are smooth.
- Burrs and turn ups inside the pipe opening must be cleared.
- Install flaring nuts in the pipe before pipe flaring.

- The flared opening must be concentric with the main pipe. No eccentricity is allowed.
- Put the pipe into the root of the pipe expander.
- Longitudinal cracks cannot be generated.

Installation of Refrigerant Pipes

Operation Sequence

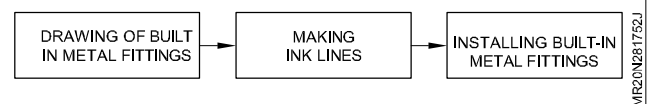
The sequence for installing the refrigerant pipe is as follows:

Preparing and installing the support, hanger, and bracket - Piping according to the drawing - Cleaning the pipe - Processing the pipe - Adding an insulation sleeve - Connecting the pipe - Fixing the pipe - Blowing contaminants in the pipe system - Performing an airtightness test - Performing insulation

Construction of Built-in Metal Fittings (Fig 19)

- Construction of supports, hangers, and brackets for pipes: These parts must be fixed securely in reasonable type and style without any tilt. The surface is clean without any dirt. The parts embedded into the wall or floor cannot be painted or coated and must be free from grease stains.
- Construction of fixing bolts for devices: Ensure sufficient rigidity for the devices. Take anticorrosive measures for exposed part of built-in fittings. If the foundation must be waterproof, takes waterproof measures.
- Construction of steel casings: Equip a steel casing for all pipes which are led through the wall or floor. Pipe welding joints cannot be placed inside the sleeve. The steel casing must be parallel with the bottom of the wall or floor but be 20 mm or more above the bottom. The diameter of the steel casing must be determined based on the thickness of the insulation layer and the inclination degree of the condensate water pipe. Fill the gap between the pipe and the sleeve with flexible and non-flammable materials. The sleeve cannot be used as a support point of the pipe.
- Operation Sequence
If possible, make ink lines on the ground and project them to the top of the building.

Fig 19



- Installing Built-in Metal Fittings
Select built-in metal fittings in accordance with local regulations.
- Installing Expansion Bolts
Use expansion bolts when built-in metal fittings are unavailable due to design change.

g Installing Expansion Bolts

If the foot pedal is 2 m or more from the ground, there must be three points of support. The foot pedal must be tightened securely with the ladder.

Do not perform operations on the top of the ladder.

Shaping and Fixing of Pipes

When installing refrigerant pipes, ensure that the directions and branches are correct with minimum length. Use minimum number of braze welding junctions and elbows. Alignment and insulation after installation cannot affect the pipe location and elevation. There shall not be flat bending or corrugation on the pipe after piping.

Use angle steel support, bracket, round steel hanger, U-type pipe clip, or flat steel to fix pipes outside the insulation layer. It is better that the insulation materials be not compressed to ensure good insulation.

The style and workmanship of supports, hangers, and brackets must follow the standard T616 HVAC Systems Design Handbook.

The minimum distance between supports, hangers, and brackets is listed in the table below:

External Diameter of the Pipe (mm)	$\phi \leq 16$	$40 > \phi \geq 19.05$	$\phi \geq 40$
Distance between Horizontal Pipes (mm)	1000	1500	2000
Distance between Vertical Pipes (mm)	1500	2000	2500

A: External Diameter of the Pipe (mm)	B: Minimum Insertion Depth (mm)	D-A: Gap between Pipes (mm)
$\phi 6.35$	6	0.05-0.21
$\phi 9.52$	7	
$\phi 12.7$		
$\phi 15.8$	8	
$\phi 19.05$		
$\phi 22.2$	10	0.05-0.27
$\phi 25.4$		
$\phi 28.6,$	12	0.05-0.30
$\phi 31.8$		
$\phi 38.1$	19	0.15-0.35
$\phi 44.5$		
$\phi 54.1$	24	0.15-0.35

j Ball Socket Welding

The ball socket welding is another form of socket welding. It uses the sleeve or pipe in a larger size for welding. The insertion depth cannot be smaller than that required by socket welding.

The pipe led through a wall or beam must be fixed by a support, hanger, or bracket on both ends at the position 300 mm away from the hole.

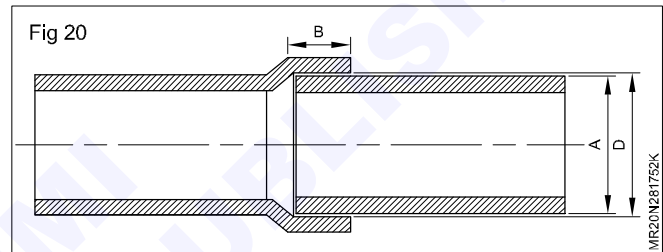
Pipe Connection

h Flaring Connection

The refrigerant pipes and IDUs are connected by using the flare opening. Therefore, the quality of flaring connection must be ensured. The flaring depth of the bell mouth cannot be smaller than the caliber. The flaring direction must face towards the direction of medium flow. Use two torque wrenches to fasten the connection

i Socket Welding (Fig 20)

The gap between socket components should be proper to ensure that the connection will not loose from the friction surface. The flaring direction of the socket component must face towards the direction of medium flow. During pipe connect, protect the braze welding part according the length specified below:



k 3.4.5 Flange Connection

The pipes with large caliber and the devices are always connected by using a flange, which must be clean and intact. Before installation, apply lubricant on the surface of the flange. Two flanges must be symmetrical. Fasten with screws at the diagonal direction to avoid inclination.

Welding Protection

Aerate with nitrogen before and during welding and keep aerating for 30 s after the welding is finished.

Equip a pressure regulator valve to the nitrogen cylinder.

The nitrogen flow is above 4-6 L/min (pressure of 0.02 to 0.05 MPa) and must be regulated based on the pipe caliber.

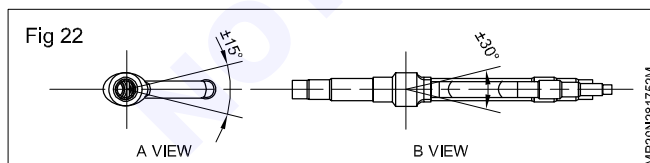
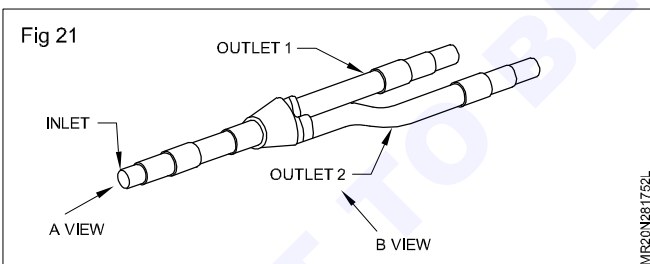
Requirements on Manifold Installation (Fig 21 to 24)

Manifolds are used to divert refrigerant. Requirements on manifold installation are as follows:

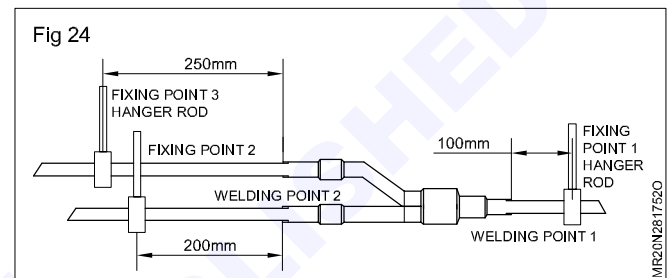
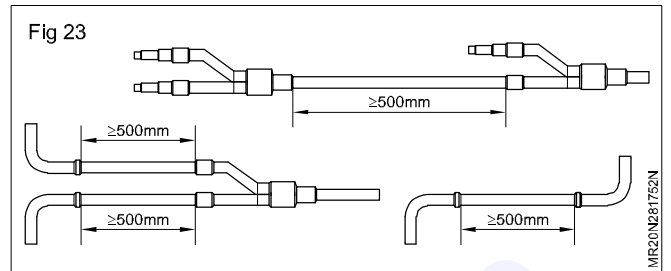
- A Ensure that the manifold is close to the IDU to reduce impact on refrigerant assignment by IDU branches.
- B The manifold must be that specified by the manufacture and match with the devices.
- C Ensure that the manifold model is correct.
- D If the outdoor unit is connected with several indoor units, you can also adopt Y-type manifold pipe. Please comply with the following rules when connecting T-type manifold pipe and Y-type manifold pipe. The downstream of Y-type manifold pipe can connect with T-type manifold pipe, but the downstream of T-type manifold pipe cannot connect with Y-type manifold pipe.

E. Y-type manifold can be laid in the following ways:

- E1 Horizontal installation: The three ports must be on the same level. The shaping size and assembly angle cannot be changed.
- E2 Vertical installation: The direction can be upwards or downwards. Three ports must be on the same elevation without inclination.



- E3 The length of a straight pipe between two manifolds cannot be less than 500 mm.
- E4 The length of a straight pipe before the main pipe port of the manifold cannot be less than 500 mm.
- E5 The length of a straight pipe between the branch of the manifold and the IDU cannot be less than 500 mm.



E6 Fixing of manifolds (Fig 25)

There must be three fixing point for both horizontal and vertical installation of the Y-type manifold.

Fixing point 1: 100 mm on the main inlet manifold from the welding point

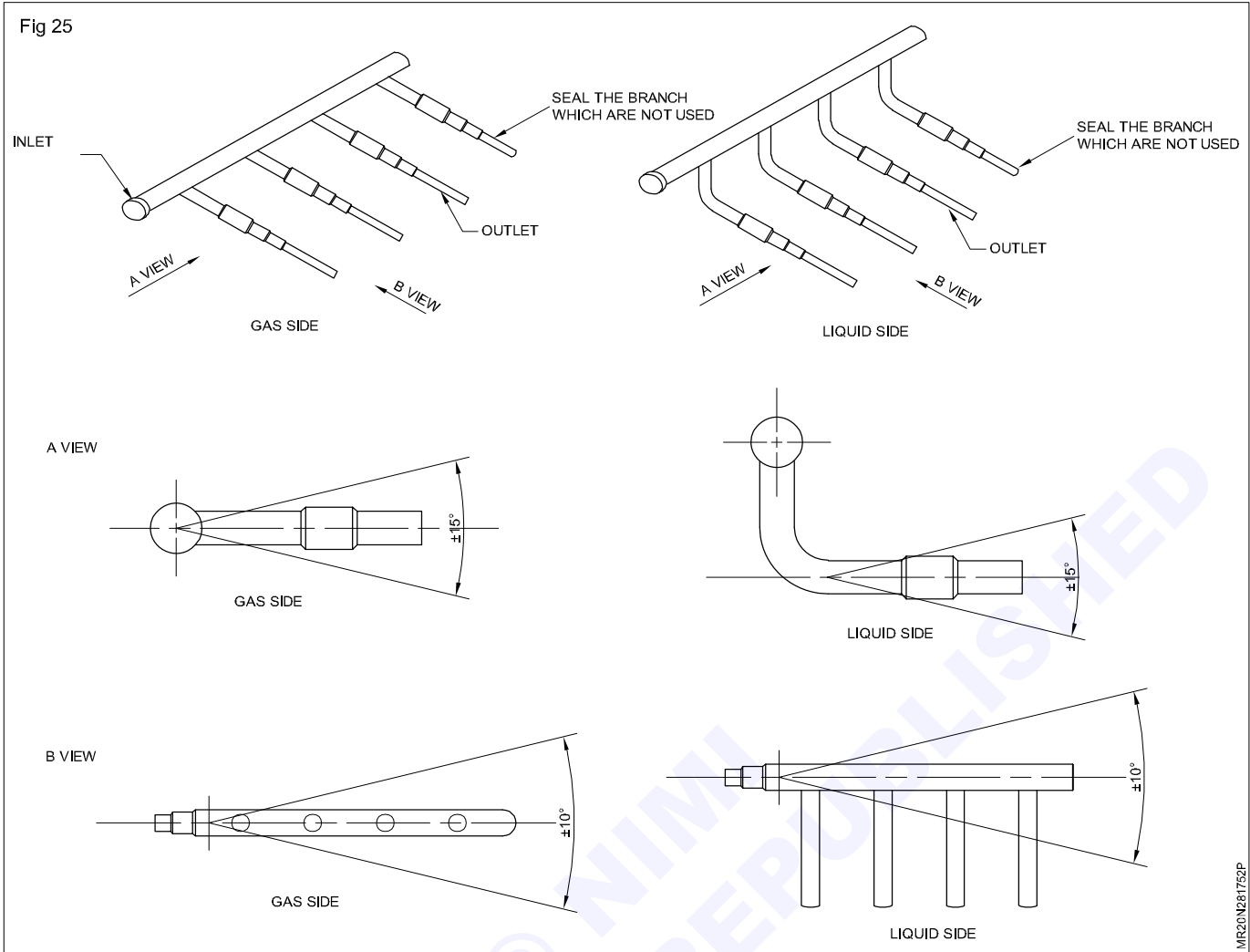
Fixing point 2: 200 mm on the main branched pipe from the welding point

Fixing point 3: 250 mm on the branched pipe from the welding point

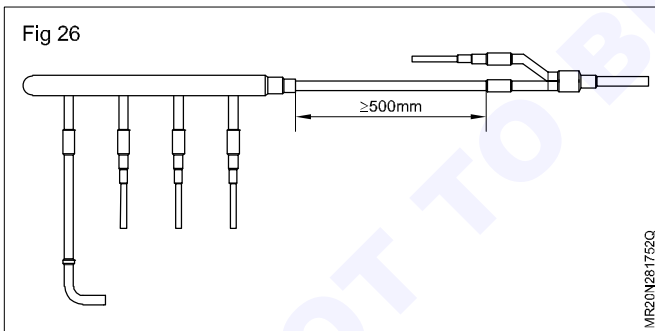
Branches of a manifold must be laid parallel and cannot be wrapped in superimposed mode.

F.T-type manifold can be laid in the following ways

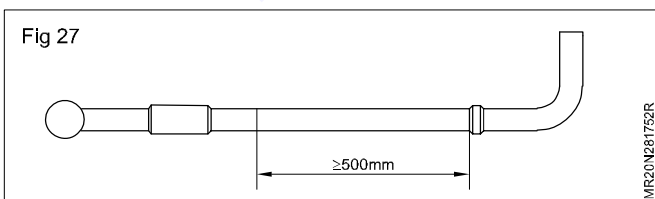
- F1 T-type manifold must be installed horizontally with inclination.



F2 The length of a straight pipe between T-type manifold pipe and Y-type manifold pipe cannot be less than 500 mm. (Fig 26)



F3 The length of a straight pipe between the T-type manifold pipe and the IDU cannot be less than 500 mm. (Fig 27)



F4 Suspend the header to the ceiling and be sure to install it so that the outlet pipes are horizontal at the lower side. (Fig 28)

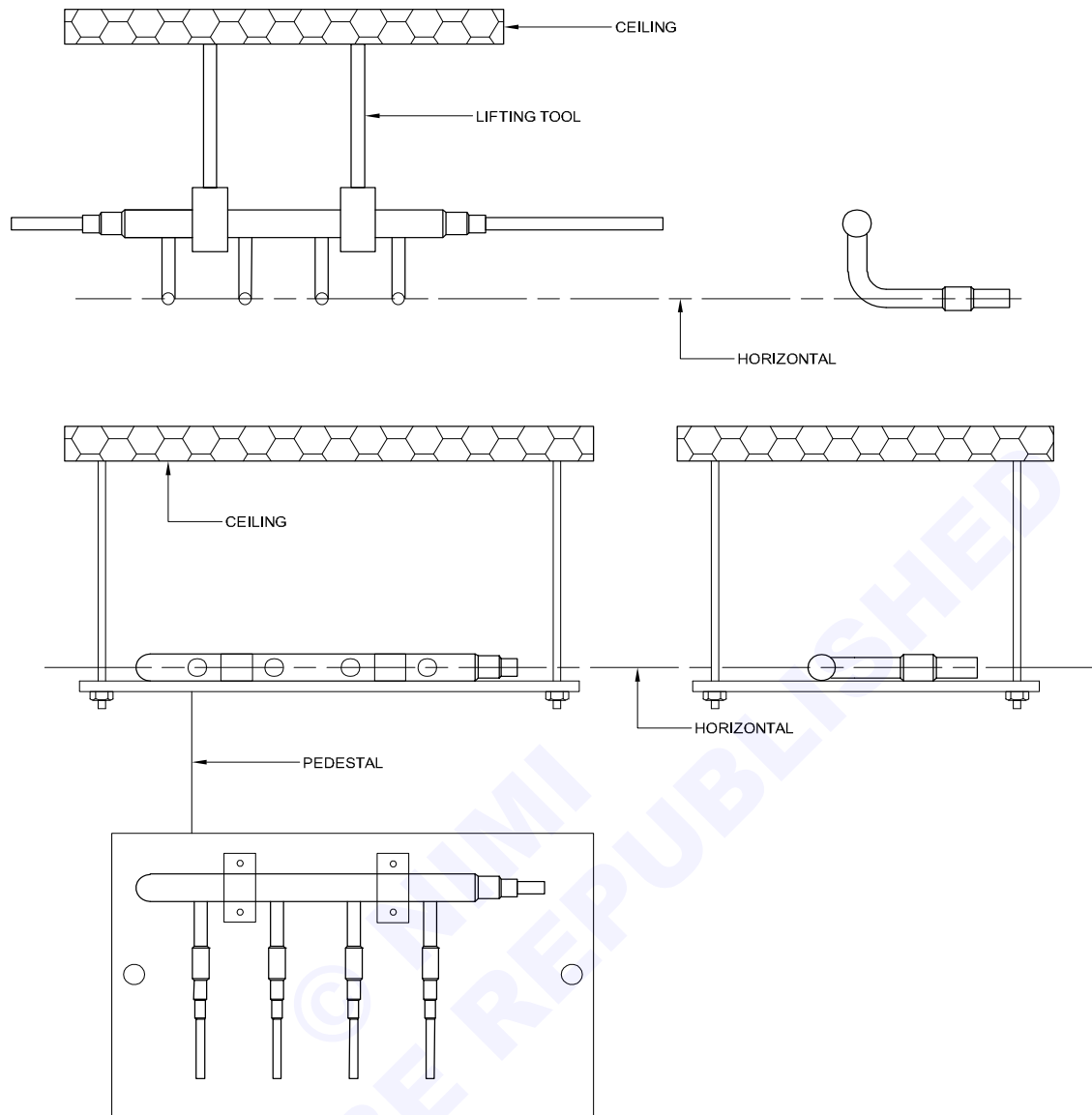
F5 The downstream of T-type manifold pipe cannot connect with Y-type manifold pipe and T-type manifold pipe.

Equivalent length of one Y-type manifold pipe is about 0.5m. Equivalent length of branch of IDU is 0.5m.

F6 Min & Max Number IDUs connectable with each T-Type manifold pipe

	Min Number IDUs	Max Number IDUs
FQ14/H1	2	4
FQ18/H1	4	8
FQ18/H2	4	8

Fig 28

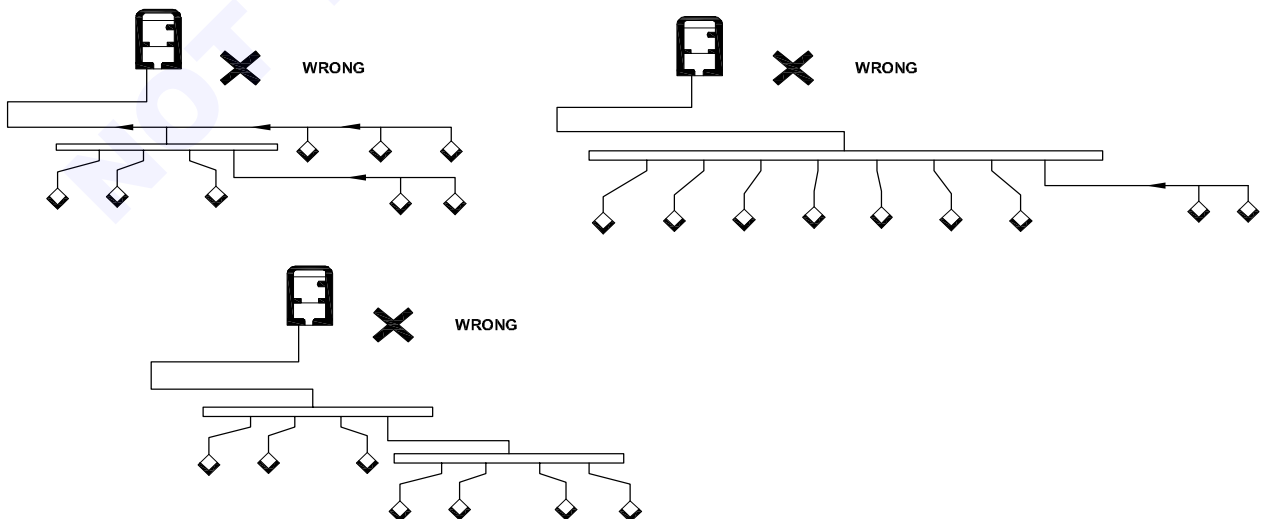


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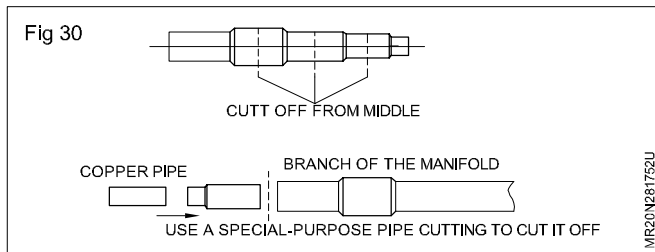
Max Indoor Unit Capacity connectable is 14kW. If T-Type manifold pipe connectable Indoor Unit Capacity satisfy demand --14KW. Indoor Unit Capacity ≤ 16KW follow need

to supply also Reducer / Expander Pipe to connect furthermore gas pipe, pipe size transition $\phi 15.9\text{mm}$ to $\phi 19.1\text{mm}$. (Fig 29&30)

Fig 29



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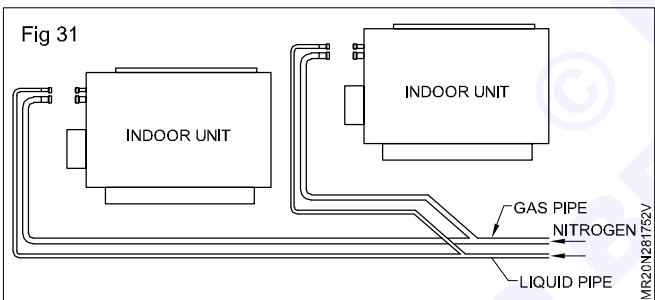
G The liquid pipe and gas pipe must have the same length and be laid in the same route.

H The manifold has an attached pipe used to adjust the diameter of different pipes. If the pipe size on site does not match the size of the manifold junction, use the pipe cutter to cut at the middle of the pipe and remove burrs. Then insert the copper pipe to proper depth. A concave bag for positioning is available to the manifold purchased from Gree.

I Because the manifold structure is complex, perform with care to ensure tight insulation.

Pipe Cleaning by Nitrogen (Fig 31)

Before connecting the flare opening of the pipe to the IDU, connect the pressure regulator valve on the nitrogen cylinder to the liquid pipe in the outdoor pipe system. Regulate the nitrogen pressure to about 5 kgf/cm² and blow nitrogen into the pipe for 1 minute. Repeat this operation for three times till the dirt and water are discharged. After cleaning the liquid pipe, perform the same operation to clean the gas pipe.



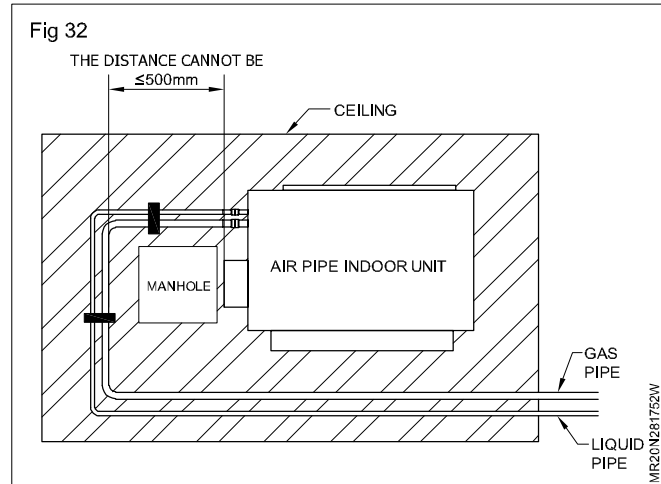
Perform an air-tightness test and a vacuum test to the entire refrigerant pipe system after the construction is finished.

There must be a secure distance between pipes. Pipes in different types must be fixed separately.

During refrigerant pipe installation, ensure a distance above 500 mm between the pipe and the electric box of the unit for maintenance. In a case when the space is not enough, the final piping way must be determined by the technical personnel. (Fig 32)

Filter and Drier Installation for the ODU

As the piping for the VRF system is complex, it is recommended that a filter is installed for the gas pipe and a drier is installed for the liquid pipe during construction. This ensures aridity and cleanness of the piping system and further improves the operation stability of the system.



The procedure is as follows:

First, weld a stop valve with the corresponding caliber to the gas pipe and liquid pipe at the position relatively close to the ODU and easy for operation.

Second, install a filter (100 mesh/ft²) between the added stop valve outside the gas pipe and the stop valve of the ODU. Then install a drier filter between the added stop valve outside the liquid pipe and the stop valve of the ODU.

Lastly, after the test run is complete,

To remove the filter from the gas pipe after starting all IDUs and keeping them running cooling mode for 24 hours: (1) Power off all units. (2) Turn off the two stop valves of the gas pipe. (3) Remove the filter. (4) Short connect with a copper pipe with the same caliber and vacuumize the pipe. (5) Open the two stop valves and keep normal running.

To remove the drier filter from the liquid pipe after starting all IDUs and keeping them running in heating mode for 24 hours: (1) Power off all units. (2) Turn off the two stop valves of the liquid pipe. (3) Remove the drier filter. (4) Short connect with a copper pipe with the same caliber and vacuumize the pipe. (5) Turn on the two stop valves and keep normal running.

Pipe Installation for the Condensate Water System Pipes

Generally, U-PVC water supply pipes bonded with special glue are adopted as condensate water pipes. PP-R, PP-C, and hot galvanized steel pipes can also be adopted. Aluminium plastic compound pipes cannot be used.

Requirements on Installation

Determine the direction and elevation of a condensate water pipe before installing it. Avoid overlapping it with other pipes to ensure straight inclination. The clamp of the pipe hanger is fixed outside the insulation layer. The height of the clamp can be adjusted.

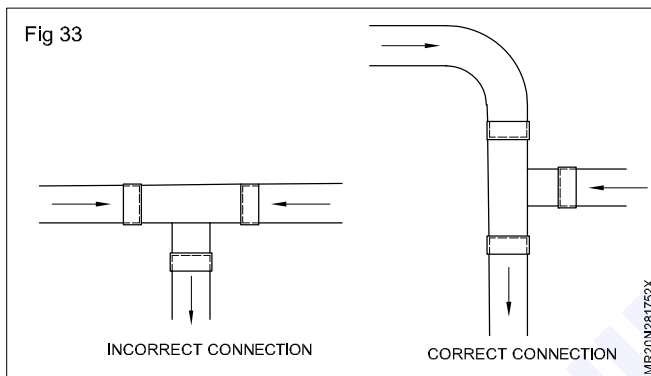
External Diameter of the Pipe (mm)	$\phi \leq 25$	$32 > \phi \geq 25$	$\phi \geq 32$
Distance between Horizontal Pipes (mm)	800	1000	1500
Distance between Vertical Pipes (mm)	1500		2500

Distance between Hangers (Fig 33)

There are at least two hangers for each vertical pipe.

The inclination degree of the condensate water pipe must be above 1% and that of the main pipe cannot be lower than 0.3%. Adverse slopes are not allowed.

When connecting three-way pipes, the two-way straight pipes must be laid on the same slope, as shown in the following figures.



The condensate water pipe cannot be tied with the refrigerant pipe.

A ventilation hole must be provided on the top of the drain pipe to ensure smoother discharge of condensate water.

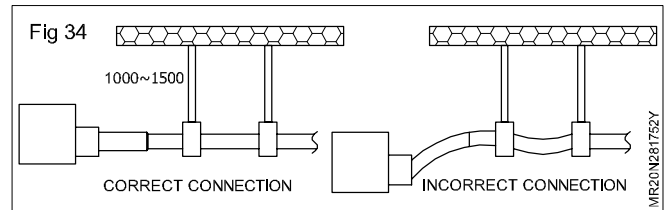
After pipes are connected, perform a test with some water and another test with full water in the pipe to check whether drainage is smooth and whether water leakage exists in the pipe system.

Equip a steel casing for all pipes which are led through the wall or floor. Pipe bonding joints cannot be placed inside the sleeve. The steel casing must be parallel with the bottom of the floor or wall. There must be a height drop of 20 mm from the ground when the pipe is led through the floor. The sleeve cannot affect the inclination degree of the pipe. Fill the gap between the pipe and the sleeve with flexible and non-flammable materials. The sleeve cannot be used as a support point of the pipe.

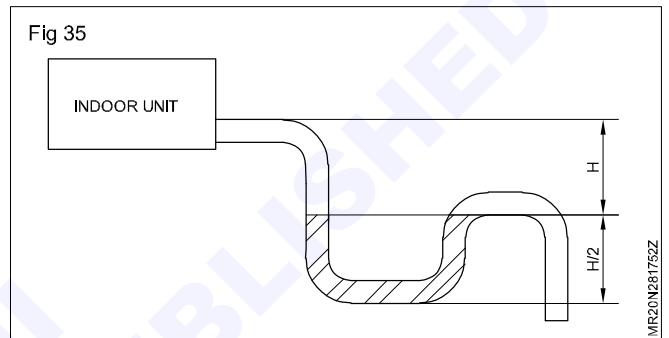
Bond the insulation material joints with special glue and then wrap them with plastic adhesive tape. The width of the adhesive tape must be 5 cm or more to prevent dewing.

Other Requirements (Fig 34)

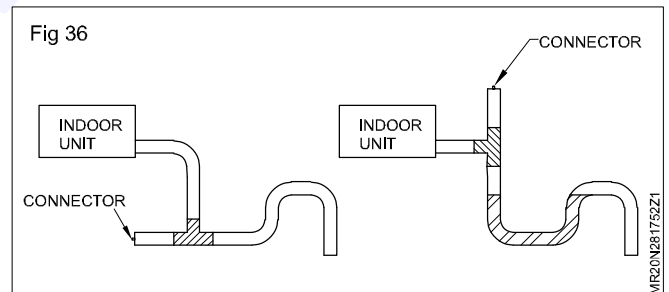
Ensure an inclination degree of more than 1% when connecting the drain pipe to the IDU.



When connecting the drain pipe to that of the IDU, fix the pipes with the bands provided upon delivery instead of using the glue to facilitate further maintenance. When connecting the drain pipe branches to the main pipe, lead through from the above part of the main pipe. If the air volume of the IDUs is high and outdoor air resorption may be caused by negative suction pressure, provide a u-type drain trap at the water outlet side of each IDU, as shown in the following Fig 35.



- Install drain trap connectors as shown in the following Fig 36.
- Install a drain trap connector for each unit.
- The drain trap connector shall be installed in a way that facilitates trap cleaning.



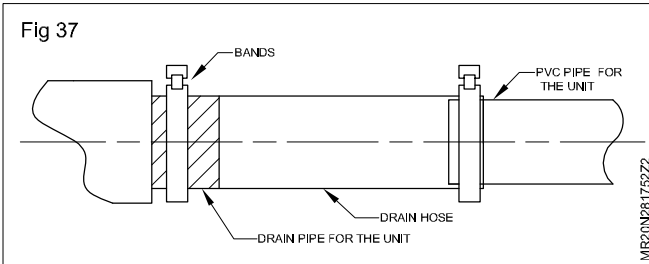
During condensate water pipe installation, ensure a distance above 500 mm between the pipe and the electric box of the unit for maintenance. In a case when the space is not enough, the final piping way must be determined by the technical personnel.

Requirements on Installation of Drain Pipes for Different Types of IDUs

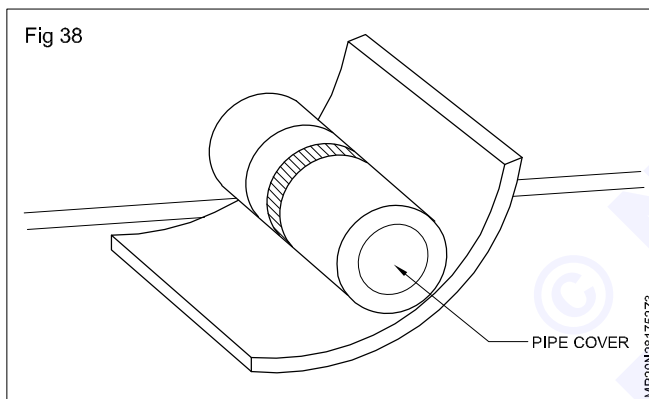
Drain Pipe Installation for Hidden Air-duct-type IDU for Air Supply

- Ensure an inclination degree of greater than 1% when connecting the drain pipe to the IDU.

- b When connecting the drain pipe to that of the IDU, fix the pipes with the bands instead of using the glue to facilitate further maintenance.
- c There is a condensate water outlet on both sides of the IDU. After one condensate water outlet is determined, use the rubber stopper to block the other outlet. Tie it with threads and strap with insulation materials to prevent leakage.
- d The connection between the drain pipe and that of the IDU is shown in the following Fig 37



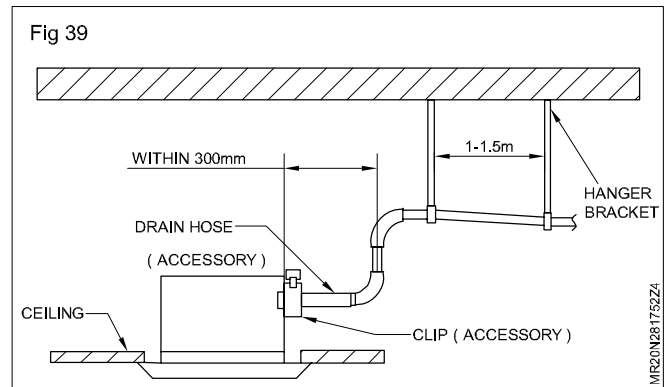
- e Apply insulation materials to the condensate water pipe joints to prevent dewing. Insulation for connection between the drain pipe and that of the IDU is shown in the following Fig 38.



Drain Pipe Installation for IDU

- a Use pipe clips instead of applying glue to connect the hoses provided upon delivery and plastic pipes on the device. Connect the other end of the joint to the elbow. The height from the suction inlet of the discharge pump is about 200 to 500 mm. Ensure a proper inclination degree while connecting to the main drain pipe.

- b The lifting pipe for drainage must be provided as shown in the following Fig 39.



- c The drain pump shall be fixed securely. Otherwise, abnormal noises will be generated.

Requirements on Independent Drainage for Each IDU

Requirements on independent drainage design for each IDU are as follows:

- a There must be a proper inclination for the drain pipe.
- b The drain pipe must be installed to facilitate drainage to the largest extent and be as short as possible.
- c If the water is discharged to the outdoor side, it cannot drop to the outdoor ground directly.

Requirements on Centralized Drainage for IDUs

- a When there are multiple IDUs in the same building, centralized drainage is adopted.
- b When a header pipe is used, the drain pipe of each IDU must be higher than the header pipe.
- c The diameter of the header pipe must be determined on the number and capacity of IDUs.
- d When installing pipe, start from the highest point of the pipe and follow the specified inclination to smoothly discharge condensate water.
- e Connect branches to the main pipe from the upper part or side instead of lower part of the main pipe.
- f Insulate all condensate water pipes, especially for joints at elbows.

Error codes in VRV/VRF

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

- various error codes in VRV/VRF
- diagnosis of the respective error codes.

Whenever a system malfunctions, it is very much needed to rectify the

Faults and return the system to its normal operating condition. In the

Latest and advance technology, error codes help us to identify the

Accurate problem happening in the system thereby helps to shoot the Trouble.

The error codes are some specific numbers that identifies what the error is

To the system. It also can be helpful to find the solution of the problem.

If we find error code we need to refer the servicing manual of the

Respective company.

Note: ERROR CODES can vary from manufacturer to manufacturer model error coder and description for reference.

	Error code	Error contents
Indoor Unit	A0	External protection device abnormality
	A1	Indoor unit PCB abnormality
	A3	Drain level control system abnormality
	A6	Fan motor lock, overload
		Indoor fan motor abnormality
		Overload/overcurrent/lock of indoor fan motor
		Blower motor not running
		Indoor fan motor status abnormality
		Low indoor airflow
	A7	Swing flap motor abnormality
	A8	Power supply voltage abnormality
		Blower motor stops for over/under voltage
	A9	Electronic expansion valve coil abnormality, dust clogging
	AF	Drain level above limit
	AJ	Capacity determination device abnormality
	C1	Transmission abnormality between indoor unit PCB and fan PCB
		Blower motor communication error
	C4	Heat exchanger liquid pipe thermistor abnormality
	C5	Heat exchanger gas pipe thermistor abnormality
	C6	Combination error between indoor unit PCB and fan PCB
		Blower motor HP mismatch
		Indoor blower does not have required parameters to function
	C9	Suction air thermistor abnormality
	CA	Remote sensor abnormality
Discharge air thermistor abnormality		

	Error code	Error contents	
	CC	Humidity sensor system abnormality	
	CE	Infrared presence/floor sensor error	
	CJ	Remote controller thermistor abnormality	
Outdoor Unit	E1	Outdoor unit main PCB abnormality	
	E3	Actuation of high pressure switch	
	E4	Actuation of low pressure sensor	
	E5	Inverter compressor motor lock	
	E6	Compressor damage alarm	
	E7	Outdoor fan motor abnormality	
	E9	Electronic expansion valve coil abnormality	
	F3	Discharge pipe temperature abnormality	
	F4	Wet alarm	
	F6	Refrigerant overcharged	
	H3	Harness abnormality (between outdoor unit main PCB and inverter PCB)	
	H7	Outdoor fan motor signal abnormality	
	H9	Outdoor air thermistor (R1T) abnormality	
	J3		Discharge pipe thermistor (R21T, R22T, R2T) abnormality
			Compressor body thermistor (R14T) abnormality
	J5	Compressor suction thermistor (R12T) abnormality Suction air thermistor (R10T) abnormality	
	J6		Heat exchanger deicer thermistor (R11T) abnormality
			Heat exchanger gas pipe thermistor (R8T, R9T) abnormality
	J7		Receiver inlet thermistor (R3T) abnormality
			Sub cooling heat exchanger liquid pipe thermistor (R7T) abnormality
J8	Heat exchanger liquid pipe thermistor (R4T, R5T) abnormality		
J9	Sub cooling heat exchanger gas pipe thermistor (R6T) abnormality Receiver gas purge thermistor (R13T) abnormality		
JA	High pressure sensor abnormality		

	Error code	Error contents
Outdoor Unit	JC	Low pressure sensor abnormality
	L1	Inverter PCB abnormality
	L3	Reactor temperature rise abnormality
	L4	Inverter radiation fin temperature rise abnormality
	L5	Inverter compressor instantaneous overcurrent
	L8	Inverter compressor overcurrent
	L9	Inverter compressor startup abnormality
	LC	Transmission error between inverter PCB and outdoor unit main PCB
	P1	Power supply voltage imbalance
	P3	Reactor temperature abnormality

	Error code	Error contents	
	P4	Inverter radiation fin temperature abnormality	
	PJ	Field setting after replacing outdoor unit main PCB abnormality or combination of PCB abnormality	
System	U0	Refrigerant shortage	
	U1	Reverse phase, open phase	
	U2	Power supply insufficient or instantaneous abnormality	
	U3	Check operation not executed	
	U4	Transmission error between indoor units and outdoor units	
	U5	Transmission error between remote controller and indoor unit	
	U7	Transmission error between outdoor units	
	U8	Transmission error between main and sub remote controllers	
	U9	Transmission error between indoor unit and outdoor unit in the same system	
	UA		Improper combination of indoor unit and outdoor unit, indoor unit and remote controller
			Incorrect electric heater capacity setting
	UC (1)	Address duplication of centralized controller	
	UE	Transmission error between centralized controller and indoor unit	
	UF	System not set yet	
UH	System abnormality, refrigerant system address undefined		

Error Codes - Sub Codes

If an error code like the one shown below is displayed when the navigation remote controller (BRC1E series) is in use, make a detailed diagnosis or a diagnosis of the relevant unit.

Indoor Unit

Error codes	Errors
A0 - 01	External protection device abnormality
A6 - 01	Fan motor locked
A6 - 10	Fan overcurrent error
A6 - 11	Fan position detection error
A6 - 20	Indoor fan motor status abnormality
A6 - 21	Indoor fan motor insufficient airflow abnormality
A8 - 01	Power supply voltage error
A9 - 01	Electronic expansion valve error
A9 - 02	Refrigerant leakage detection error
AH - 03	Transmission error (between the self-cleaning decoration panel and the Indoor unit) (when the self-cleaning decoration panel is mounted)
AH - 04	Dust detection sensor error (when the self-cleaning decoration panel is mounted)
AH - 05	Dust collection sign error (when the self-cleaning decoration panel is mounted)

Error codes	Errors
AH - 06	Air filter rotation error (when the self-cleaning decoration panel is mounted)
AH - 07	Damper rotation error (when the self-cleaning decoration panel is mounted)
AH - 08	Filter self-cleaning operation error (when the self-cleaning decoration panel is mounted)
AH - 09	Filter self-cleaning operation start disabled error (when the self-cleaning decoration panel is mounted)
AJ - 01	Capacity setting error
AJ - 02	Electronic expansion valve setting error
C1 - 01	Transmission abnormality between indoor unit PCB and fan PCB
C1 - 07	Blower motor communication error
C6 - 01	Defective combination of indoor unit PCB and the fan PCB
	Blower motor HP mismatch
C6 - 02	Indoor blower does not have required parameters to function
U4 - 01	Indoor-outdoor transmission error
UA - 13	Refrigerant type error
UA - 15	Not applicable for self-cleaning decoration panel [when the self-cleaning decoration panel is mounted]
UA - 17	Incorrect electric heater capacity setting

Note: 1. The system can keep operating, however, be sure to check and repair.

Refer to the related Exercise: in the practical book to find out the diagnostic and checking processes of these error codes.

- 2 The system may or may not continue operation depending on the conditions.

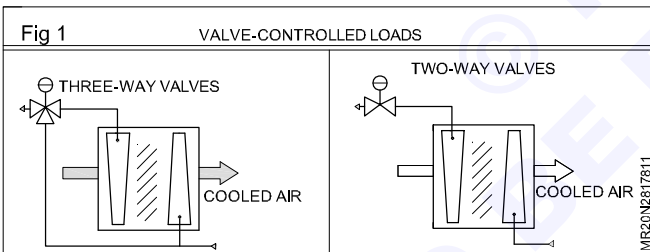
Understanding and checking of modulating valve in chiller system

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

- **modulating valve**
- **expansion valves.**

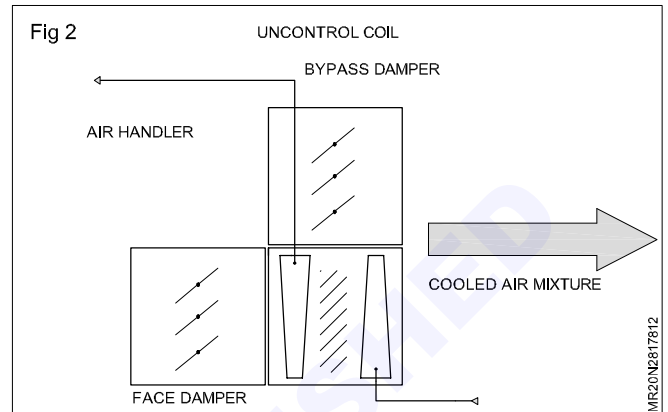
Valves: Manual or automatic valves regulate the flow of water throughout the piping system. valves perform four basic functions: 1) starting, stopping, and directing flow; 2) regulating or throttling flow; 3) preventing backflow; and 4) relieving or regulating pressure. Balance valves, also called circuit setter, are a special type of regulating valve that limit flow at design conditions. This allows the system to flow. Excessive pressure drop across these valves can waste a considerable amount of energy. Valve bodies are available in many configurations according to type of service. Regardless of function, the basic valve components are the body, seat, stem and packing or gasket. Valve actuators control water flow through automatic valves in response to electronic or pneumatic control signals. Either two-way or three-way valves reduce flow and are commonly found in variable-flow systems. Three-way valves maintain a single flow rate by diverting the water around the coil. Heat transferred from the loads can be controlled in a number of ways.

Three-way valve, two-way valve Variable-speed pump uncontrolled coils. (Fig 1 & 2)



Variable - speed pumping load control

By using pump for each coil, the flow may be controlled by varying the pump speed. In such systems, there may be no control valves at the coil. This can reduce both the valve and the valve installation costs. Uncontrolled coils shows a control variation using an uncontrolled or "wild" coil. In this system, control of the conditioned air supply is executed by face-and-bypass dampers that permit a portion of the air to bypass the coil surface. Advantages of the strategy are the elimination of control valves and improved part-load dehumidification. A disadvantage is the all the water is pumped all the time; however, in systems with very small water pressures drops, this system arrangement may work economically.



Three-way valve load control

A three-way control valve regulates the amount of water passing through a coil in response to loads. The valve bypasses unused water around the coil and requires a constant flow of water in the system, regardless of load. A drawback of this bypass is that the temperature of the water leaving the three-way valve is reduced at part-load conditions. This can be a major cause of so-called "low DT syndrome" discussed on page 63 in the section Chilled Water-System Issues. Three-way valves are used in many existing systems. Valve-controlled loads.

Two-way valve load control

A two-way, water modulating valve at the coil performs the same water throttling function as the three-way valve. The coil sees no difference between these two methods. The chilled-water system, however, sees a great difference. In the case of the two-way valve, all flow in the coil circuit is throttled. No water is bypassed. Consequently, a system using two-way valves is a variable-flow chilled-water system. The temperature of the water leaving the coil is not diluted by bypass water so at part-load conditions, the system return-water temperature is higher than with three-way valve control.

Modulating control valves: There are two valve types, two-way and three-way. Either type can be used for both constant-flow and variable-flow pumping.

Two-way valves: These can be used in a constant-flow pumping system in conjunction with a bypass valve that controls pressures. They allow unused water to return to the central plant if the supply pressure gets too high due to a number of the valves closing. They can also be used in variable-flow pumping systems where the pump output is controlled directly by the differential pressure.

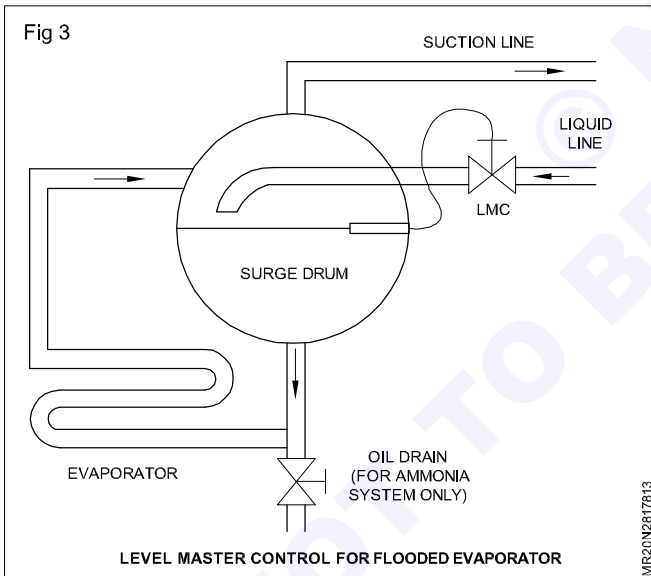
Three-way valve: These are traditionally used in constant-flow pumping system, where the unused water is bypassed at the coil. They are also used in variable flow pumping systems. In special cases, several may be installed at the end of the longest piping runs. The sum of their flow equals the minimum flow the pump can produce in stably. This also allows the piping system to stay at the temperature set point in case another air handler requires immediate chilled or heating water.

Float switch

The float switch in conjunction with liquid line solenoid valve is sometimes used as a liquid flow control for flooded system. A throttling valve (manual) may be needed between the solenoid valve and the evaporator inlet.

Level Master Control (LMC) (Fig 3)

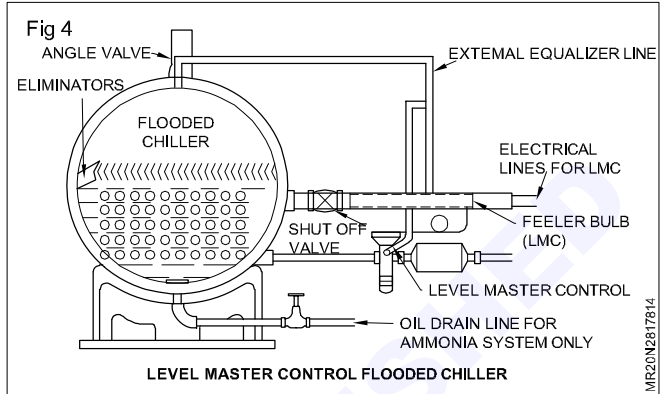
The LMC, is another throttling device used in flooded chiller. Figures represent LMC for the flooded evaporation (chiller). It is a modified thermostatic expansion valve with an electrical heater incorporated in its feeler bulb. As the refrigerant vapour cannot get superheated in a flooded chiller, the heat necessary at the feeler bulb for opening the valve is supplied by a small wattage electric heating element in the feeler bulb. The sensing bulb is fixed in the chiller so as to have direct contact with the refrigerant liquid in the chiller. It is located at a level at which the liquid level has to be maintained should be such that it submerges the chiller tube bundle.



Regarding the control & equipments mostly discussed is previous chapters. In package air conditioner most of controls are used.

Checking procedure of the control items explained clearly in practical topic.

Pressure relief valve (Fig 4): It is safety device used is shell & tube condenser to release the excess pressure before major damage the condenser shell. It acts on pressure.



Fusible plug: It is also safety device used in shell & tube condenser to protect the shell from excess pressure generates inside the shell. It acts on temperature. The lead packing metals (use) when high temperature generates due to high pressure.

Difference with pressure relief valve: Pressure relief valve re-set after release the excess pressure.

The fusible release entire the gas when melted/fuse the lead packing.

FCU and Water Control Valves

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

- fan Coil Unit and its types
- water Control Valves and types.

Fan Coil Units: The Fan Coil Unit (FCU) is a sheet metal cabinet. The houses a chilled water coil, a blower with motor and an air filter. These are generally used, where multiply storey buildings of cold storage plants, or multiple storey buildings of cold storage plants, or multiple area like big Hotel's rooms are to be cooled independently, using central air- conditioning plant.

Types of fan coil unit (Fig 1)

Fan coil units are divided into types

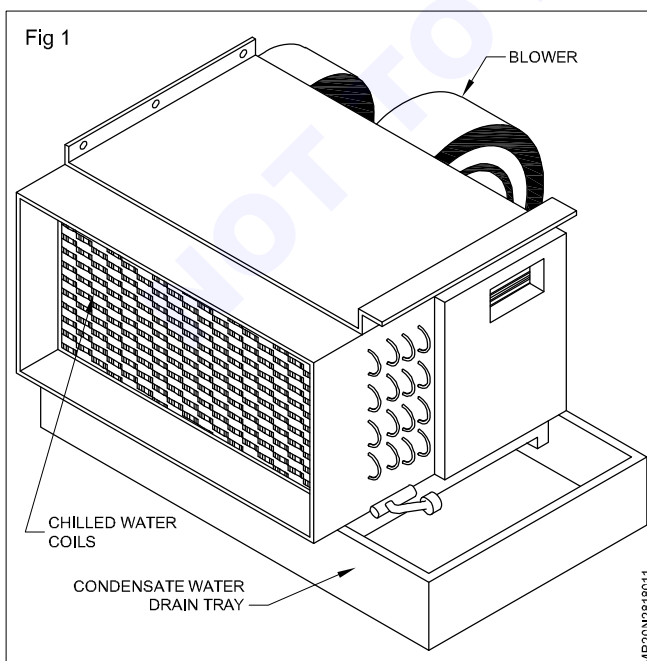
1 Two-pipe fan coil unit:

Two-pipe fan coil units have one supply and one return pipe. The supply pipe supplies either cold or hot water to the unit depending on the time of year.

2 Four-pipe fan coil units:

Four-pipe fan coil units have two supply pipes and two return pipes. This allows either hot or cold water to enter the unit at any given time. Since it is often necessary to be at and cool different areas of a building at the same time, due to differences in internal heat loose or heat gains, the four-pipe fan unit is most commonly used.

The water is chilled centrally and pumped to various parts of the buildings through insulated pipes. The chilled water enters to FCU, where heat exchange takes place between the room air and the chilled water in the coil. Air is forced by the blower, passed over the coils. The air speed can be controlled by the closing the fan speed by selected switch.

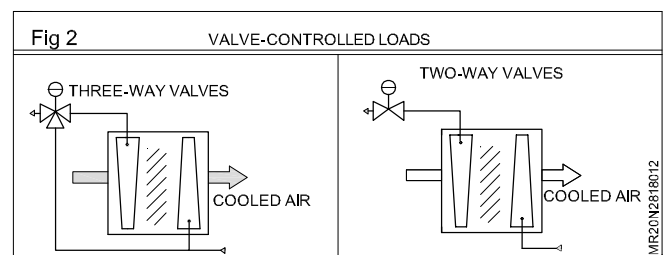


The thermostat controls the solenoid valve that closes the chilled water flow, when the room attains the desired temperatures while the temperatures raises it allows the chilled water into the coil.

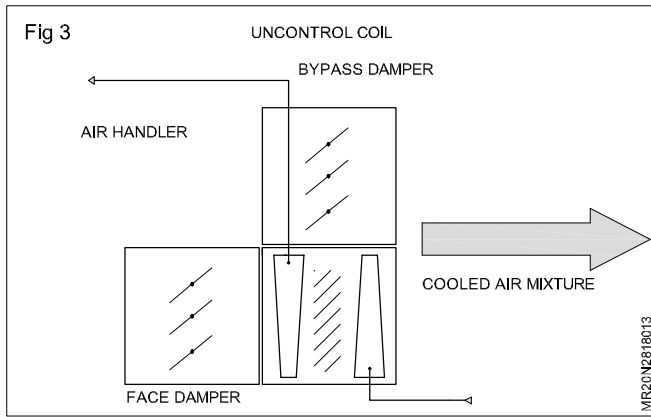
Introduction (Fig 2)

Valves: Manual or automatic valves regulate the flow of water throughout the piping system. Valves perform four basic functions: 1) starting, stopping, and directing flow; 2) regulating or throttling flow; 3) preventing backflow; and 4) relieving or regulating pressure. Balance valves, also called circuit setter, are a special type of regulating valve that limit flow at design conditions. This allows the system to be balanced so that every coil in the system has adequate flow. Excessive pressure drop across these valves can waste a considerable amount of energy. Valve bodies are available in many configurations according to type of service. Regardless of function, the basic valve components are the body, seat, stem, and packing or gasket. Valve actuators control water flow through automatic valves in response to electronic or pneumatic control signals. Either two-way or three-way valve control the flow of heating or cooling water. Two-way valve reduce flow and are commonly found in variable-flow systems. Three-way valve maintain a single flow rate by diverting the water around the coil. Heat transferred from the loads can be controlled in a number of ways:

Three-way valve tow-way valve Variable-speed pump, uncontrolled coils.



Variable-speed pumping load control (Fig 3): By using a pump for each coil, the flow may be controlled by varying the pump speed. In such systems, there may be no control valves at the coil. This can reduce both the valve and the valve installation costs. Uncontrolled coils shows a control variation using an uncontrolled or "wild" coil. In this system, control of the conditioned air supply is executed by face-and -bypass dampers that permit a portion of the air to bypass the coil surface. Advantages of the strategy are the elimination of control valves and improved part-load dehumidification. A disadvantage is the all the water is pumped all the time; however, in systems with very small water pressures drops, this system arrangement may work economically.



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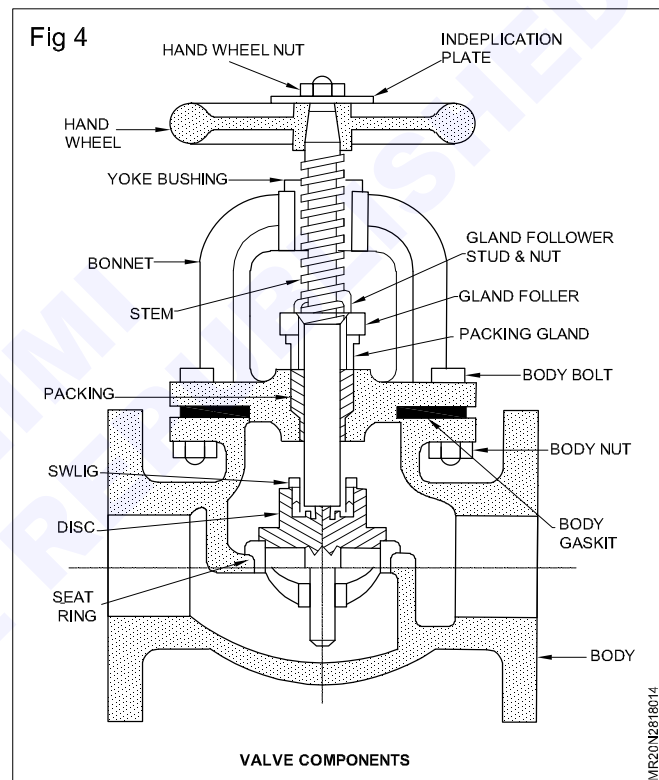
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Humidity control

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

- humidifiers and De-humidifiers
- humidity control
- use of hygrometer.

Humidifier is a device used in the air conditioning application to add water vapour to the air for maintaining comfort condition of human beings.

There are various method of humidifying. The air will be humidified when you expose the large surface of water vapour in a dry moving air. (e.g. Steam)

De-humidifier is a device used in A/C area, to remove excess moisture from air by condensing it in to water. Humidifying equipment may consist of cold wet surface through which air is blown and moisture is condensed out by coming in contact with cold walls. When the coil surface is at temperature is below the dew point temperature of the air. The coil surface temperature must be kept above the freezing temperature to prevent frost accommodation over the surface which may block the circulation of air.

Humidity control

The instrument, which controls the relative humidity of an air-conditioning space at a satisfactory level is known as humidity control or humidistat.

It is connected in series with the line to close or open the electric circuit of a humidifier or de-humidifier as on when require. The element of the humidistat changes as the position of the humidity changes. This element is called hygroscopic element. It is usually made of human hair or woolen. Its size is increased as the humidify increase and decreases with the decrease of humidity. It should be kept in an open space but it should be kept free from dust because the dust will product insulation on the element and will effect its functioning.

Humidity sensors used in HVAC&R for direct humidity indication or operating controls are separated into the following categories: mechanical hygrometers and electronic hygrometers.

Humidifiers, Dehumidifiers and humidity controls are commonly used in electric industry, textile & aircrafts.

Mechanical Hygrometers

Mechanical hygrometers operate on the principle that hygroscopic materials expand when they absorb water vapor or moisture from the ambient air. They contract when they release moisture to the surrounding air. Such hygroscopic materials include human and animal hairs, plastic polymers like nylon ribbon, natural fibers, wood, etc. When these materials are linked to mechanical linkages or electric transducers that sense the change in

size and convert it into electric signals, the results in these devices can be calibrated to yield direct relative-humidity measurements of the ambient air.

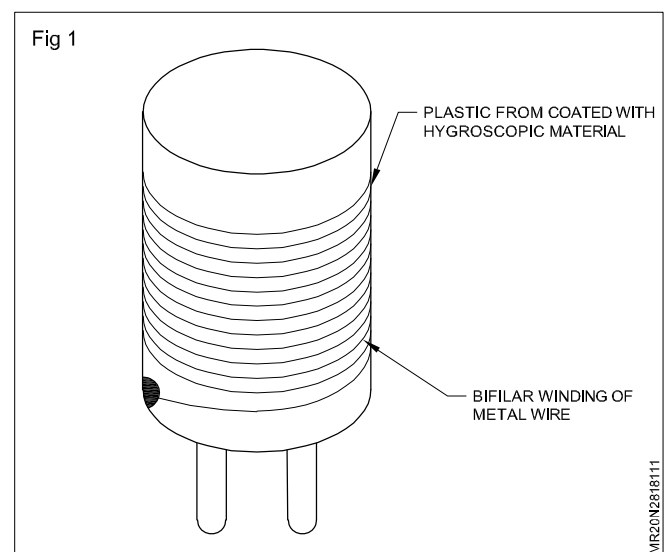
Electronic Hygrometers (Fig 1)

There are three types of electronic hygrometers: Dunmore resistance hygrometers, ion-exchange resistance hygrometers, and capacitance hygrometers.

Dunmore Resistance Hygrometer. In 1938, Dunmore of the National Bureau of Standards developed the first lithium chloride resistance electric hygrometer in the United States. This instrument depends on the change in resistance between two electrodes mounted on a hygroscopic material. The electrodes could be, e.g., a double-threaded winding of noble-metal wire mounted on a plastic cylinder coated with hygroscopic material. The wires can also be in a grid-type arrangement with a thin film of hygroscopic material bridging the gap between the electrodes.

At a specific temperature, electric resistance decreases with increasing humidity. Because the response is significantly influenced by temperature, the results are often indicated by a series of isothermal curves. Relative humidity is generally used as the humidity parameter, for it must be controlled in the indoor environment. Also the electrical response is more nearly a function of relative humidity than of the humidity ratio.

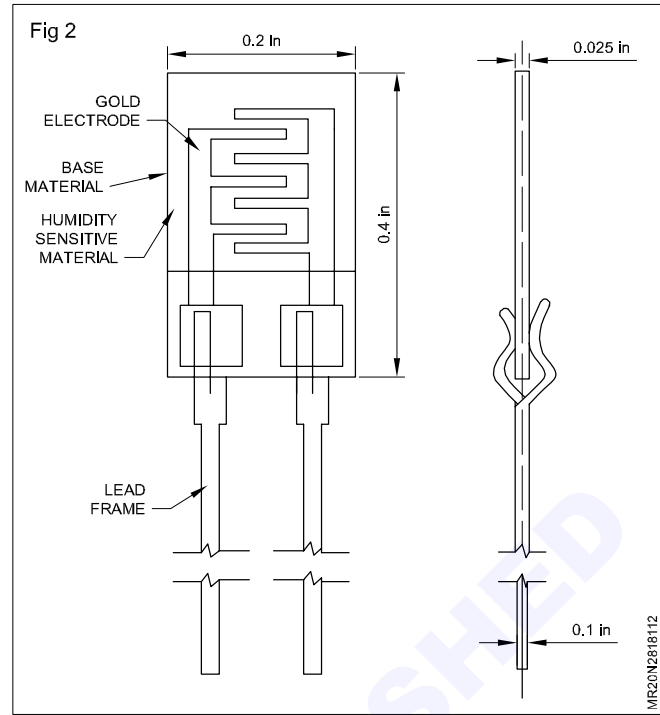
In addition to lithium chloride, lithium bromide is sometimes used as the sensor.



Ion-Exchange Resistance Hygrometer. The sensor of an ion-exchange resistance electric hygrometer is composed of electrodes mounted on a base plate and a high-polymer resin film, used as a humidity-sensing material, cross-linking the electrodes. Humidity is measured by the change in resistance between the electrodes. When the salt becomes conductive because of the presence of water vapor in the ambient air, the greater the ionization becomes, and therefore, the greater the concentration of mobile ions. On the other hand, lower relative humidity reduces the ionization and results in a lower concentration of mobile ions. The resistance of the humidity-sensing material reflects the change in relative humidity of the ambient air.

Capacitance Hygrometer (Fig 2)

The commonly used capacitance sensor consists of a thin-film plastic foil. A very thin gold coating covers both sides of the film as electrodes, and the film is mounted inside a capsule. The golden electrodes and the dividing plastic foil form a capacitor. Water vapor penetrates the gold layer, which is affected by the vapor pressure of the ambient air and, therefore, the ambient relative humidity. The number of water molecules absorbed on the plastic foil determines the capacitance and the resistance between the electrodes.



Construction and study of commercial AC plant

Objectives: At the end of this lesson you shall be able to
 • **construction and working of various commercial AC plants.**

Heating, ventilation, and air conditioning (HVAC) system is designed to achieve the environmental requirements of the comfort of occupants and a process.

HVAC systems are more used in different types of buildings such as industrial, commercial, residential and institutional buildings. The main mission of HVAC system is to satisfy the thermal comfort of occupants by adjusting and changing the outdoor air conditions to the desired conditions of occupied buildings. Depending on outdoor conditions, the outdoor air is drawn into the buildings and heated or cooled before it is distributed into the occupied spaces, then it is exhausted to the ambient air or reused in the system. The selection of HVAC systems in a given building will depend on the climate, the age of the building, the individual preferences of the owner of the building and a designer of a project, the project budget, the architectural design of the buildings.

HVAC systems can be classified according to necessary processes and distribution process. The required processes include the heating process, the cooling process, and ventilation process. Other processes can be added such as humidification and dehumidification process. This process can be achieved by using suitable HVAC equipment such as heating systems, air-conditioning systems, ventilation fans, and dehumidifiers. The HVAC systems need the distribution system to deliver the required amount of air with the desired environmental condition. The distribution system mainly varies according to the refrigerant type and the delivering method such as air handling equipment, fan coils, air ducts, and water pipes.

Classification of HVAC systems (Fig 1)

The major classification of HVAC systems is central system and decentralized or local system. Types of a system depend on addressing the primary equipment location to be centralized as conditioning entire building as a whole unit or decentralized as separately conditioning a specific zone as part of a building. Therefore, the air and water distribution system should be designed based on system classification and the location of primary equipment.

Central HVAC systems

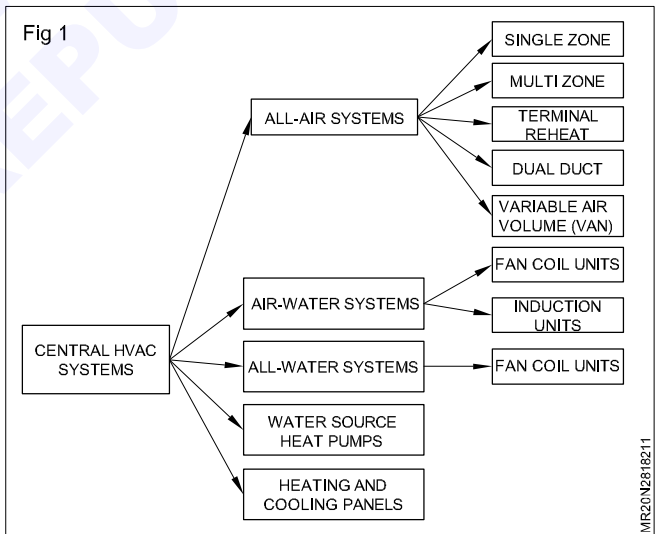
A central HVAC system may serve one or more thermal zones, and its major equipment is located outside of the served zone(s) in a suitable central location whether inside, on top, or adjacent to the building. Central systems must condition zones with their equivalent thermal load. Central HVAC systems will have as several control points

such as thermostats for each zone. The medium used in the control system to provide the thermal energy sub-classifies the central HVAC system.

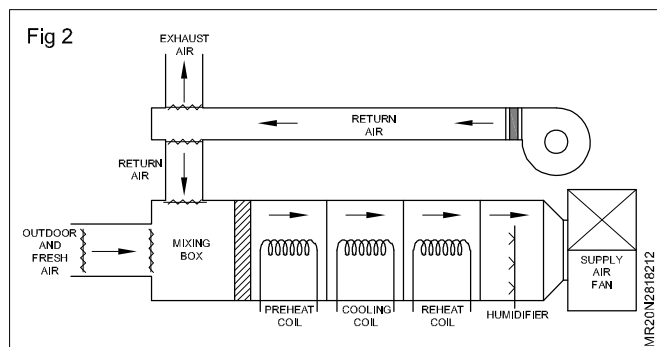
The thermal energy transfer medium can be air or water or both, which represent as all-air systems, air-water systems, all-water systems. Also, central systems include water-source heat pumps and heating and cooling panels. All of these subsystems are discussed below. Central HVAC system has combined devices in an air handling unit, which contains supply and return air fans, humidifier, reheat coil, cooling coil, preheat coil, mixing box, filter, and outdoor air.

All-air systems

The thermal energy transfer medium through the building delivery systems is air. All-air systems can be sub-classified based on the zone as single zone and multizone, airflow rate for each zone as constant air volume and variable air volume, terminal reheat, and dual duct.



Single zone (Fig 2)



A single zone system consists of an air handling unit, a heat source and cooling source, distribution ductwork, and appropriate delivery devices. The air handling units can be wholly integrated where heat and cooling sources are available or separate where heat and cooling source are detached. The integrated package is most-commonly a rooftop unit and connected to ductwork to deliver the conditioned air into several spaces with the same thermal zone. The main advantage of single zone systems is simplicity in design and maintenance and low first cost compared to other systems. However, its main disadvantage is serving a single thermal zone when improperly applied.

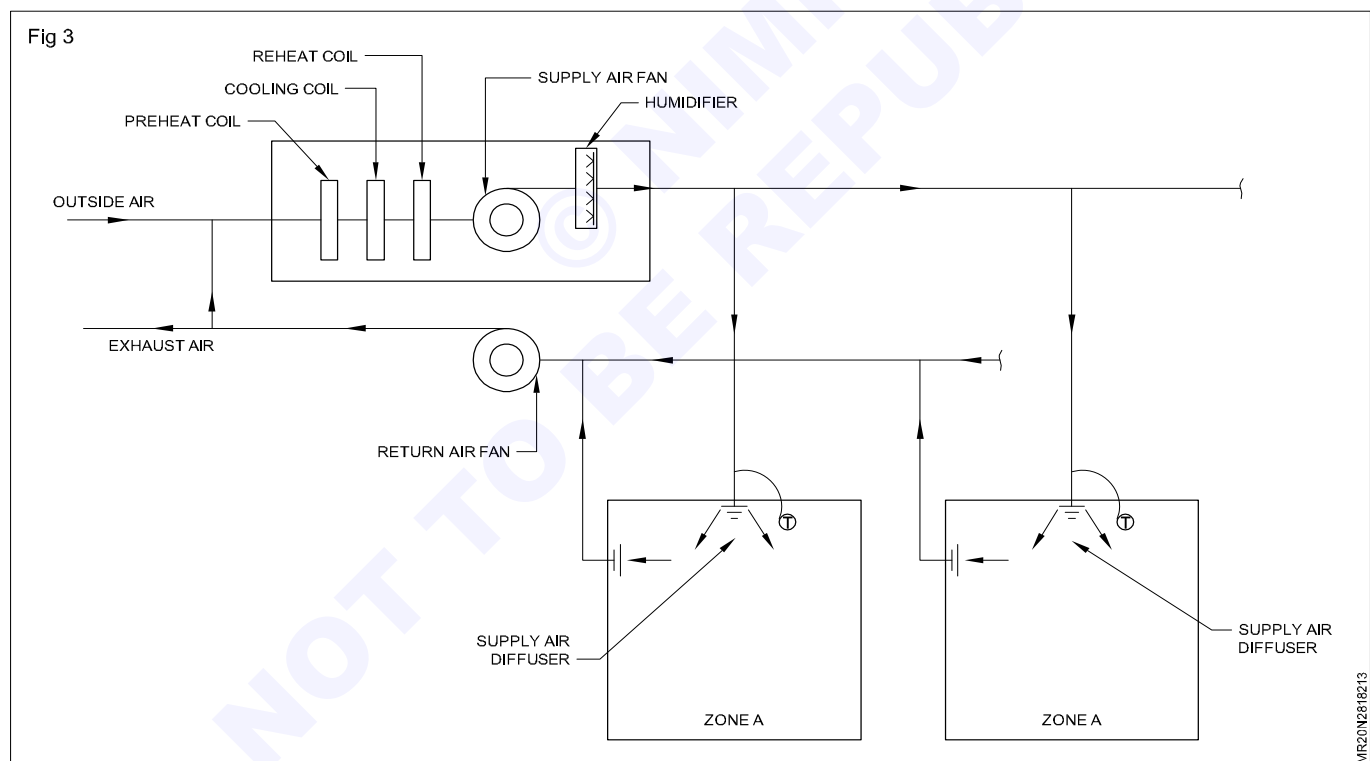
In a single zone all-air HVAC system, one control device such as thermostat located in the zone controls the operation of the system, as shown in. Control may be either modulating or on-off to meet the required thermal load of the single zone. This can be achieved by adjusting the output of heating and cooling source within the packaged unit.

Although few buildings can be a single thermal zone, a single zone can be found in several applications. One family residential buildings can be treated as single zone systems, while other types of residential buildings can include different thermal energy based on the occupation

and building structure. Movements of occupants affect the thermal load of the building, which results in dividing the building into several single zones to provide the required environmental condition. This can be observed in larger residences, where two (or more) single zone systems may be used to provide thermal zoning. In low-rise apartments, each apartment unit may be conditioned by a separate single zone system. Many sizeable single story buildings such as supermarkets, discount stores, can be effectively conditioned by a series of single zone systems. Large office buildings are sometimes conditioned by a series of separate single zone systems.

Multi-zone (Fig 3 & 4)

In a multi-zone all-air system, individual supply air ducts are provided for each zone in a building. Cold air and hot (or return) air are mixed at the air handling unit to achieve the thermal requirement of each zone. A particular zone has its conditioned air that cannot be mixed with that of other zones, and all multiple zones with different thermal requirement demand separate supply ducts, as shown in. Multi-zone all-air system consists of an air handling unit with parallel flow paths through cooling coils and heating coils and



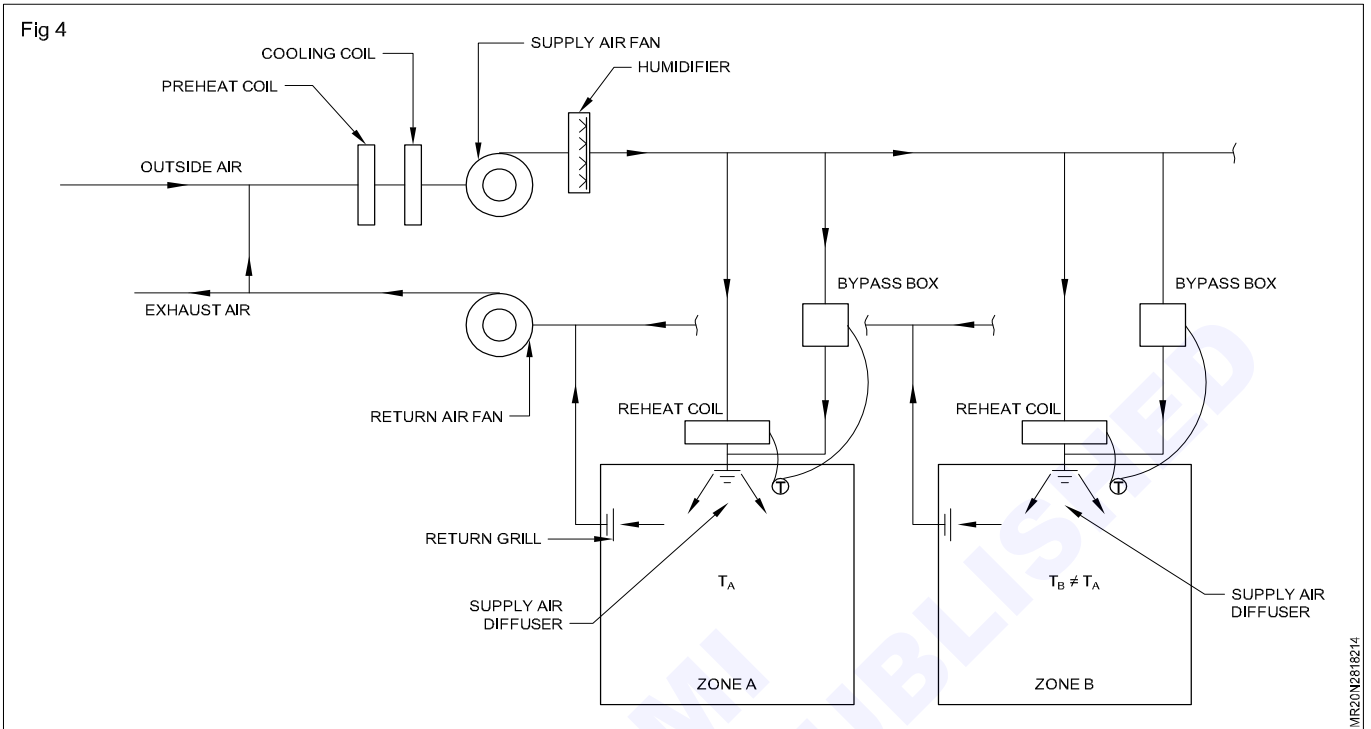
internal mixing dampers. It is recommended that one multi-zone serve a maximum of 12 zones because of physical restrictions on duct connections and damper size. If more zones are required, additional air handlers may be used. The advantage of the multi-zone system is to adequately condition several zones without energy waste associated with a terminal reheat system. However, leakage between the decks of air handler may reduce energy efficiency. The main disadvantage is the need for multiple supply air ducts to serve multiple zones.

Terminal reheat

A terminal reheat all-air system is a multiple zone, which considers an adaptation of single zone system. This can be performed by adding heating equipment, such as hot water coil or electric coil, to the downstream of the supply air from air handling units near each zone. Each zone is controlled by a thermostat to adjust the heat output of heating equipment to meet the thermal condition. The supply air from air handling units is cooled to the lowest

cooling point, and the terminal reheat adds the required heating load. The advantage of terminal reheat is flexible and can be installed or removed to accommodate changes in zones, which provides better control of the thermal conditions in multiple zones. However, the design of

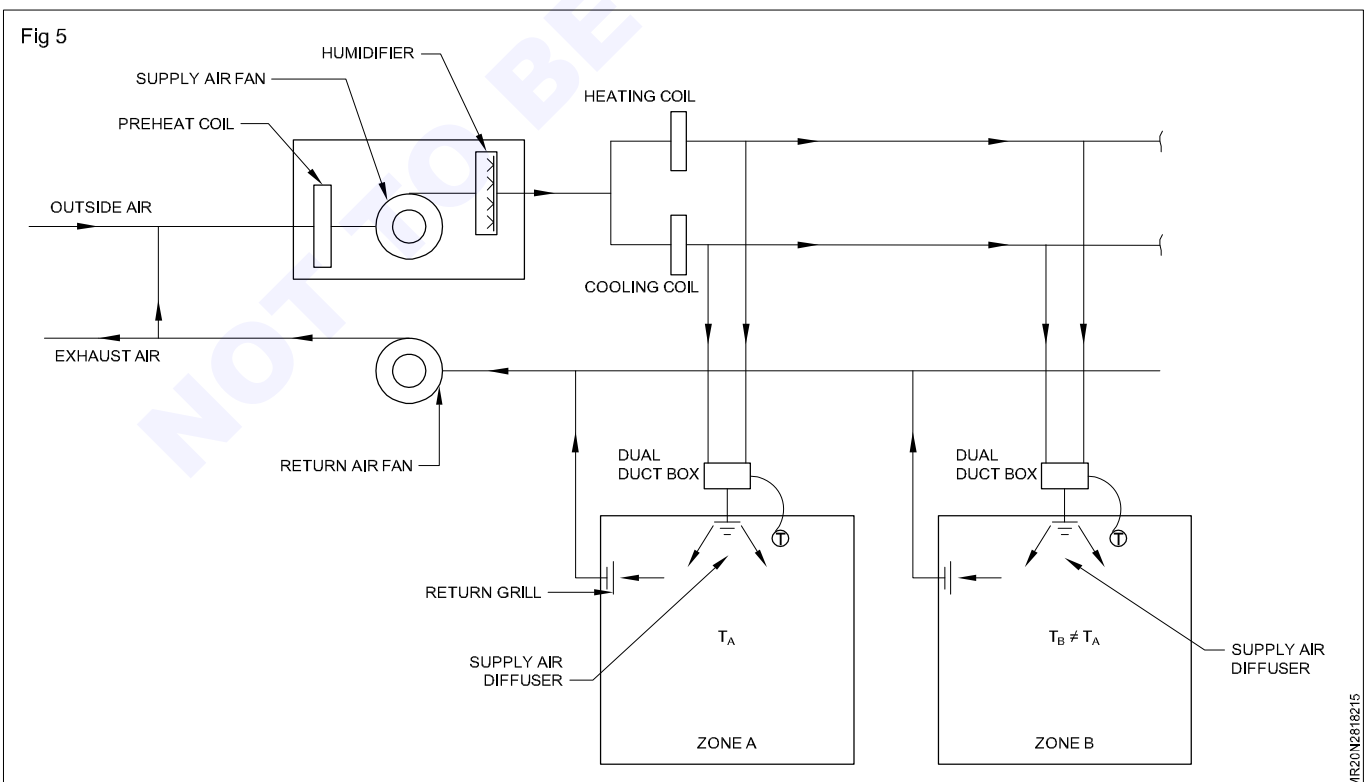
terminal reheat is not energy-efficient system because a significant amount of extremely cooling air is not regularly needed in zones, which can be considered as waste energy. Therefore, energy codes and standards regulate the use of reheat systems.



Dual duct (Fig 5)

The dual duct all-air system is a terminal-controlled modification of the multi-zone concept. A central air handling unit provides two conditioned air streams such as a cold deck and a hot deck. These air streams are distributed throughout the area served by the air handling

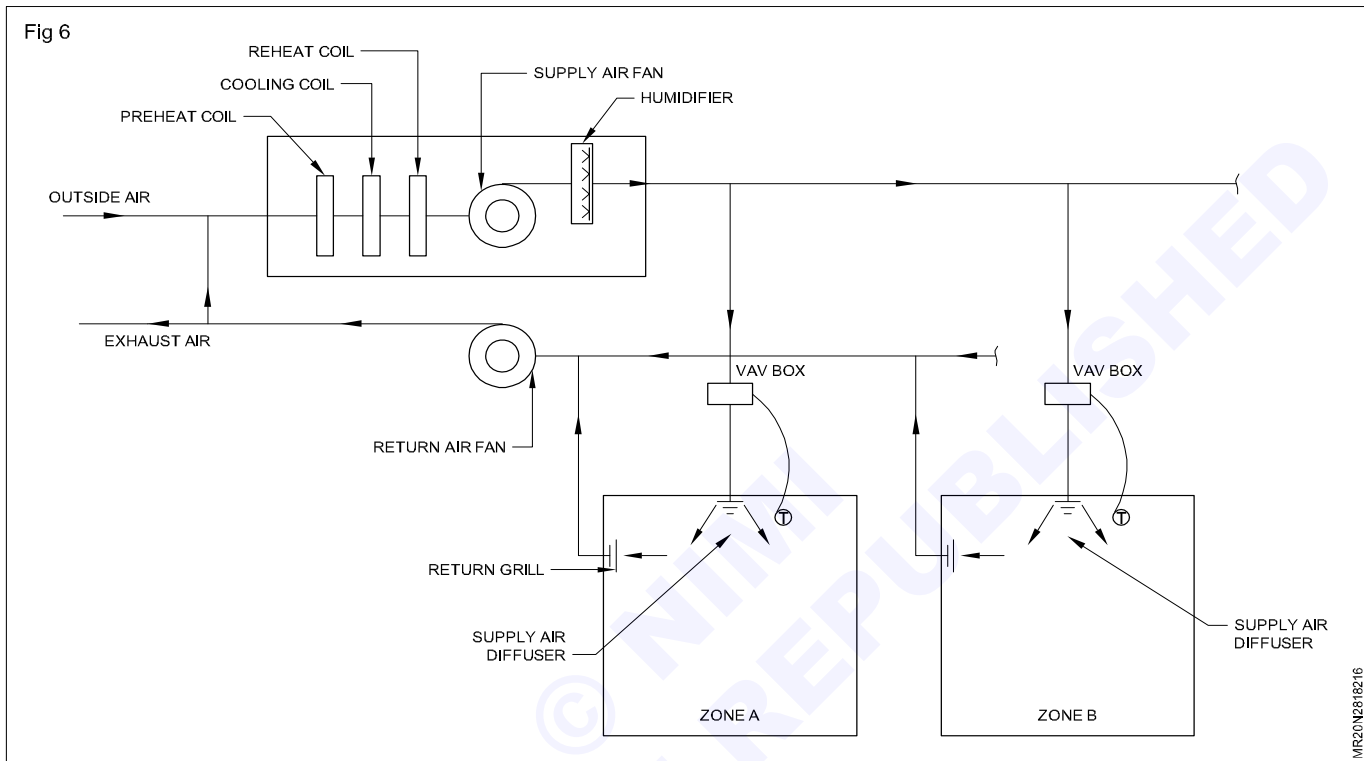
unit in separate and parallel ducts. Each zone has a terminal mixing box controlled by zone thermostat to adjust the supply air temperature by mix the supply cold and hot air. This type of system will minimize the disadvantages of previous systems and become more flexible by using terminal control.



Variable air volume (Fig 6)

Some spaces require different airflow of supply air due to the changes in thermal loads. Therefore, a variable-air-volume (VAV) all-air system is the suitable solution for achieving thermal comfort. The previous four types of all-air systems are constant volume systems. The VAV system consists of a central air handling unit which provides supply air to the VAV terminal control box that located in each zone to adjust the supply air volume. The temperature of supply air of each zone is controlled by

manipulating the supply air flow rate. The main disadvantage is that the controlled airflow rate can negatively impact other adjacent zones with different or similar airflow rate and temperature. Also, part-load conditions in buildings may require low air-flow rate which reduces the fan power resulting in energy savings. It may also reduce the ventilation flow rate, which can be problematic to the HVAC system and affecting the indoor air quality of the building.



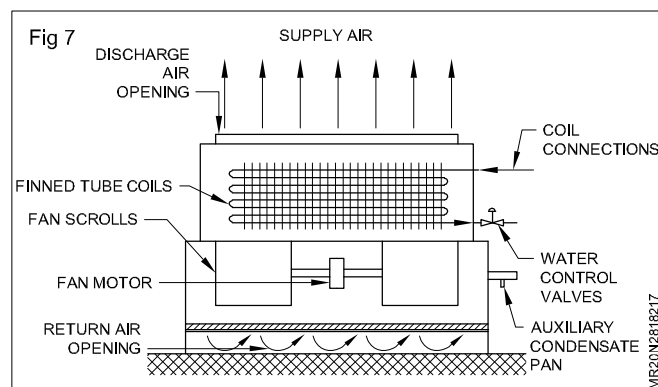
All-water systems

In an all-water system, heated and cooled water is distributed from a central system to conditioned spaces [4, 5]. This type of system is relatively small compared to other types because the use of pipes as distribution containers and the water has higher heat capacity and density than air, which requires the lower volume to transfer heat. All-water heating-only systems include several delivery devices such as floor radiators, baseboard radiators, unit heaters and convectors. However, all-water cooling-only systems are unusual such as valance units mounted in the ceiling. The primary type that is used in buildings to condition the entire space is a fan-coil unit.

Fan-coil units (Fig 7)

Fan-coil unit is considerably small unit used for heating and cooling coils, circulation fan, and proper control system. The unit can be vertically or horizontally installed. The fan-coil unit can be placed in the room or exposed to occupants, so it is essential to have appropriate finishes and styling. For central systems, the fan-coil units are connected to boilers to produce heating and to water chillers to produce cooling to the conditioned space. The desired temperature of a zone is detected by a thermostat which controls the water flow to the fan-coil units. In

addition, occupants can adjust fan coil units by adjusting supply air louvers to achieve the desired temperature. The main disadvantage of fan-coils is ventilation air and only can be solved if the fan-coil units are connected to outdoor air. Another disadvantage is the noise level, especially in critical places.



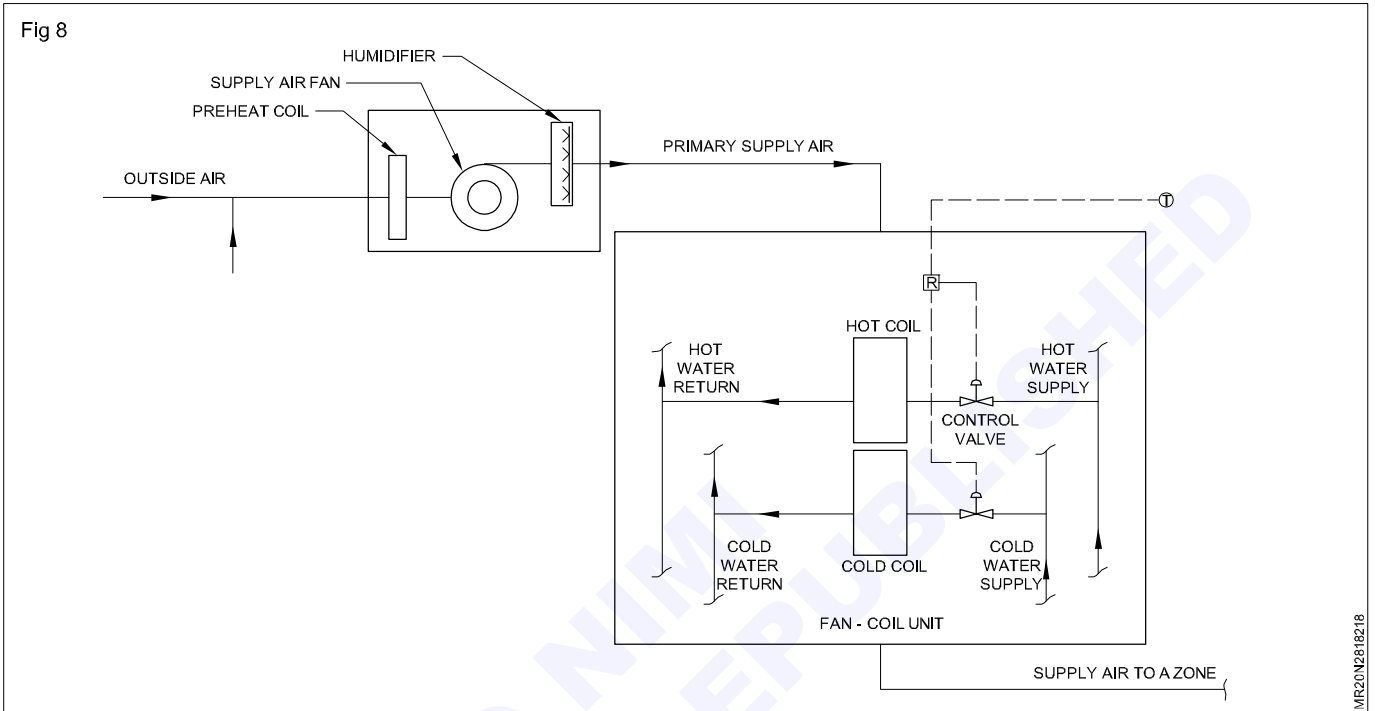
Air-water systems

Air-water systems are introduced as a hybrid system to combine both advantages of all-air and all-water systems [5]. The volume of the combined is reduced, and the outdoor ventilation is produced to properly condition the

desired zone. The water medium is responsible for carrying the thermal load in a building by 80-90% through heating and cooling water, while air medium conditions the remainder. There are two main types: fan-coil units and induction units.

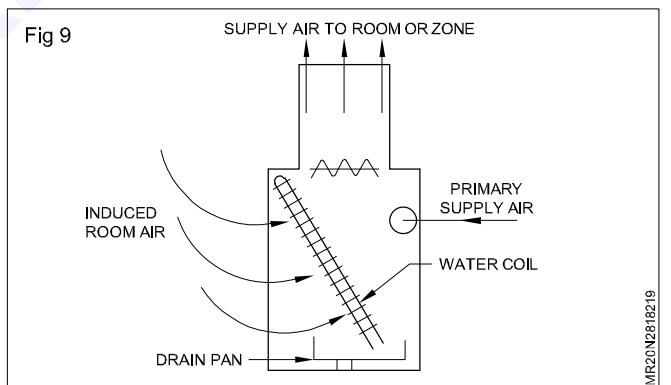
Fan-coil units (Fig 8)

Fan-coil units for air-water systems are similar to that of all-water systems except that the supply air and the conditioned water are provided to the desired zone from a central air handling unit and central water systems (e.g., boilers or chillers). The ventilation air can be separately delivered into space or connected to the fan-coil units. The major types of fan-coil systems, are 2 pipes or 4-pipes systems.



Induction units (Fig 9)

Induction units are externally similar to fan-coil units but internally different. An induction unit induces the air flow in a room through cabinet by using high-velocity airflow from a central air handling unit, which replaces the forced convection of the fan in the fan-coil by the induction or buoyancy effect of the induction unit. This can be performed as mixing the primary air from the central unit and the secondary air from the room to produce a suitable and conditioned air into the room/zone.



Chiller, Packaged chiller, reciprocating, screw scroll and centrifugal chiller

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

- chiller and its types
- packaged Chiller
- screw, reciprocating, scroll and centrifugal type chiller.

Chiller and its types (Fig 1)

Chiller is a device which is used in commercial HVAC machineries to cool secondary refrigerants like brine or water by evaporating liquid refrigerant for further use or to condition large spaces. In the chiller the liquid refrigerant moves inside the tubes and water or brine flows outside the tubes i.e. inside the shell. Due to temperature difference, the refrigerant takes heat from the water or brine and turns the liquid refrigerant into vapour form, in turn making the secondary refrigerant cold enough.

Based on Vapour compression system chillers are further classified as

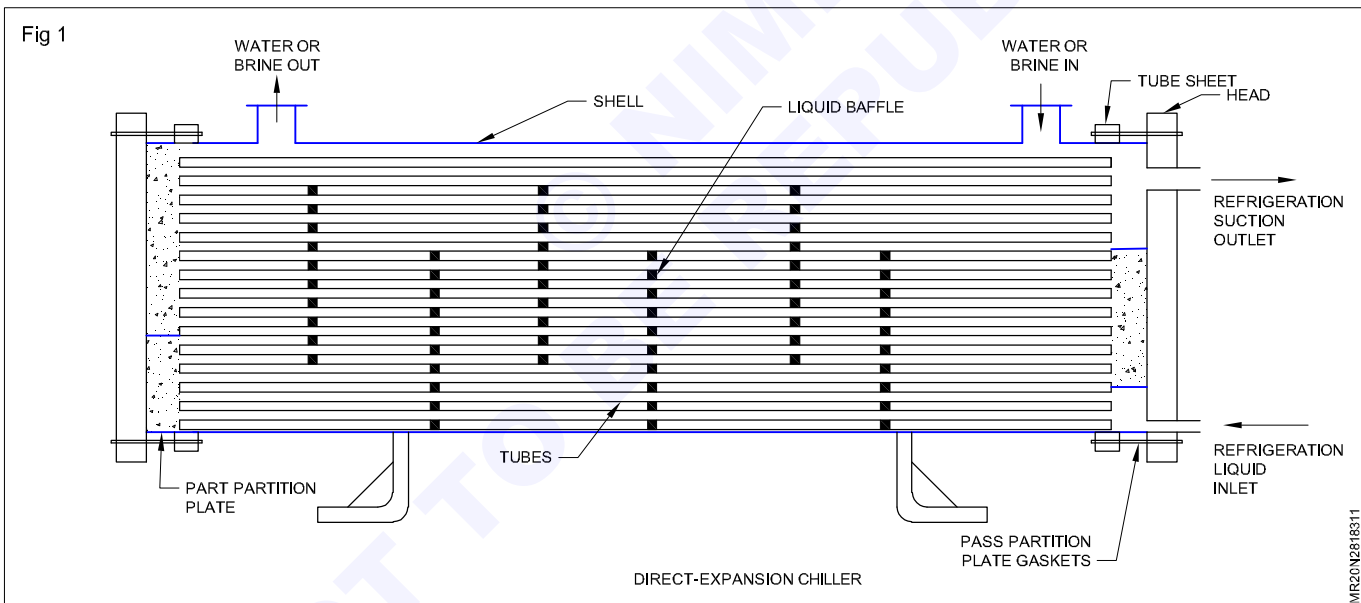
- a Chillers system with air-cooled condenser and
- b Chiller system with water cooled condenser.

Both these types are further classified as

- a DX Chiller
- b Flooded type chiller

Both these above mentioned types have some common types, they got their names based on the compressor types used in the system, they are:

- Reciprocating Chiller
- Screw Chiller
- Scroll Chiller
- Centrifugal Chiller



DX Chiller

The Working of a DX chiller is similar to the dry-expansion coil. The liquid refrigerant is fed through an expansion valve. The water or liquid to be cooled flows inside in the shell, while the refrigerant is in the tubes. When the flow rate or liquid viscosity is high, short, widely spaced baffles are used to reduce the velocity and minimize the pressure drop through the chiller. When the flow rate or liquid viscosity is low, longer, more closely spaced baffles are used in order to increase fluid velocity and improve the heat transfer coefficient. The number and the length of the refrigerant circuits required to maintain the refrigerant velocity through the chiller tubes within reasonable limits depend on the total chiller load, good strainers should be

provided on the inlet water line to the chiller. In applications where the water side surface can get fouled up much, it is therefore not advisable to use a DX chiller.

Flooded Chiller

In flooded chillers, water/brine is circulated through the tube bundle and the refrigerant is on the shell side. So it is possible to brush and clean the water tubes. The flooded chiller is more suitable than a DX chiller. For applications where the water surfaces can get fouled up.

The liquid-refrigerant level in the shell is maintained such that it completely submerges the water tube bundle. Thus, the evaporator surface is always remain wetted by the refrigerant, which improves the heat-transfer capacity of the flooded chiller over the DX chiller.

Due to the agitation caused by the boiling of the liquid refrigerant the liquid can 'fountain' to the suction outlet and get entrained into the suction line along with the refrigerant vapour. To trap such escaping liquid and to prevent it from entering the suction line and the compressor, an ' accumulator' or surge drum ' is provided at the suction outlet of the chiller. The accumulator is much bigger in size and cross sectional area as compared to the suction line.

Packaged Chillers

Most liquid chillers in use today are specified as part of a package that includes, along with the chiller, a complete condensing unit with associated piping, controls, and other accessories. The condensing unit may be either air- or water-cooled with reciprocating screw or centrifugal compressor

An air-cooled chiller package employing three parallel reciprocating compressors.

The included electronic control panel features a microprocessor that continuously monitors data from a network of sensors and controls to accurately maintain control set points and ensure efficient operation under various load conditions.

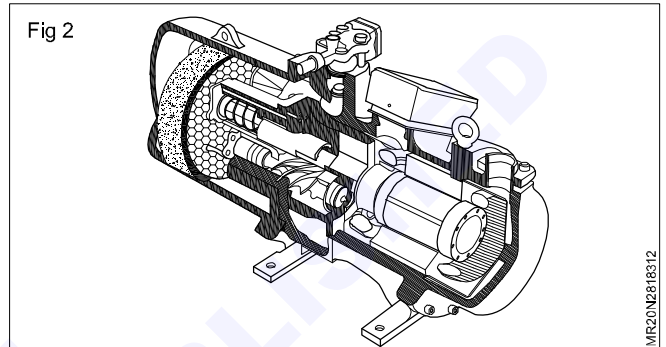
Screw Chiller unit can be of either with air cooled or water cooled condenser.

Air-cooled Screw Chiller Unit adopts twin-screw compressor designed with the most advanced. Air-cooled Screw Chiller Unit dispense with many auxiliaries such as cooling tower. Cooling water pump boiler. relevant piping system and so on. System structure is suppleness, installation space is frugal, maintenance manage is convenience and the unit is energy-saving, the unit apply to the area where water is shortage. Air-cooled Screw Chiller Unit installs outside , adopts advanced technique, low-noise, high-energy efficiency, semi-enclosed two-screw compressor. Two-screw compressor matches with the high-energy efficiency evaporator and condenser, it can exerts the best performance. In the condenser , the fins arrange in some size in the condenser pipe, and also adopts high-efficiency ,low-noise fan. Screw compressor , high-efficiency evaporator, high-heat exchange efficiency condenser and microcomputer control box connect by bolts, adopt steel-structure, spray antirust paint in the surface, all these can ensure the reliably running and the performance. Air-cooled Screw Chiller Unit adopts twin-screw compressor designed with the most advanced, industrial third-generation asymmetric technology of 5 gear teeth to 6 gear teeth. It has a variable capacity, and is high-efficiency and energy-saving. It has the humanistic microcomputer control system with remote control function. The Air-cooled Screw Chiller Unit features of compact size, low noise high energy-efficiency ratio and long service life, and is easy to operate and maintain. Thus they find a wide utilization in a great variety of locations, such as hotels, restaurants, office buildings, stores and hospitals. And they are also applicable to the air conditioning sites in metallurgical, chemical, mechanical, and electronic industries.

Components

Compressor (Fig 2)

- 1 Air-cooled Screw Chiller Unit adopts twin-screw compressor designed with the most advanced, industrial third-generation asymmetric technology of 5 gear teeth to 6 gear teeth. The rotors are processed by high-precision CNC and each part is well-proportioned and none-gap matching, which minimizes the friction resistance and clearance lost, guarantees quit running and good duration. Compare to single-screw compressor, the twin-screw compressor has the strong points of gapless-loss, high- efficiency cubage, low-noise few easy workout parts.



- 2 The lubricant is supplied automatically by pressure difference inside the compressor. It is unnecessary to add an extra lubricant pump. Every movement component can keep the best lubrication in the compressor.
- 3 Adopts special High Precision and zero clearance bearing ensure the longest useful time, the long lifespan of which ensure screw-type main unit to run continuously more than 30,000 hours.

Evaporator

Shell-and-tube evaporator adopts high-efficiency rifled pipes; special tube layout design and the state change the flow velocity the pressure drop of the refrigerant are seriously considered in refrigerant condition to ensure sufficient evaporation, in order to strengthen the refrigerating capacity.

Condenser

Finned heat exchanger adopts high-efficiency heat transfer tubes with the distinguishing feature of high efficiency and soon.. The unit is able to adjust the capacity matching with load change to advance the efficiency of compressor, reduce the energy consumption, and increase the unit's service life. The fans install in the top of condenser to supply low-noise, high-power which are low-noise, balance-run, small-shake. Aluminous-fin cupreous corrosion resistant tube is cross banding to supply high coefficient of heat transfer.

Water Cooled Screw Chiller:

Semi-hermetic twin compressor

The semi-hermetic screw compressor is developed especially for applications in air-conditioning and refrigeration. With high operating load design, each compressor is of high efficiency and reliability in all operating conditions. Each compressor has the latest and advanced 5-to-6 Patented Screw Rotor Profile designed to ensure high capacity and efficiency in all operating conditions.

The compressor is equipped with separated radial and axial bearings, liquid injection and economizer connection, PTC motor temperature thermistors and discharge temperature thermistors, a motor protector, and oil level switch and oil pressure differential switch and other accessories. The complete accessories and their new designs guarantee the compressor has the best reliability, longest bearing life during heavy duty running and strict operating conditions.

The slide valve for capacity control is located in the compressor chamber. The slide valve is actuated by injection of pressurized oil into the cylinder from the oil sump as well as bypass of oil through solenoid valves in each oil lines with pressure differential.

The screw compressors are equipped with either 3-step/ 4- step capacity control system or continuous (stepless) capacity control system. Both of the capacity control systems consist of a modulation slide valve, piston rod, cylinder, piston and piston rings. The slide valve and the piston are connected by a piston rod. The principle of operation is using the oil pressure to drive the piston in the cylinder. The lubrication oil flows from the oil sump through the oil filter cartridge and capillary then fills into the cylinder due to the positive oil pressure bigger than the right side of spring force plus the high pressure gas. The positive pressure differential causes the piston to move toward the right side in the cylinder. When the slide valve moves toward the right side, the effective compression volume in the compression chamber increases. This means the displacement of refrigerant gas also increases, as a result the refrigeration capacity also increases. However, when any of the step solenoid valve (for 4-step capacity control system) is opened, the high pressure oil in the cylinder bypasses to the suction port, which causes

the piston and the slide valve to move toward the left side, and then some of the refrigerant gas bypasses from the compression chamber back to the suction end. As a result, the refrigeration capacity decreases because of the reduction of displacement of refrigerant gas flowing in the system. The piston spring is used to push the piston back to its original position, i.e. minimum load position in order to reduce the starting current for the next starting.

Evaporator

shell and tube type evaporator having refrigerant in the shell and chilled water inside the tubes.

Advantage of this type evaporator is higher heat transfer performance and reduced refrigerant charge.

Distributor located on the top side of inside shell makes uniform flow of refrigerant, this refrigerant flows downward by gravity as a continuous film. The shell is of welded carbon steel construction with steel tube sheets and copper heat exchange tubes. Removable steel water boxes at both ends of the cooler allow tube cleaning without disturbing the refrigerant circuit. Tubes are mechanically expanded into tube sheets with double grooves to ensure leak tight and trouble free operation. Multiple compressor/ circuit chillers have coolers with separate refrigeration circuits for each compressor. Each refrigeration circuit is provided with its own pressure relief valve. All chillers are fitted with drain valves on the removable heads and shell. All coolers are factory insulated with 19mm of closed cell expanded synthetic rubber with all joints vapor sealed.

Expansion device

Expansion unit consists of butterfly valve and orifice. At 100% load situation, the pressure loss at the orifice is smaller than the refrigerant pressure loss in the condenser, thus the super-cooled refrigerant passes through the orifice.

At this stage the maximum amount of refrigerant is flowing into the evaporator. As the load reduces gradually, the circulating amount of refrigerant also reduces and accordingly the refrigerant level in the condenser is getting low.

When the amount of liquid refrigerant reduces, the gas amount in the orifice is getting larger, raising the resistance thus controlling the flow rate.

Data sheet for different types of chiller:

CHILLER	COND Used	Capacity	COP Using Air cooled cond	COP Using water cooled cond	Compression process
Reciprocating	Air cooled/ water cooled	50-500 TR	2-5	4-6	Uses Piston
Screw	Air cooled/ water cooled	70-600 TR	3-4	5-6	Helical Rotors
Scroll	Air cooled/ water cooled	40-400 TR	3-5	5-7	Spiral Scroll
Centrifugal	water cooled	150-6000 TR	-----	6-8	Rotating Impeller

Controls used in Air-conditioning

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

- **electrical control systems used in air-conditioners**
- **electronic control systems used in air-conditioners**
- **pneumatic control systems used in air-conditioners.**

In simplest term, the control is defined as the starting, stopping or regulation of heating, ventilating, and air conditioning system. Controlling an HVAC system involves three distinct steps: A) Measure a variable and collect data B) Process the data with other information C) Cause a control action. The above three functions are met through sensor, controller and the controlled device.

The control system is a vital piece of the mechanical apparatus. It is the brain of the HVAC equipment. Control system is a vast topic to get covered in a single chapter, here we will study important and commonly used controls and control devices. A control system generally consists of a sensing element, controller, controlled device, relays, contactors, time delay relays, transducers, timers, thermostat, thermistor, HP/LP Cut out, OLP etc. The parameters are sensed by the sensing element and produce a proportional effect on the system.

There are many types of controls used in HVAC industry, here we will discuss the three of them:

- 1 **Electric:** These controller uses electrical energy at operating voltages, the energy supplied is controlled by a control device like switch or relay.
- 2 **Electronics:** These controllers are having Semiconductor sensors like transducers, actuators, thermistors etc.
- 3 **Pneumatic:** These types of controllers use compressed air to control HVAC Systems.

The capacity of the HVAC system is typically designed for the extreme conditions. Most operation is part load/off design as variables such as solar loads, occupancy, ambient temperatures, equipment & lighting loads etc. keep on changing throughout the day. Deviation from design shall result in drastic swings or imbalance since design capacity is greater than the actual load in most operating scenarios. Without control system, the system will become unstable and HVAC would overheat or overcool spaces. The simplest control in HVAC system is cycling or on/off control to meet part load conditions. If building only needs half the energy that the system is designed to deliver, the system runs for about ten minutes, turns off for ten minutes, and then cycles on again. As the building load increases, the system runs longer and its off period is shorter. One problem faced by this type of control is short-cycling which keeps the system operating at the inefficient condition and wears the component quickly.

The HVAC control system is typically distributed across three areas:

- 1 The HVAC equipment and their controls located in the main mechanical room. Equipment includes chillers, AHU, heat exchangers, pump sets.
- 2 "Air Handling Units (AHUs)" may heat, cool, humidify, dehumidify, ventilate, or filter the air and then distribute that air to a section of the building. AHUs are available in various configurations and can be placed in a dedicated room called secondary equipment room or may be located in an open area such as roof top air-handling units.
- 3 The individual room controls depending on the HVAC system design. The equipment includes fan coil units, variable air volume systems, terminal reheat, unit ventilators, exhausters, zone temperature/humidistat devices etc.

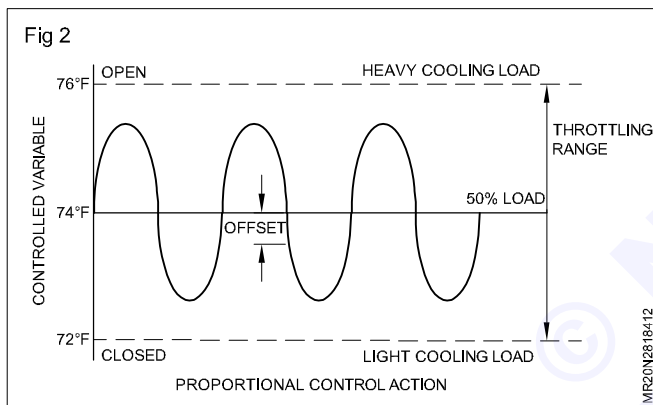
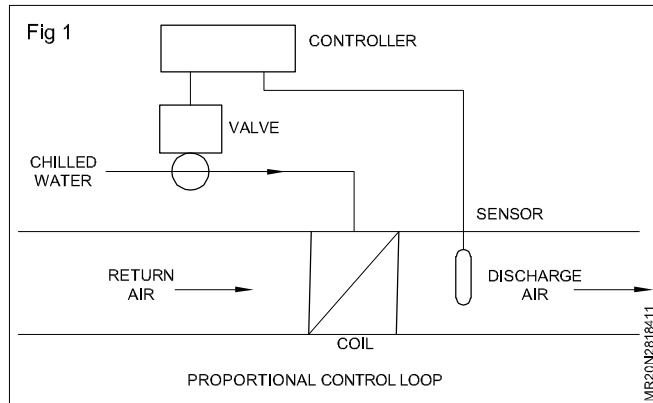
Electric controlled devices provide ON / OFF or two-position control:

In residential and small commercial applications, low voltage electrical controls are most common. A transformer is used to reduce the volt alternating current (AC) to a nominal volt. This voltage signal is controlled by thermostats, and can open gas solenoid valves, or solenoid valves on the DX cooling operate two position valves and damper or turn on-off fans and pumps. The control element occupies on of two possible positions based on two set values of the controlled variable. There is a differential zone between these two values and the controller cannot act in this zone. For example, a snap action thermostat which controls a two way or three-way valve, depending on the space temperature it acts within a specific range suppose 25° to 22°. A relay or contactor is used to switch line voltage equipment with the low voltage control signal. Step control is an improvement over two position control where relays provide multiple outputs in an operated sequence.

Proportional Control (Fig 1&2)

In this type of control, there is a final control element that moves to a position proportional to the deviance of the value of the controlled variable from a set point. The position of the final control element is the linear function of the value of the controlled variable. With this form of control the valve or damper is positioned in intermediate positions in proportion to the response to slight changes in the controlled condition. Therefore the controlled device

does not run through its complete stroke as in the case of two-position control. Also the controlled device does not continue to move until it reaches a limit as in floating control. Instead, with this form of control, the controlled device immediately assumes a position in proportion to the system requirement. A linear relationship exists between the input and the output. Proportional control maintains a set point with variations above and below that temperature.



For example: The temperature of the return air is measured by the sensor placed in the return air side in a chilled water cooling coil and sends a signal to the controller. The controller calculates the change, if a change in valve position is required, and sends signal to the valve actuator accordingly to reposition the valve ultimately changing the water flow through the coil and thus brings the air temperature back to the set point.

- Set point is desired value
- Control point is actual value
- Set point - control point = Error or Offset

Proportional integral (PI) control

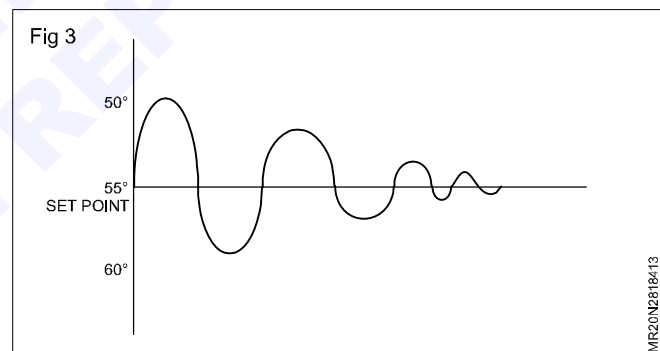
It is sometimes referred to as proportional with reset and is designed to eliminate offset. The controller always tries to match the set point and every time the load changes, the controller attempts to make the set point and the control point the same. PI control measures offset or error over time. The error is integrated, and a final adjustment is made to the output signal from a proportional part of this model. PI control response will work the control loop to reduce the offset to zero. The main advantage of this type of control is that the offset can be reduced.

A well set-up PI control loop will operate in a narrow band close to the set point and not over the entire throttling range.

PI control loops do not perform well when set points are dynamic, sudden load changes occur, or the throttling range is small.

Proportional-Integral Derivative (PID) Control (Fig 3)

PID is a precision process control application and is recommended in systems where the load changes often and the controller is expected to compensate automatically due to frequent changes in set point, the amount of energy available, or the mass to be controlled. PID control adds a predictive element to the control response, which takes care of sudden changes in deviation due to disturbances or in other words (PID) control speeds up action of PI control. This controller combines proportional control with two additional adjustments, which helps the unit automatically compensate for changes in the system. The derivative function added to the PID Control is proportional to the rate of change and opposes any change. PID control locks the control system to the set point, narrowing the HVAC system operating range to just a few tenths of a degree, eliminating the widely varying temperature swings experienced in proportional control, and maintaining the zone temperature within tenths of a degree of the set point. As a result, the system uses the minimum amount of mechanical cooling or heating to maintain zone temperature.



When the control point comes closer to the set point, the derivative action reduces the corrective action to slow down the approach to set point, ensuring the control does not overshoot.

Thermostatic switch

The two-positions on-off thermostat is the simplest control. One of its functions is to control the room temperature by sensing it. This is generally located in the return air passage or in the conditioned space.

Humidistat

The humidistat has a hygroscopic material with a sensing element which is sensitive to moisture, the sensing element senses the relative humidity level in the space and acts accordingly. It can also be a two-position on-off switch.

Electrical Overloads

OLP protects motor against overload conditions.

Some Fluid flow controls are

Solenoid valve: Operation of This is controlled by thermostat, pressure switch, humidistat etc. which are used on compressor capacity control systems, as pilot valve, on an external equalizer etc.

Liquid Refrigerant throttling devices: TXV, high and low side float valve are some examples of the throttling devices which meters and throttle the liquid refrigerant before entering the evaporator.

Liquid flow regulation devices: These devices regulates the flow of water or any other liquid in any particular component of the system. Such as mixing valve and diverting valve.

Diverting valve is similar to that of solenoid valve in operation except there is a diverting port in it which can divert the flow of any fluid when not in demand.

Mixing valve: This kind of valve is used when there is any demand for mixing of fluids. This valve has two inlet and one outlet port and is driven by a special two winding reversing modulating motor.

HP CUT OUT SWITCH: When the discharge pressure exceeds the safe limit that is preset point it gets cut out stopping the compressor.

LP cut out switch: When the suction pressure falls below the preset point it gets cut off and stops the compressor.

Pressure relief valve: It relieves excess pressure when system pressure rises to its preset value.

Oil safety switch: When net oil pressure falls below the preset point it stops the compressor.

Time Delay Relay: It is used to prevent the short cycling of a compressor. This device is used to delay the operation of the system for a specific time duration.

Electronic Controlled Devices can be either modulating or two-position (ON/OFF).

Electronic control systems usually have the following characteristics

- 1 Controller: Low voltage, solid state
- 2 Inputs: 0 to 1V dc, 0 to 10V dc, 4 to 20 mA, resistance element, thermistor, and thermo couple.
- 3 Outputs: 2 to 10V dc or 4 to 20 mA device.
- 4 Control Mode: Two-position, proportional or proportional plus.

Integral (PI) Other features of electronic control systems include:

- 1 Controllers can be remotely located from sensors and actuators.
- 2 Controllers can accept a variety of inputs.
- 3 Remote adjustments for multiple control scan be located together, even though sensor sand actuators are not.

- 4 Electronic control systems can accommodate complex control and over ride schemes.
- 5 Universal type outputs can interface many different actuators.
- 6 Display meters indicate input or output values.

An electronic control system can be enhanced with visual displays that show system status and operation. Many electronic controllers have built-in indicators that show power, input signal, deviation signal, and output signal. An indicator light can show on/off status or, if driven by controller circuits, the brightness of a light can show the relative strength of a signal.

Variable Frequency drive

Modulation of the system capacity with varying load on the system can be achieved by varying the component speed, such as compressor, fan, pump etc. as efficiency or capacity is directly related to the component speed. Motor speed is directly related to the frequency of power supply to the motor. We can vary the speed of these components by directly varying the frequency of the power supply. This can be achieved by VFD. This can be used with single and three phase ac induction motors. It consists of an inverter that varies the frequency to the drive motor, and do not affect the torque developing capacity of the motor. This provides a smooth rpm control. Its operation is controlled by proportionating control. In the HVAC systems there is requirement for flow to vary based on temperature. In this instance the VFD is controlled both by a temperature sensor and differential pressure. The temperature controller actuates the control valve that regulates chilled water supply to the heat exchanger and the pressure changes in a system as a result of opening and closing of control valve provides control signal to the VFD. Sometime in process applications the temperature controller directly controls the VFD to allow flow of cold liquid in the system to increase or decrease based on the actual temperature required by the process.

The fan VFD controls in the air-handler units employ the same philosophy as pumps. The HVAC system in this case uses variable inlet terminal boxes (VAV) at multiple zones of the space. As the damper in the VAV boxes is throttled based on the temperature reading from thermostat, the pressure buildup in the duct is sensed by a pressure sensor, which alters the speed of the fan to maintain the constant duct static pressure. With VFD, the power factor gets improved to at least 95%.

Electronic and Micro-processor based controller (Direct Digital Control)

DDC is microprocessor or computer based open or closed loop control of an output device based upon input data and a sophisticated control algorithm, typically proportional, integral and derivative. DDC provides effective, sophisticated strategies for the optimum control and efficiency. The modern HVAC design rely on direct digital control (DDC) system. In DDC, the inputs and outputs - in the form of input/output (IO) modules - send information to and from a microprocessor.

The microprocessor could be programmed to do a specific task. DDC control consists of microprocessor-based controllers with the control logic performed by software. DDC is a control loop in which a digital controller periodically updates a process as a function of a set of a measured control variables and a given set of control algorithms.

A DDC receives electronic signals from the sensors, converts electronic signals to numbers and performs mathematical operations on these numbers with the help of a microprocessor. The output is again a number which is converted to a voltage signal to operate an actuator. The microprocessor accepts sampling input data at chosen intervals and recalculates the program using new data and adjusts its output accordingly. The direct digital control loop consists of three main components: a sensor, a controller, and a controlled device. The sensor measures the data, the controller (processor) processes the data and the controlled device causes an action. Sensors and controlled devices are connected directly to the processor (computer). The controller's function is to compare its input (from the sensor) instructions, such as set point, throttling range and action, then produce an output signal. The control logic usually consists of a control response along with other logical decisions that are unique to the specific control application. Data, in the form of signals from input devices connected to the input terminals on the controller, is conditioned by the input multiplexer then converted to digital values by the analog to digital converter prior to entering the DDC micro-processor. Digital computations are performed on this data based on the set of instructions (program) installed in the DDC controller. The outputs as a result of this digital processing are converted to analog by the analog converter.

Most of the inputs and outputs are analog in nature and these are converted to digital and back using analog-to-digital and digital-to-analog converters which are included in the controller. The elements of a simple microprocessor based controller are: Microprocessor, program memory, input and output devices, timing devices, working memory.

Resistance Temperature Detectors (RTD)

RTD operates on the principle that the electrical resistance of a metal changes predictably and in an essentially linear and repeatable manner with changes in temperature. RTD have a positive temperature coefficient (resistance increases with temperature). The resistance of the element at a base temperature is proportional to the length of the element and the inverse of the cross sectional area.

Heat load calculation

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

- detailed study of heat load calculation
 - tonnage calculation as per heat load.
-

Heat load

The heat develop inside the condition space from various sources is known as heat load or cooling load. Without heat load calculation we are not able to select proper

Common materials used in RTD sensor are BALCO (70 percent nickel and 30 percent iron) wire, Copper, Platinum, 10K Thermistors, and 30K Thermistors.

Thermistors

These are temperature sensitive semiconductors that exhibit a large change in resistance over a relatively small range of temperature. There are two main types of thermistors, positive temperature coefficient (PTC) and negative temperature coefficient (NTC). NTC thermistors exhibit the characteristic of falling resistance falling with increasing temperature. These are most commonly used for temperature measurement. Unlike RTD's, the temperature-resistance characteristic of a thermistor is non-linear, and cannot be characterized by a single coefficient.

Pneumatic system

The most popular control system for large buildings historically has been pneumatics which can provide both On-Off and modulating control. Pneumatic actuators are described in terms of their spring range. Common spring ranges are 3 to 8 psig (21 to 56 kPa), 5 to 10 psig (35 to 70 kPa), and 8 to 13 psig (56 to 91 kPa). Compressed air with an input pressure can be regulated by thermostats and humidistat. By varying the discharge air pressure from these devices, the signal can be used directly to open valves, close dampers, and energize other equipment. The copper or plastic tubing carry the control signals around the building, which is relatively inexpensive. The pneumatic system is very durable, is safe in hazardous areas where electrical sparks must be avoided, and most importantly, is capable of modulation, or operation at part load condition. While the 24-volt electrical control system could only energize a damper fully open or fully closed, a pneumatic control system can hold that damper at 25%, 40% or 80% open. This allows more accurate matching of the supply with the load. Pneumatic controls use clean, dry & oil free compressed air, both as the control signal medium and to drive the valve stem with the use of diaphragms. It is important that dirt, moisture and oil are absent from the compressed air supply. The main disadvantages are: it is less reliable and noisier when compared to electronic systems.

rated Air conditioning unit As result either capacity of the unit will be more or less. Which will be effected during whole life of equipment.

Orientation of building

For Air-conditioning system always north face building is the best in view of better performance and East is preferable one. On other hand South may be considerable but West faced building absorbs more heat comparatively, due which it is not at all advisable.

Note

Before heat load calculation should collect the data.

- 1 State and station
- 2 Altitude
- 3 Latitude
- 4 Dbt (Dry bulb temperature)
- 5 Wbt (Wet bulb temperature)
- 6 Rh (Relative humidity)
- 7 Daily range

Heat from outside and inside

Heat from outside

- 1 Source of Heat
- 2 Load estimation Guide
- 3 Estimate the ACR Load

Source of heat

- 1 Out side heat
- 2 Inside generated heat
- 3 Out side source heat
- 4 A/C Machine Heat
- 5 Visitors Heat

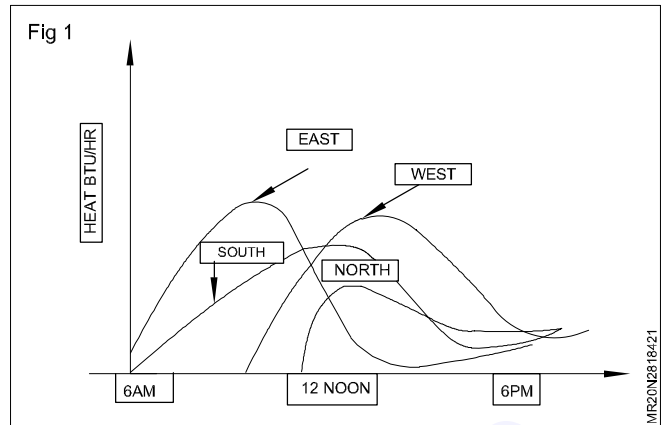
Out side heat

- 1 Solar Heat
- 2 Machine AHU
- 3 Visitors Heat
- 4 Air Leakage
- 5 Fresh Air

Solar heat load come through radiation and conduction (Fig 1)

- a Radiation come through glass window.
- b Conduction through Wall, 6AM

At the time of heat load calculation following points should be consider



- 1 Types of wall material
- 2 Window fixed side and Material
- 3 Ground Floor Not effected Heat
- 4 1st floor and above lower floor's condition, roof material, floor material
- 5 Roof: RCC, Asbestos sheet, false ceiling material leakages
- 6 Exposed sun

Infiltration

Leakage in side, Ventilation, IAQ (Indoor air quality) fresh air CFM/person.

By pass factor

Air passes through condenser net By pass related with leakage factor.

Occupancy

Sensible heat from Visitors+ Latent heat added

Air distribution system

Duct or pipe some heat will add when the conditioned air will pass through duct.

Equipments

Sensible and Latent heat from Equipments, Maximum added latent heat.

Data sheet : After calculate all the value following table and instruction fill up the data table.

Cooling load estimate form					
<p>1 Design Condition Humidity Gr/lb</p> <p>Outside _____</p> <p>Inside _____</p> <p>Difference _____</p>	<p>Dry bulb temperature °F</p> <p>_____</p> <p>_____</p> <p>_____</p>	<p>Wet bulb temperature °F</p> <p>_____</p> <p>_____</p> <p>_____</p>			
ITEMS	Cooling Load, BTU/Hr.				
	Single zone air cycle load			Multi zone load	
	Sensible	Latent	Sub total=(L+S)	Factor	Refrigeration load
<p>2 Sensanle heat gain through Glass (Table - 2)</p> <p>East _____ x _____ = _____</p> <p>West _____ x _____ = _____</p> <p>North _____ x _____ = _____</p> <p>South _____ x _____ = _____</p> <p>Total heat gain through glass _____ - x _____ = _____</p>					
<p>3 Transmission gain (Table - 3)</p> <p>Wall Sq.feet x Factor x Temp. diff. DB</p> <p>East _____ x _____ = _____</p> <p>West _____ x _____ = _____</p> <p>North _____ x _____ = _____</p> <p>South _____ x _____ = _____</p> <p>Partitions _____ x _____ = _____</p> <p>Roof _____ x _____ = _____</p> <p>Ceiling _____ x _____ x _____ = _____</p> <p>Floor _____ x _____ x _____ = _____</p> <p>_____ x _____ = _____</p> <p>Total heat gain through glass _____</p>					
<p>4 Internal heat gains, People & Lights Table (4)</p> <p>Numbers Sensible heat Latent heat</p> <p>People _____ x _____ = _____</p> <p>People _____ x _____ = _____</p>					

Light watts _____ x 3.4 = Total heat gain of people & light (Sen + Latent =	_____	_____	_____ x _____ =	_____
5 Internal heat gains, Motor & Appliances Table (5) Numbers Sensible heat Latent heat Motors _____ x 3.393 = Appliances(use values given in Table 5) = = _____ Total of other internal heat gain (Sen + Latent = = _____ x _____ x 1.00 =	_____	_____	_____	_____
6 Ventilation or infiltration Table (6 & 7 use larger quantity only) Cubic feet/min _____ Dry bulb temp. Diff. _____ _____ x _____ x 1.8 Cubic feet/min _____ Specific humidity. diff _____ _____ x _____ x 0.067 = Total heat gain ventilation or infiltration (Sensible + Latent heat)	_____	_____	_____ x _____ =	_____
7 Total sensible & Latent heat load	_____	_____		
8 Total zone air cycle load			_____	
9 Total multi zone refrigeration load				

Select capacity of compressor and CFM required

Tonnage calculation: Total heat gain [BTU/Hr]/12000BTU/Hr Or 3000 K.cal/Hr

Total heat gain ÷ Suppose 12000BTU/Hr = Tonnage Required

Example 1

Total heat gain 120000 BTU/hr

Tonnage required = 120000BTU/Hr÷12000BTU/hr = 10 TR

If the calculated value of compressor capacity not available select nearest higher value compressor.

Example 2

Consider 10 ton, CFM required = Tonnage x 400 = 10 ton x 400 = 4000

Actual CFM reqd = calculated CFM +20% = 4000 + 800 = 4800

Product load

Refrigerator Freezer, cold Storage rate of transfer conductivity kg/sec.

Heat load reduction

- 1 Insulating the wall roof
- 2 Quality of glass(Double glass pane window reduce 40% to 60% heat load)
- 3 Ventilation blind (Louvers)
- 4 Using Sun film
- 5 Sun Shed
- 6 Arrest doors leakage
- 7 Roof (Water spraying, permanent water storing, covering by cemented water tank.)
- 8 False ceiling.

U Factor value means

'U' factor or the 'U' value is a measure of thermal (heat) transmittance through the conduction, convection, and radiation per unit area. Coefficient of heat transfer from hotter Zone to colder Zone Conduction method followed for heat transfer "U" Factor.

Zoning air

Heat transfer by conduction = Area xDT x U_ factor.

DT = Out side design Data - Inside Design Data

Inside design data

T = 24°C+ -1°C RH:- 50% {cooling in Summer}

Inside design data

T = 20°C+ -1°C RH:-35% {heating in winter}

Air movement

4.5-7.5 CM/Min Measured 5' above ground level.

Outside design

Maximum enriched temperature.

Inside Design : Desired Temperature.

Load and Estimate determine size of ACR Equipment to maintain side design condition during periods of maximum extreme outside temperature.

Types of construction

- 1 Wall
- 2 Window
- 3 Roof
- 4 False Ceiling
- 5 False Ceiling
- 6 Partition
- 7 Doors
- 8 Visitors
- 9 Equipments

10 Exhaust Fan

11 Occupants

Heat gain

Radiation Maximum Through Glass Radiation due to solar gain.

Total Heat = Factor on Chart x Area

Solar Heat Gain = Factor x solar heat gain through glass x Area {BTU/Hr} solar heat.

Conduction

Thermal resistance conduction = Area x DT x U factor

DT = out side temperature -- Inside temperature radiation = Area x DT x U heat gain add by people, 1.Sensible heat 2.Latent heat.

Heat gain add by light

- 1 Incand lamp,
- 2 Florescent lamp {Wattage x 3.4}

Motor = H.P x 3000 BTU/Hr

Appliances to computer

- 1 Fax
- 2 Printer
- 3 Copier

Canteen equipment

- 1 Tea coffee Machine
- 2 Gas Oven

Ventilation : 5 to 7.5 cfm/person

Hotel : 15 to 30cfm/person

Heavy Splash : 30 to 50cfm.

Sensible Heat : CFM x 1.8 x D

Latent heat : CFM x 0.68 x DT

Infiltration

Window Leakage 22 BTU/Hr, Doors Leakage 65 BTU/Hr/Person x No of customer/Hr.

Exhaust fan = 1000 CFM 10% Extra will add compare with Ventilation and Infiltration.

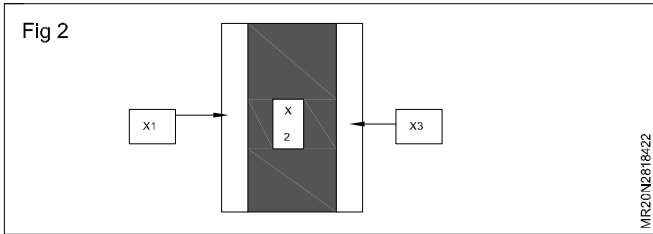
How to reduce load (Fig 2)

Air quantity standard CFM = 400 cfm/Ton 360 CFM out side air carried by the person outside air add 20% extra.

- 1 Window change, Wall Rectify, Partition Improving [1" Insulation can reduce 48% heat load, 2" Insulation can reduce 14% heat load, 3" Insulation can reduce 8% heat load, 4" Insulation can reduce 2% heat load]

Specific humidity = Gm/kg of Dry Air Grain x 0.0648
= 1 gm

1 grain = 1/0.0648gm



$R_1 + R_2 + R_3 \dots \dots R_n = 1/K$ Value of the material Table No:8

Roof absorbed heat (Fig 3)

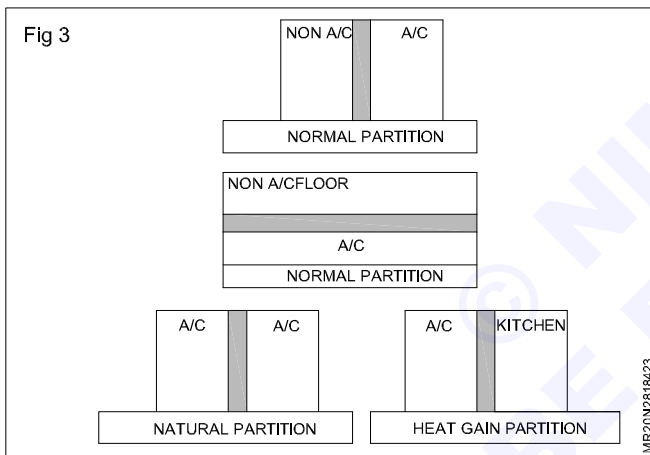
Formula: $Q = UA \times DT$ $Q = \text{BTU/Hr}$

A = Area of Sq Feet $DT = \text{ETD} + \text{CETD}$
[not exposed to the sun]

ETD = Equivalent temperature difference
CETD = Correction equivalent temperature difference

Formula : $Q = UA \times DT$ $Q = \text{BTU/Hr}$
A = Area of sq Feet $DT = \text{DBT} - \text{WBT}$

Normal partition $DT_i = DT - 5$
Heat gain portion $DT_i = DT + 10$



Heat gain through people

$Q = LH + SH$ Where,
LH = Latent Heat SH = Sensible Heat
Total Heat gain = Q x no of people collect data according to the activity

Heat gain through light

$Q = \text{Watt} \times 3.4$
Incandescent Lamp $Q = \text{Watt} \times 1.25 \times 3.4$ fluorescent lamp

Light required for room Sq. feet x 2.4 = Total watt.

Heat gain through motor: $\text{HP} \times 3000 = Q$

Heat gain through infiltration: Infiltration by crack method

Find out the perimeter x Crack valve = CFM
 $Q = \text{Infiltration LH} + \text{Infiltration SH}$
Infiltration LH = _____ CFM x T.D x 1.08,
Infiltration SH = _____ CFM x Gr/Lb x 0.68

Heat gain through ventilation

$\text{CFM} = \text{No of people} \times \text{CFM per person}$
Outside air = ventilation
 $\text{LH} = \text{CFM} \times \text{T.D} \times \text{BF} \times 1.08$
 $\text{SH} = \text{CFM} \times \text{Gr/Lb} \times 0.68$
Ventilation = LH + SH = Q

ADP value, Typical by pass Factor - data collect from table

Weight of the construction material required for ETD available at Related data table.

Solar Gain From Slash = No of slash x 1.17 BTU/Hr
Data collect from "Ashre" or "Ishare" Table.

Study & various components used in Automotive Air-Conditioning

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

- heat transfer in an automobile
- description of various components used in Automotive AC.

Introduction

Due to varying conditions of heating, ventilating, cooling and dehumidification in the atmosphere at various places, the air-conditioning of automobiles is very essential. To maintain human comfort and improve internal atmosphere in an enclosed space, proper control of freshness temperature, humidity and cleanliness of the air is required.

Heat transfer in an automobile (Fig 1)

When a car is driven or parked in the sun, heat enters the vehicle from many sources. These sources include:

- Ambient air
- Sunlight
- Engine heat
- Road heat
- Transmission
- Exhaust heat

All of these and other miscellaneous heat sources, increase the air temperature within the vehicle. In a high ambient temperature situation, (e.g. on a 37°C day), the interior of a vehicle left standing in the sun with windows closed could reach 65 - 70.

Description of various components used in Automotive AC

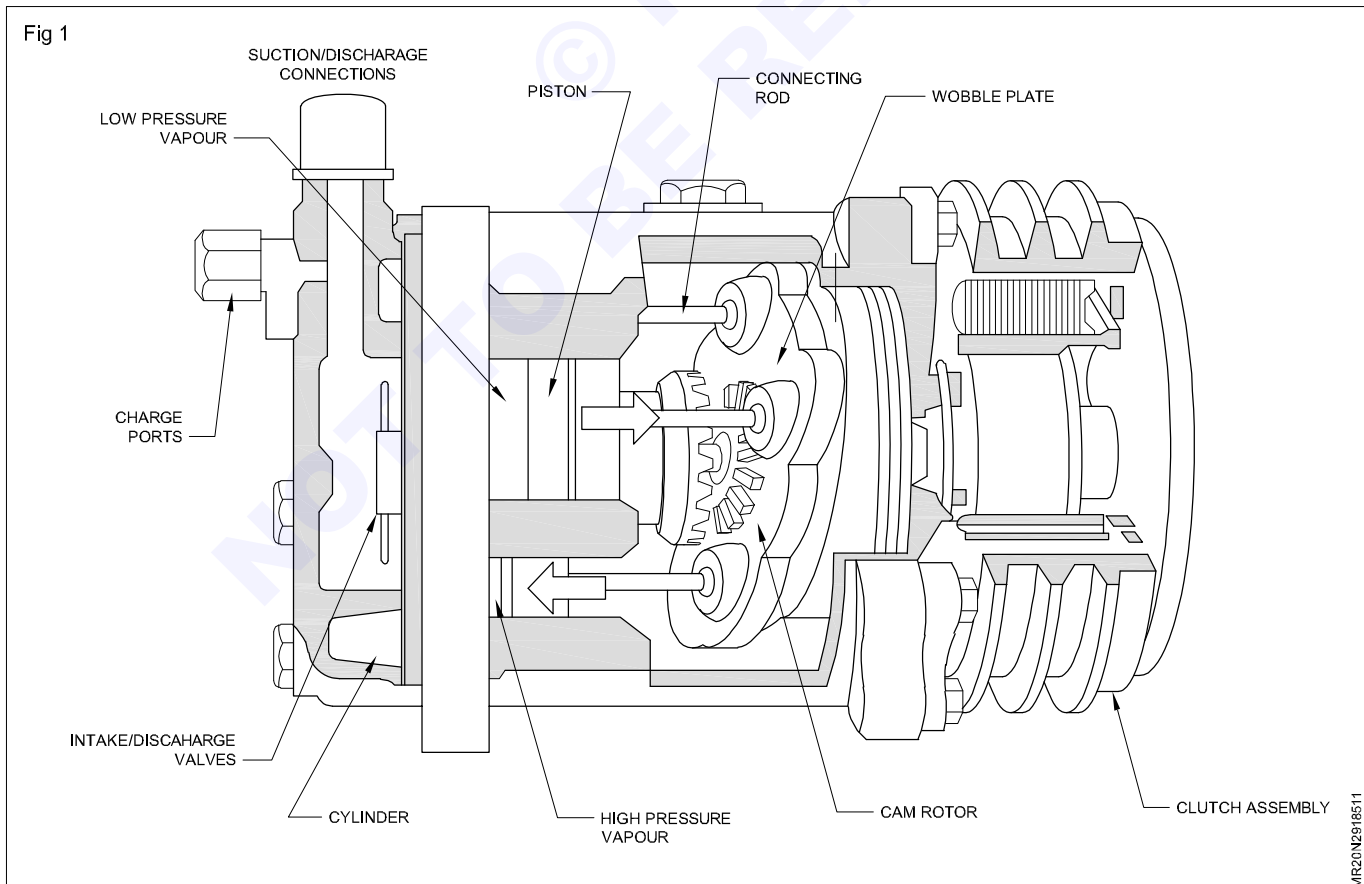
Compressors

General

There are various makes and types of compressors used in automotive air conditioning systems operating on R134a. The internal design could be Piston, Scroll, Wobble plate, Variable stroke or Vane. Regardless, all operate as the pump in the A/C system to keep the R134a and lubricating oil circulating, and to increase the refrigerant pressure and thus temperature.

Wobble plate

A reciprocating piston, fixed displacement compressor. The pistons are operated by a wobble plate, which moves them backwards and forwards in the cylinders. As the front shaft turns the wobble plate angle changes, causing the pistons to move in and out, pulling refrigerant vapor in through the suction side, compressing it and discharging this high pressure vapor into the condenser.

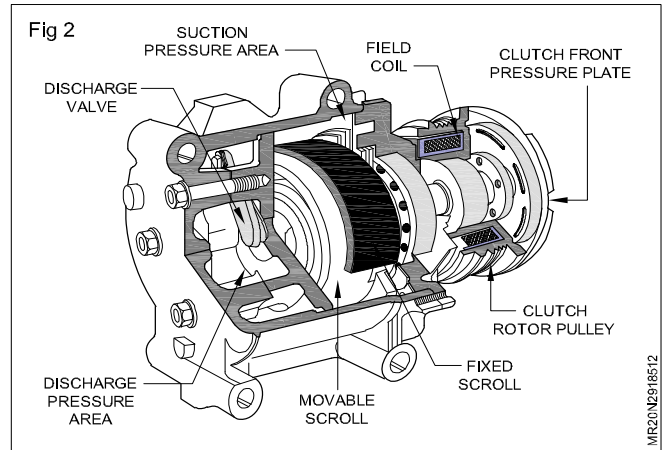


Compressors

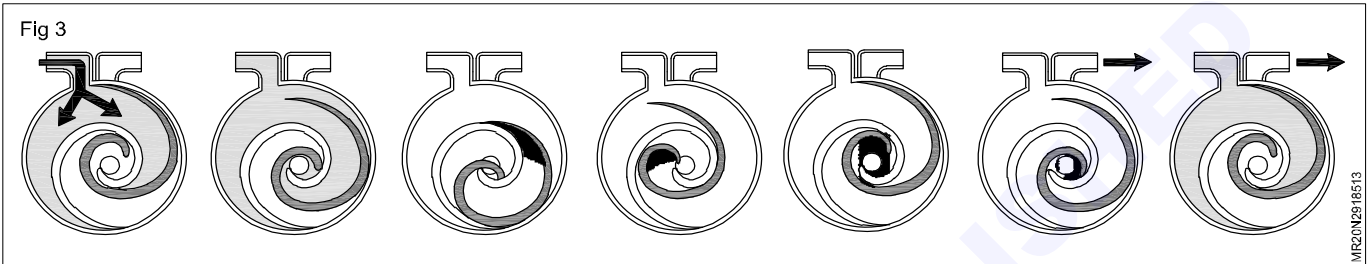
Scroll type (Fig 2)

This compressor uses a unique design with two scrolls, one fixed and one is movable, both are inter-leaved.

The movable spiral is able to ORBIT or oscillate without actually fully rotating. The movable scroll is connected to the input shaft via a concentric bearing. As the movable scroll oscillates within the fixed spiral, a number of pockets are formed between the spiral. As these pockets decrease in size the refrigerant is squeezed, the pressure increases and is discharged through a reed valve at the discharge port in the rear section of the compressor.



Compression Cycle (Fig 3)

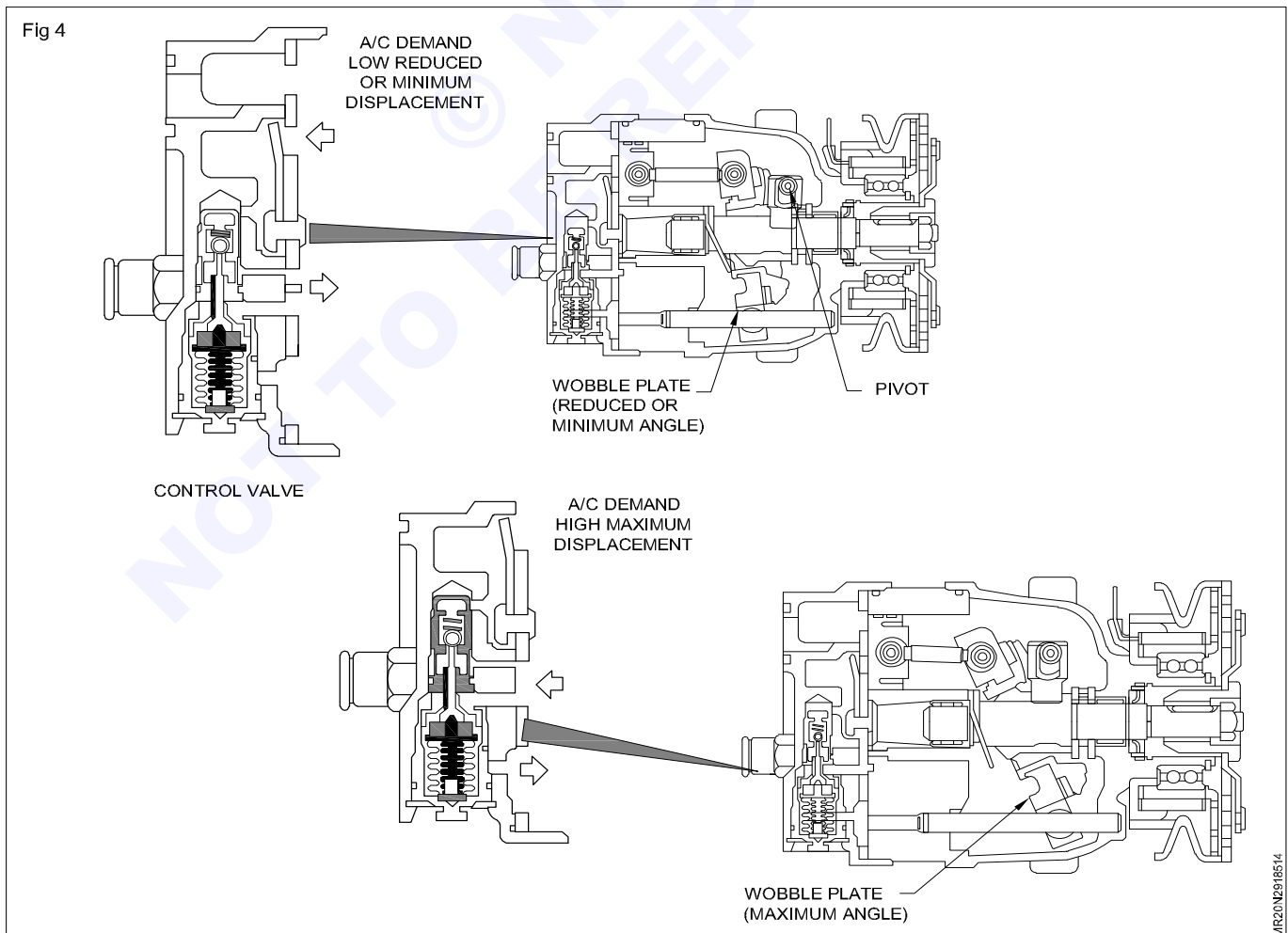


Compressors

Variable stroke - V5 Compressor (Fig 4&5)

The V5 compressor is a non-cycling variable displacement compressor. The compressor varies displacement to

control capacity to meet A/C system demand at all operating conditions. The compressor features a variable angle wobble plate in five (V5) cylinder axial piston design.



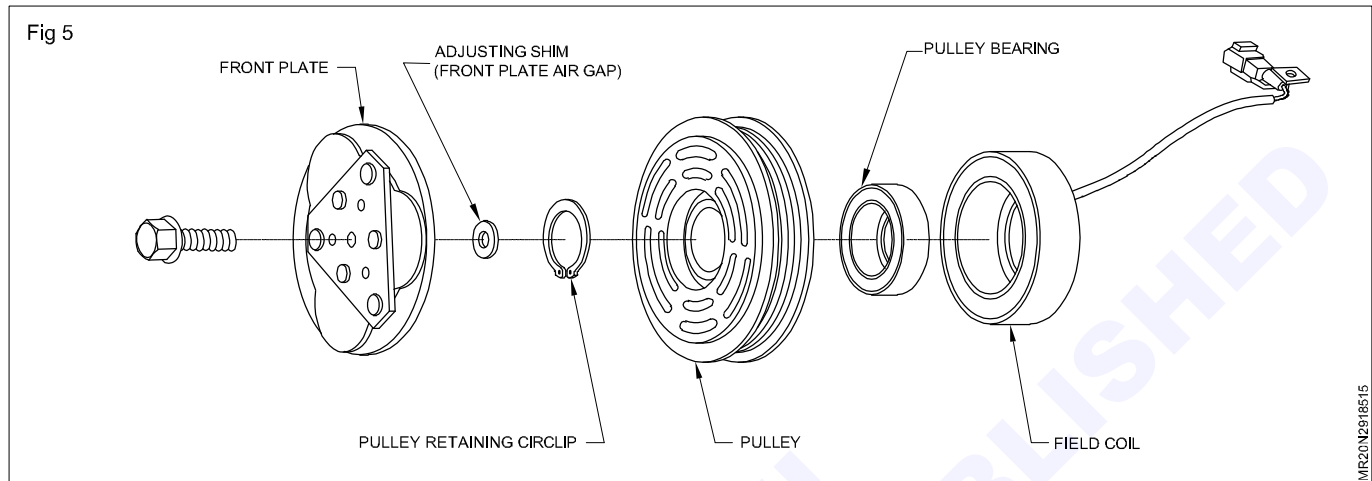
Displacement is controlled by a bellows actuated control valve located in the rear cylinder head. This control valve senses and responds to the system suction pressure or A/C system demand. Through regulation of compressor crankcase pressure, the wobble plate angle, and therefore compressor displacement is variable.

In general, the compressor discharge pressure is much greater than the compressor crankcase. Which is greater than or equal to the compressor suction pressure. At maximum displacement, compressor crankcase pressure

is equal to the compressor suction pressure. At reduced or minimum displacement, the compressor crankcase pressure is greater than the suction pressure.

Compressor Clutch

The clutch is designed to connect the rotor pulley to the compressor input shaft when the field coil is energized. The clutch is used to transmit the power from the engine crankshaft to the compressor by means of a drive belt.



Condensers (Fig 6&7)

The Condenser function is to act as a heat exchanger and allow heat to flow from the hot refrigerant to the cooler outside air.

R134a entering the condenser will be a high-pressure high temperature vapor. As the R134a vapor travels through the tubes of the condenser heat is given off to the cooler ambient air; the refrigerant vapor condenses and changes to a liquid state.

At this point a large amount of heat is given off by the R134a. The refrigerant will now be a hot, high pressure liquid.

Design types

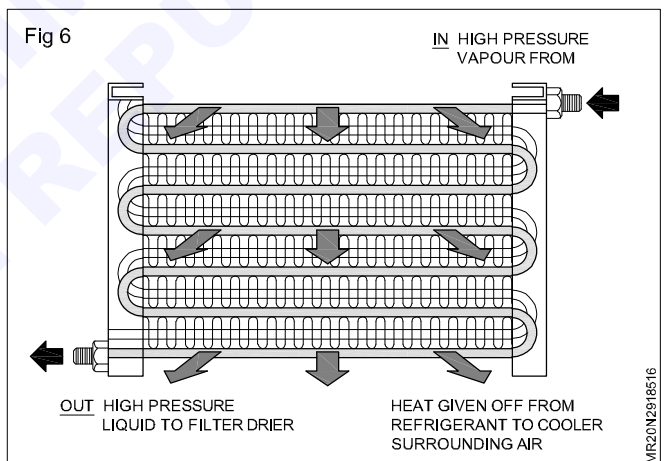
Serpentine

This type of condenser consists of one long tube which is coiled over and back on itself with cooling fins in between the tubes.

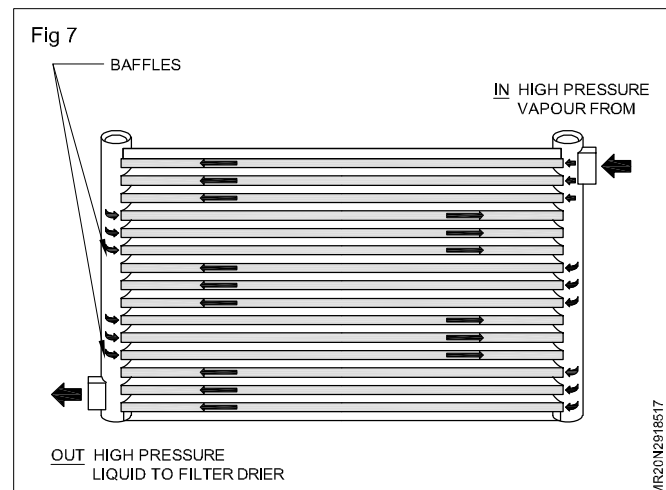
Parallel flow design (Recommended for R134a)

This design is very similar to a cross flow radiator. Instead of refrigerant travelling through one passage (like serpentine type), it can now travel across numerous passages. This will give larger surface area for the cooler ambient air to contact.

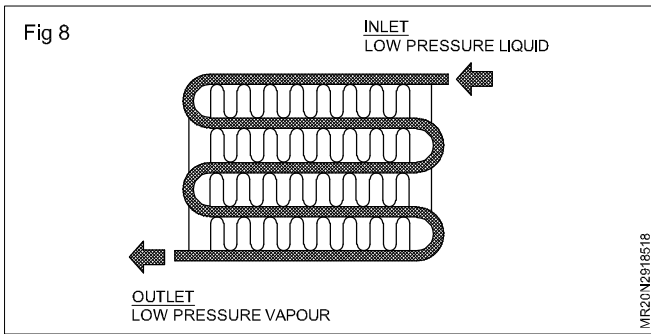
Serpentine flow



Parallel flow



Evaporator (Fig 8)



The evaporator unit where the cooling effect is obtained is usually located inside the passenger compartment below the dashboard. A high capacity blower circulates the air in the car interior across the evaporator coils, and this drops the temperature of the air inside the passenger compartment. The heat picked up by the refrigerant goes back to the compressor in the vapour form, where the refrigerant is again compressed and the cycle goes on.

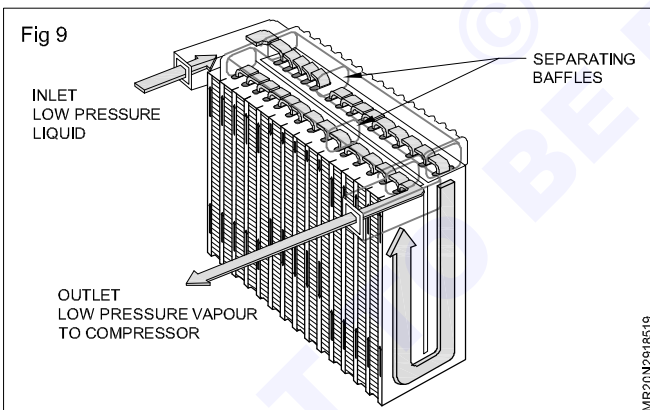
Design types

Serpentine

This type of evaporator consists of one long tube which is coiled over and back on itself with cooling fins in between the tubes. Same design as the serpentine condenser but approximately five times deeper.

Plate & Fin Laminated Evaporators (Fig 9)

Similar operation to the parallel flow condenser where the refrigerant has a multi flow pass creating a large surface area.



Most manufacturers prefer to use the plate and fin design for R134a because of 20% performance increase over the serpentine design.

Thermal Expansion Valves (Fig 10)

Refrigerant flow to the evaporator must be controlled to obtain maximum cooling, while ensuring that complete evaporation of the liquid refrigerant takes place. This is accomplished by the thermal expansion valve (TXV).

- 1 From Filter Drier
- 2 To Evaporator Inlet
- 3 Capillary tube
- 4 Metering Orifice

- 5 Ball Valve
- 6 Spring
- 7 Diaphragm
- 8 Refrigerant
- 9 Pressure Compensating Tube

Pressures in control (Fig 11 to 12)

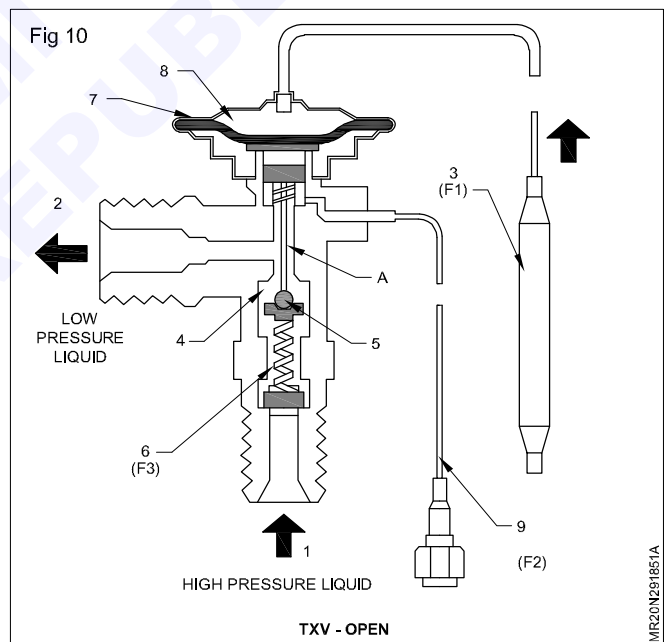
As shown in the illustration, the TXV controls the refrigerant flow by using a system of opposing pressures which will call:

F1 - Temperature sensing capillary tube Sealed tube filled with refrigerant. This refrigerant is also filled above the diaphragm (7). The capillary tube sensing bulb (3) is attached to the evaporator outlet tube surface.

F2 - Pressure compensation tube This is a hollow tube connected to the evaporator outlet tube and senses the pressure of the R134a refrigerant leaving the evaporator coil. (Other TX valves may not use this tube as pressure is provided internally within the valve).

F3 - Pressure spring

This spring (6) is located under the ball valve (5).

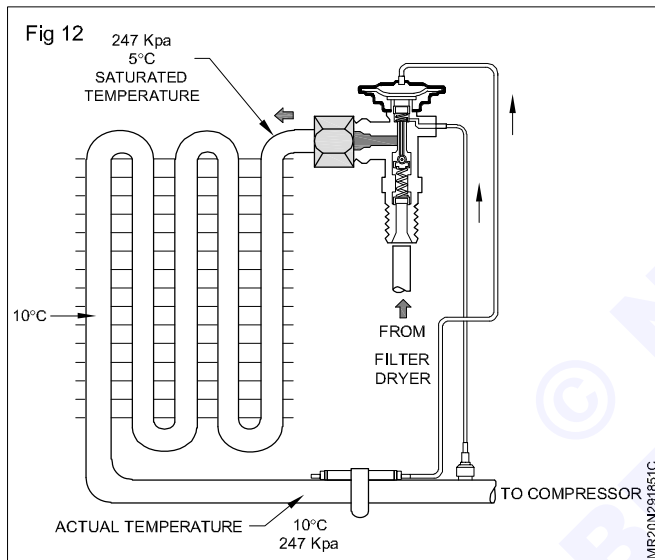
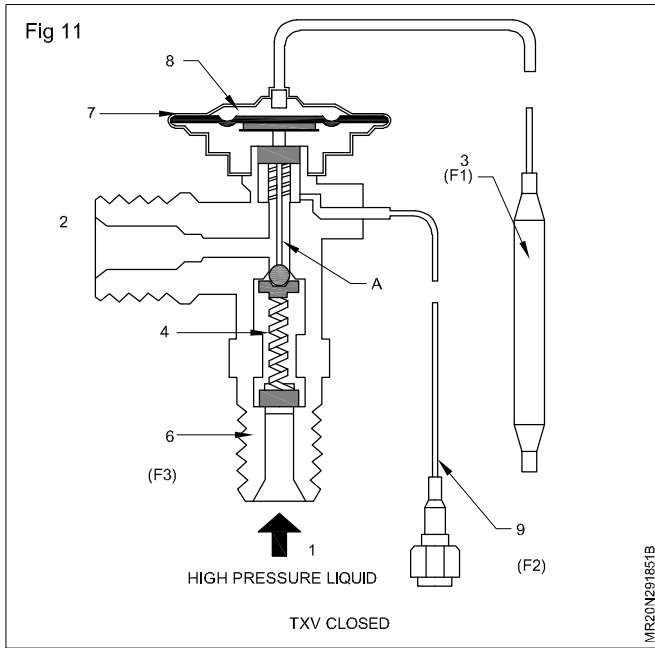


Operation Open: When the evaporator outlet tube temperature increases, the refrigerant (3) in the capillary tube expands, forcing the diaphragm (7) downwards and thus pushing pin (A) also downwards causing the ball valve (5) to move away from the metering orifice (4), allowing more R134a to enter the evaporator inlet side.

Closed

As the evaporator outlet tube becomes cooler, the refrigerant in the capillary tube

(3) contracts. Forces F2 and F3 cause the diaphragm (7) and pin (A) to move upward allowing the ball valve to move towards the metering orifice (4), restricting the R134a flow. The outlet tube gets warmer and the process starts over.



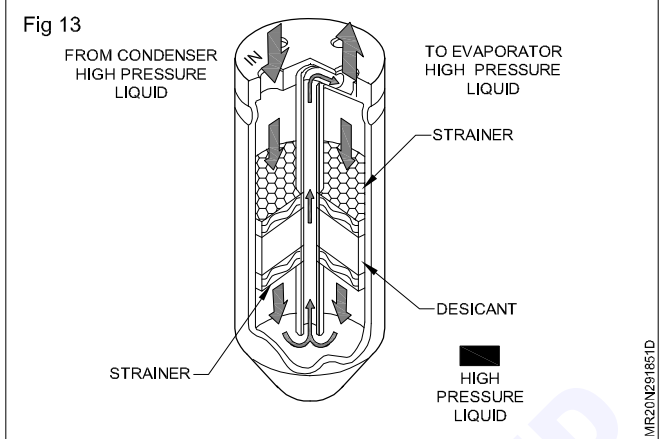
Filter Drier Receiver (Fig 13)

The filter drier acts as a particle filter, refrigerant storage container and most importantly moisture absorber.

Moisture, temperature and R134a causes hydrofluoric and hydrochloric acid. The silica gel beads (desiccant) located in the FDR absorb small quantities of moisture thus preventing acid establishment.

Most R134a filter dryers have NO sight glass. This is because at approximately 70°C refrigerant temperature the PAG oil will foam giving a false impression of low gas charge. If the FDR does utilize a sight glass ensure correct diagnosis when viewing.

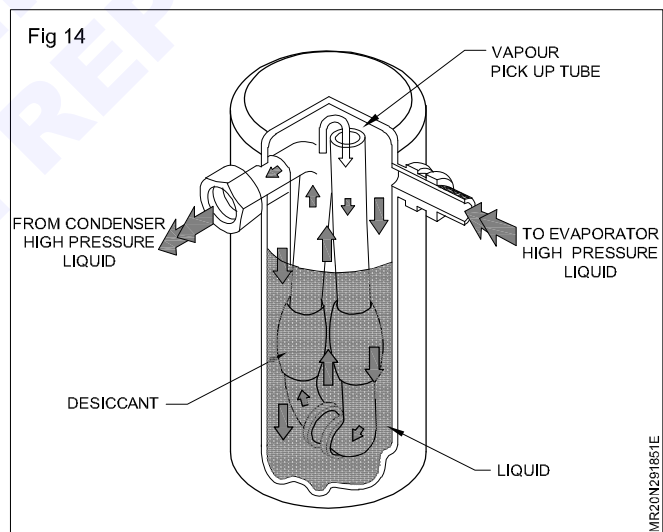
Note: Ensure the connection indicated with the word "IN" is connected to the condenser outlet.



Accumulator (Orifice Tube System) (Fig 14)

The function of the accumulator is to store refrigerant, filter particles, absorb moisture and separate vaporous R134a from liquid R134a.

The normal process of the Orifice Tube system works when R134a leaves the evaporator coil as a mixture of vapor and liquid. This liquid enters the accumulator and falls to the bottom. The vapor rises to the top and continues onto compressor. The liquid R134a in the bottom of the accumulator gradually vaporizes off. This vapor rises, then pulls into the compressor.

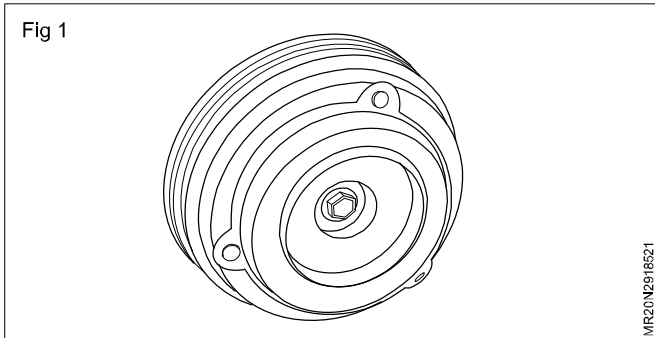


Compressor clutch

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

- details of compressor clutch
- magnetic clutch operation, freewheeling (de engaging clutch)
- servicing and testing magnetic clutch operation.

Compressor Clutch and its operation: A compressor clutch provides the means of torque transfer from the engine Front End Accessory Drive to the compressor rotating assembly. **Electromagnetic clutches** operate electrically but transmit torque mechanically. (Fig 1)



The ability of the clutch to engage and disengage is critical on several levels.

Firstly, to stop compressor operation when the cooling demand in the cabin is satisfied. If not disengaged when this occurs a phenomena known as "evaporator freeze" happens. Airflow becomes obstructed under these conditions.

Secondly there are conditions that occur in an AC system of which the compressor operation needs to cease, such as

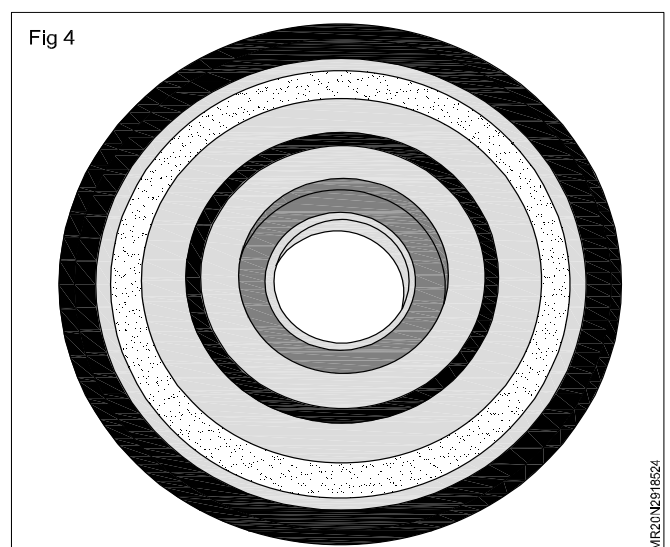
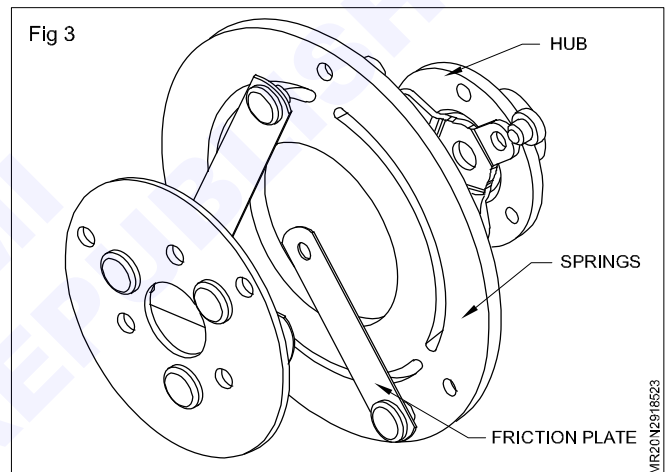
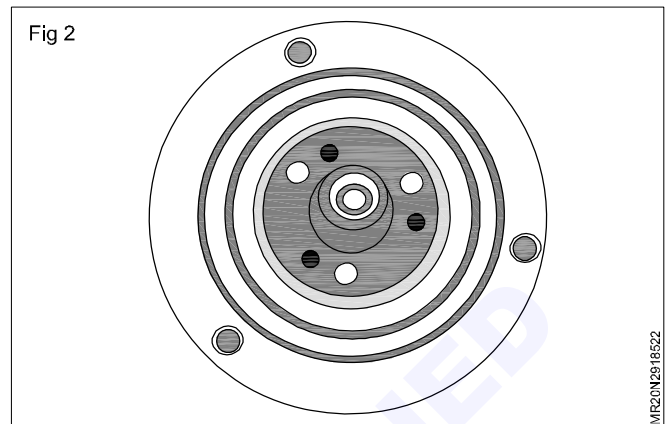
- 1 Excessive Discharge Pressure & temperature
- 2 Low Refrigerant Charge
- 3 Low suction pressure & temperature.

A AC compressor clutch has three key components; they are (Figs 2 to 5)

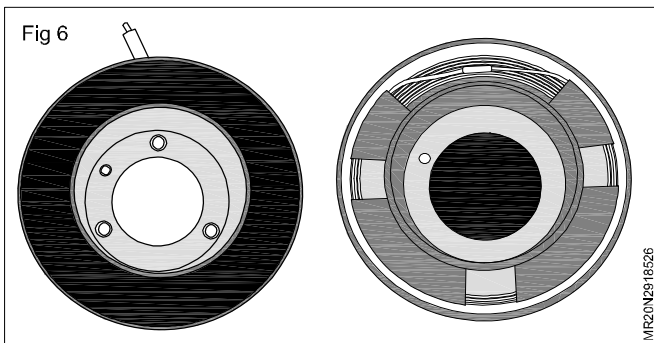
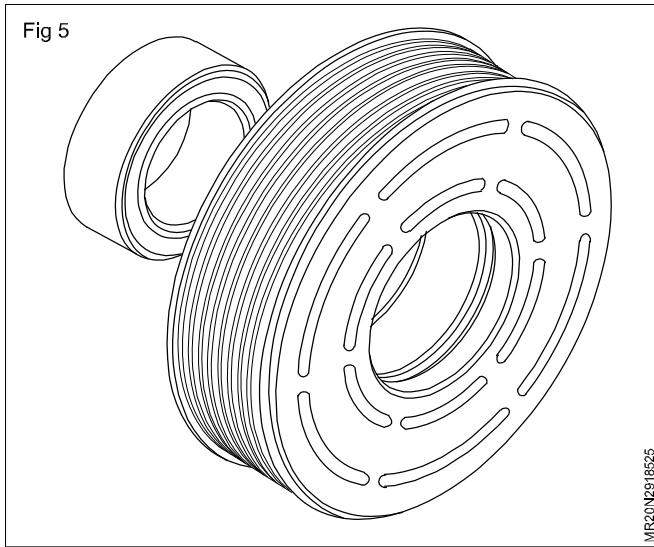
- 1 Armature - coupled directly to the compressor shaft to transfer the rotational torque from the pulley to the compressor
- 2 Rotor or Pulley - Belt driven and coupled to the engine drive train
- 3 Coil - Electrically connected to the AC relay and produces an electromagnetic field when energized.

Armature: Coupled to the compressor shaft using either a key or a spine. It's comprised of several parts, first the hub which connects to the compressor. Second the springs which connect the hub to the friction plate, these "springs" can be steel or rubber. Lastly the friction plate which mates directly to the pulley friction surface.

Rotor: Normally mounted on the compressor nose, the rotor is connected to the accessory drive using the drive belt. It has two basic parts, the rotor and the rotor bearing which is a sealed two-row bearing.



Coil: Normally mounted on the compressor body the clutch coil provides the electromagnetic field which attracts the armature when energized. As shown on the bottom picture it is simply a continuous wrap of copper wire which produces a strong magnetic field. The copper wire is wound on a plastic "bobbin" and then inserted into a steel can. Epoxy is then deposited resulting in a water resistant component.

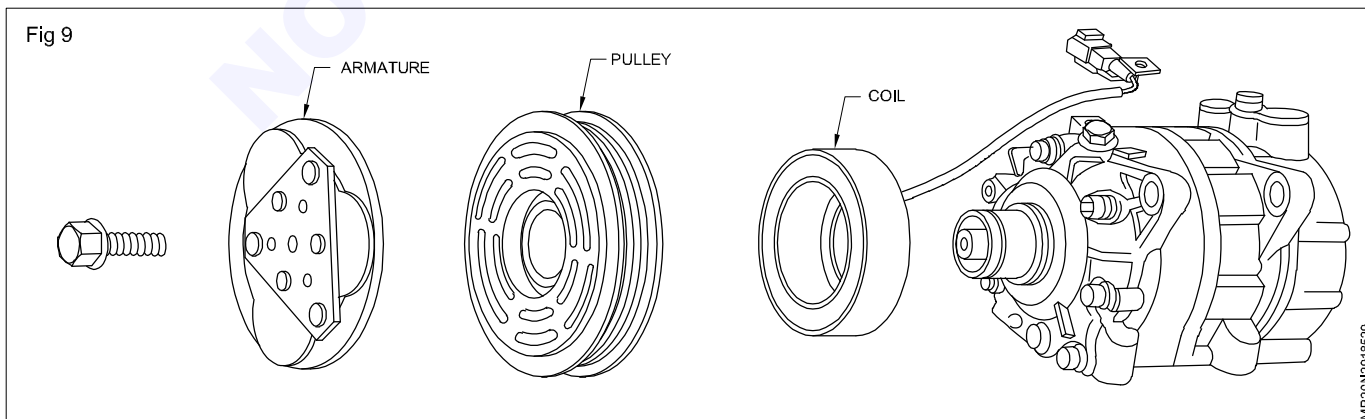
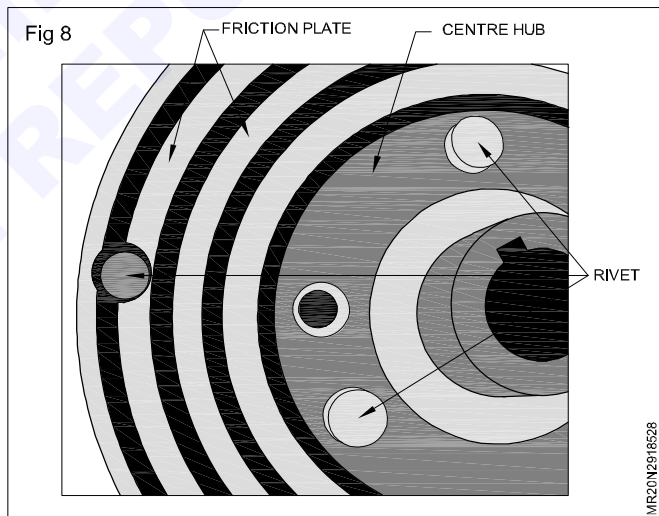
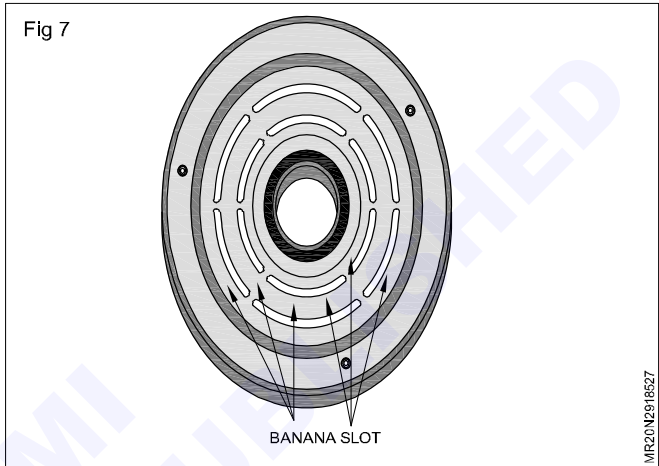


Let it be a coil of a horseshoe magnet with a north and south pole. Lines of magnetic flux extend perpendicular to the circular coil wires. When energized the flux field overcomes the air gap between the armature and pulley which pulls the armature into contact with the pulley friction surface. Once contacted the magnetic force and friction between the surfaces results in the armature turning until fully moving at the same speed as the pulley. The lines of flux actually pass into the rotor and in turn attract and pull the armature into contact to complete the clutch engagement. The "banana" slots in the pulley allow the passage of these north / south magnetic flux to the armature. (Fig 6)

freewheeling (de engaging clutch) (Figs 7 to 9)

The clutch is designed to connect the rotor pulley to the compressor input shaft when the field coil is energized. The clutch is used to transmit the power from the engine crankshaft to the compressor by means of a drive belt.

When the clutch is not engaged the compressor shaft does not rotate and refrigerant does not circulate the rotor pulley free wheels. The field coil is actually an electromagnet, once energized it draws the pressure plate towards it, locking the rotor pulley and the pressure plate together causing the compressor internals to turn, creating pressure and circulating refrigerant.



Check and replace magnetic clutch and electrical wiring of automobile A.C

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

- explain the function of magnetic clutch
- explain the operation of magnetic clutch
- explain purpose of using bearing in the clutch mechanism
- when to replace the bearing
- explain the purpose of battery
- explain the purpose of blower switch
- explain the purpose of HP-LP switch
- explain the electrical components how they connected in the circuit.

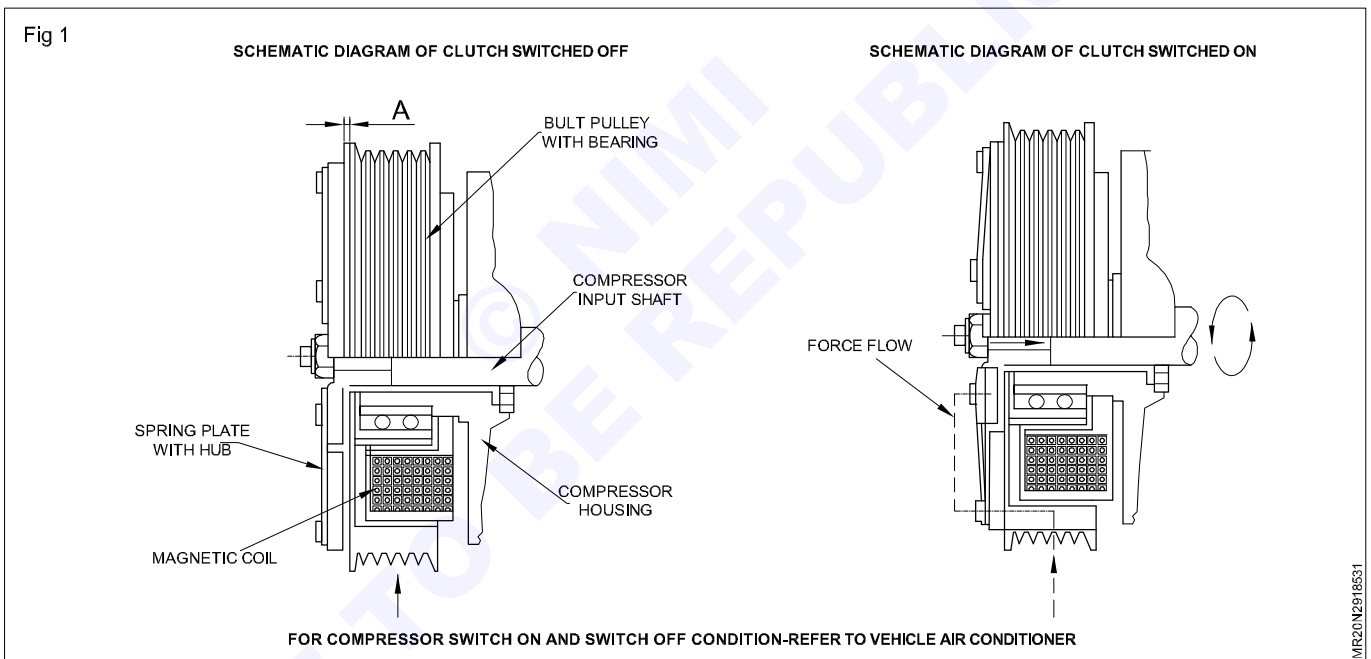
Function of magnetic clutch (Fig 1)

The vehicle engine drives the belt pulley (arrow) by means of the ribbed V-belt. The belt pulley rotates freely when the compressor is switched off.

When the compressor is turned on, voltage is supplied to at the magnetic coil. A magnetic force field is created. This force field draws the spring plate towards the rotating belt pulley (the open space "A" is bridged) and makes a connection between the belt pulley and the shaft of the compressor.

The compressor runs on until the electrical supply to the magnetic coil is present. When it is open the spring plate is then retracted by the belt pulley by means of springs. the belt pulley again runs without driving the compressor shaft.

Operation: When the voltage is applied to the clutch field coil, the clutch plate (which is connected to the compressor shaft) is drawn into contact with the pulley and the compressor rotates. When voltage is disconnected from the clutch field coil the clutch plate is released and the compressor ceases to rotate.



Purpose of bearing in the clutch mechanism

When clutch engage with compressor pulley heavy friction is occurring, to reduce the friction of the pulley rotation. Provided "bearing clutch mechanism".

Replacing of bearing

When bearing damage or noise will heard it must change the bearing.

Magnetic clutch

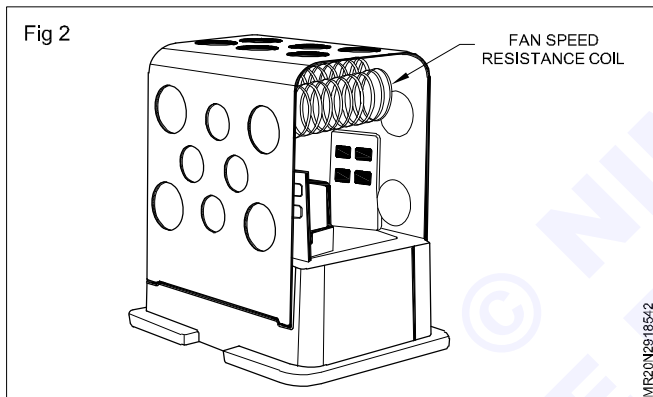
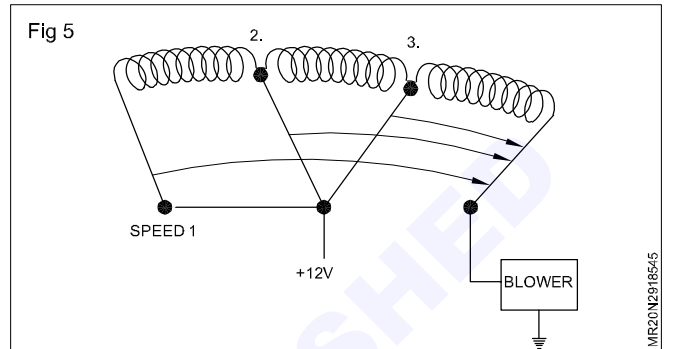
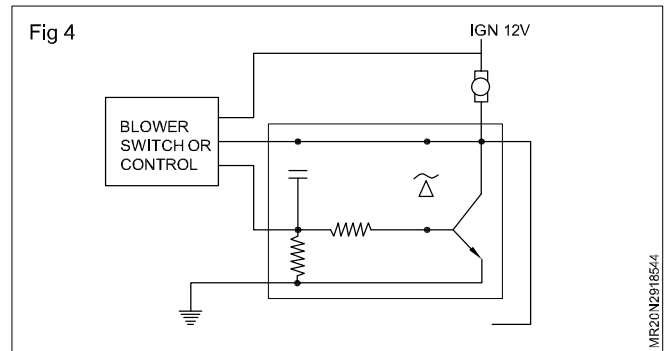
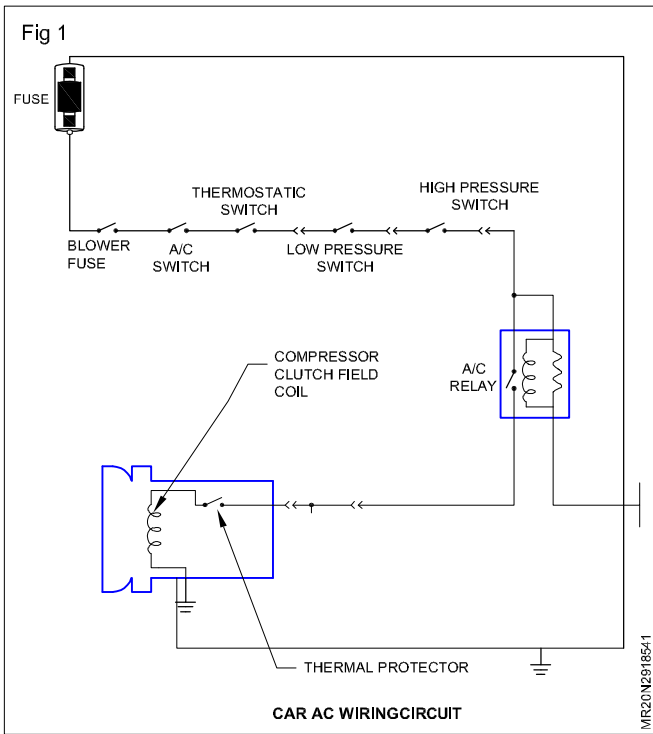
The drive train is connected between the compressor and vehicle engine while the engine is running by means of the magnetic clutch.

Design

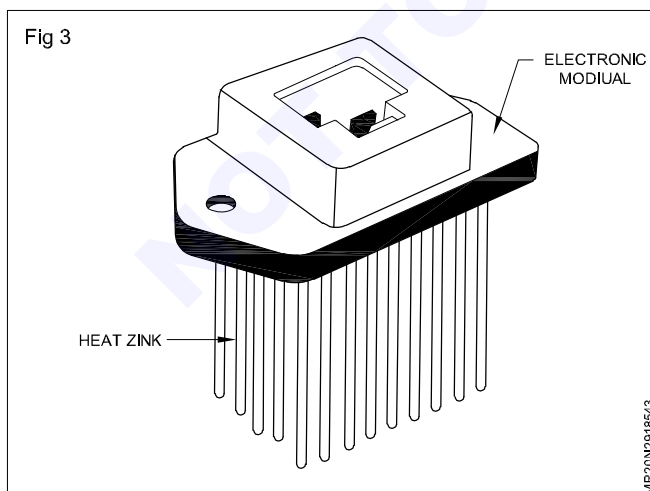
The clutch comprises

- Belt pulley with bearing
- Spring plate with hub
- Magnetic coil

The hub of the spring plate is permanently mounted the compressor input shaft. The belt pulley is mounted in a pivot bearing on the housing of the compressor at the shaft output. The magnetic coil is permanently connected to the compressor housing. There is an open space "A" between the spring plate and the belt pulley.



This type of speed controller is normally used with the electronic climate control (ECC) system. The highest blower speed when selected is normally from direct battery voltage via a relay.



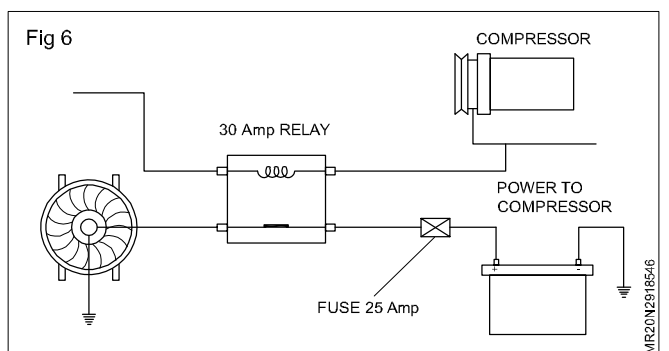
Condenser electric fan: Most vehicles with air conditioning require an electric fan to assist air flow, either pushing or pulling the air through the condenser, depending on which side of the condenser the fan is placed.

The majority of vehicles using R134a require this additional condenser cooling due to the higher operating pressures of R134a. Also most modern vehicles now have smaller grilles or bumper bar openings. This causes poor air flow conditions especially by the amount of air flow over the condenser.

The condenser fan is operated with A/C engaged in various ways:

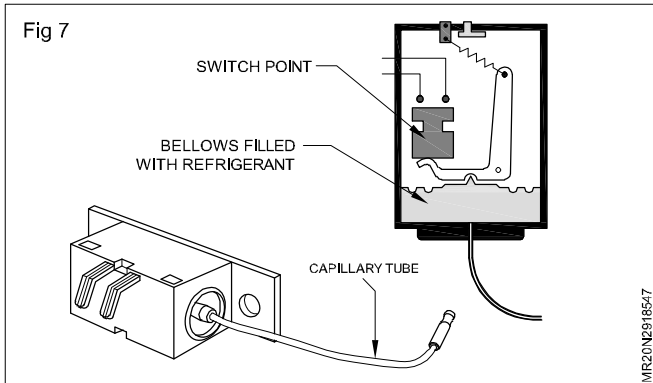
- Medium pressure switch;
- Indirect connection to the compressor clutch
- Via the Electronic Control Module (ECM);
- Signal from the A/C switch activation.

Compressor Cycling Controls (Figs 6 to 8)

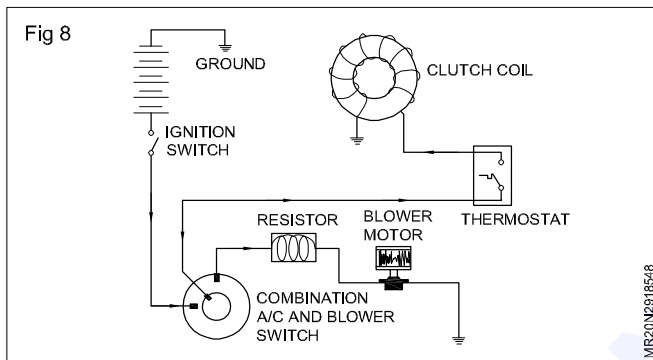


Thermostatic switch (Anti ice-up device): The thermostat is connected in series to the compressor clutch. When the temperature of the evaporator coil approaches freezing this temperature is sensed by the thermostat capillary tube which is in contact with the evaporator fins. The capillary tube contains refrigerant which expands or contracts depending on the temperature on this tube. The points inside the thermostatic switch open up when the refrigerant in the capillary tube contracts (sensing a cold evaporator coil) and interrupt the A/C

electrical circuit turning the compressor off. When the evaporator temperature rises again to a preset point (4 - 5?) the thermostat points then close. The refrigerant in the capillary tube has expanded (sensing a warmer evaporator coil and the electrical circuit is re-established to the compressor clutch.



Electrical circuit



Thermistor and Amplifier: This has the same function as the thermostatic switch except rather than mechanical action with contact points and capillary tube, the thermistor and amplifier is electronically activated. The thermistor is a sensing probe but unlike the thermostat capillary tube it senses the air temperature coming off the evaporator coil.

Thermistor

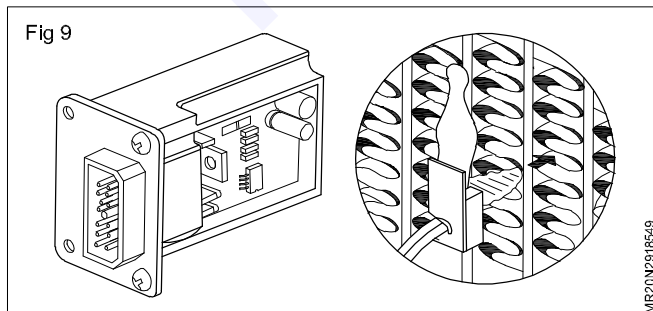
Electrical wiring containing a sensor which is a NTC resistor.

(Negative Temperature Co-efficient).

Amplifier (Fig 9)

A small electronic device containing a circuit board and electrical components.

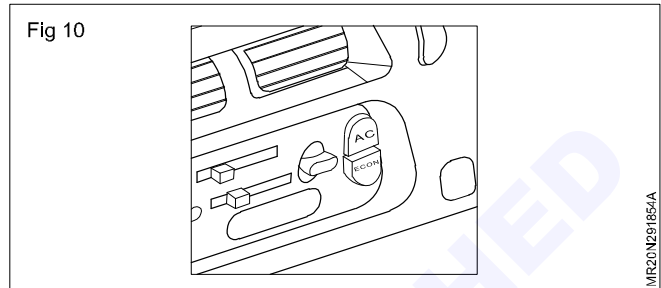
Thermistor resistance is amplified and used to control or switch the A/C clutch on or off.



Economy mode (Fig 10)

This function is normally associated with the use of a thermistor amplifier. In economy mode the compressor cut out temperature is set higher than a normal A/C mode. This means the compressor stays on for a lesser time, decreasing engine load and improving fuel economy and engine performance.

Center vent temperatures will also be slightly higher due to the compressor cycling off at a higher evaporator temperature.



Pressure cycling switch - Electrical (Fig 11)

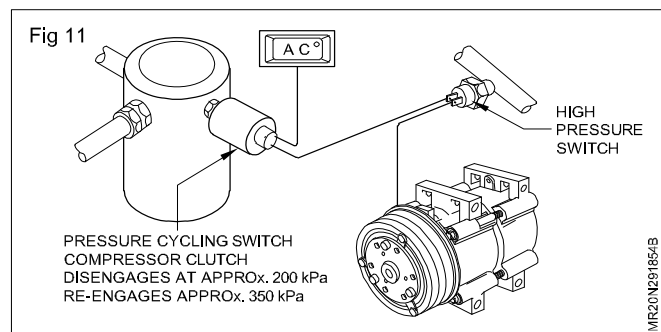
Some vehicles using the Cycling Clutch Orifice Tube (CCOT) system utilize a pressure switch located in the low side of the A/C system between the evaporator and compressor for compressor control.

This pressure switch is electrically connected in series with the compressor clutch.

Once the low side pressure reaches approximately 200 kPa, the compressor clutch is deactivated by the pressure switch opening. A low side pressure of approximately 200 kPa corresponds to an evaporator coil temperature of approximately + 0.40C (above freezing point).

Once the compressor is deactivated the low pressure rises followed by the evaporator coil temperature rising. At a pre-determined low pressure point, the pressure switch reactivates the compressor clutch. The evaporator temperature lowers again and the compressor re-engages.

Note: Normally a low pressure cut off switch is not used with a pressure cycling switch as the pressure cycling switch is located on the low side. It serves as a low pressure cut off also.



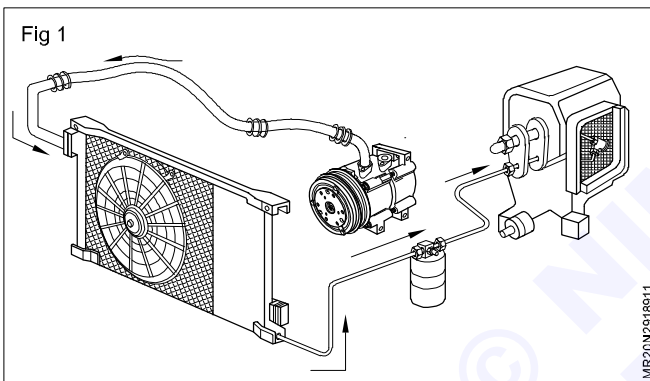
Working cycle of Automotive (Bus) Air-Conditioning

Objectives: At the end of this lesson you shall be able to
 • working cycle of bar A/C.

Principles of Air Conditioning

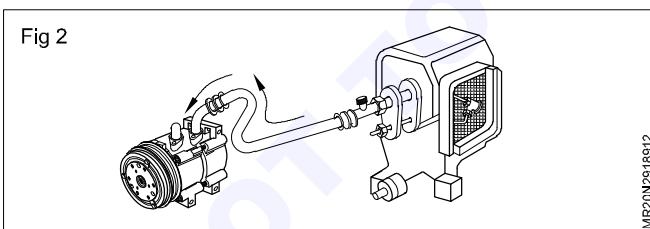
High pressure side (Fig 1)

Low pressure R134a vapor entering the compressor is compressed to become high pressure/temperature R134a vapor. This is then circulated along with lubricant oil to the condenser. As the high pressure/temperature vapor travels through the condenser, heat is released to the cooler ambient air passing over the condenser tubes condensing the vapor into a liquid. This high pressure/temperature liquid then travels through the filter drier onto the expansion valve where a small variable orifice provides a restriction against which compressor pushes.



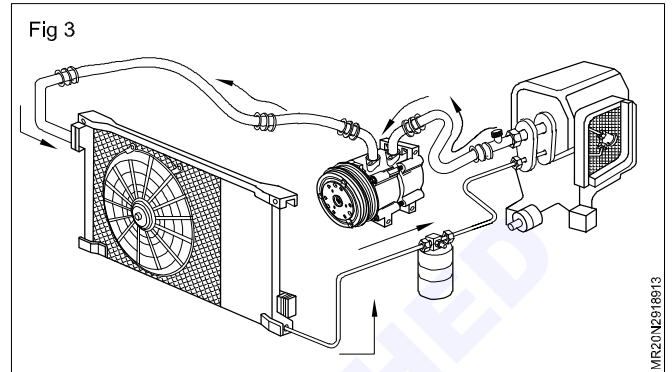
Low pressure side (Fig 2&3)

Suction from the compressor pulls the high pressure/temperature liquid R134a through small variable orifice of the TX valve and into the low-pressure side of the A/C system.



The R134a is now under low pressure/temperature vapor where heat from the cabin being blown over the evaporator coil surface is absorbed into the colder low pressure refrigerant. The R134a is then pulled through the evaporator and into the compressor. The A/C cycle begins again as the R134a vapor is compressed and discharged under pressure.

The bus air conditioning system mainly consists of the condenser, evaporator, compressor, magnetic clutch, alternator, fresh air device, blower, fan, return air grille, control panel, pipeline system and electric-controlled system.



The reservoir, filter drier, sight glass, cut-off valve, expansion valve, and fresh air device are located in the interior of the evaporator.

The compressor is mounted on the side of the engine, and the climate control panel of the bus air conditioning system has its own starting system, which is located beside of the instrument board.

The rooftop mounted evaporator assembly of most bus air conditioning system's evaporator use the traditional FRP housing also some bus air conditioning are adopting the SMC housing to protect its components and remain a good insulation performance which is lighter, higher strength and more environmental.

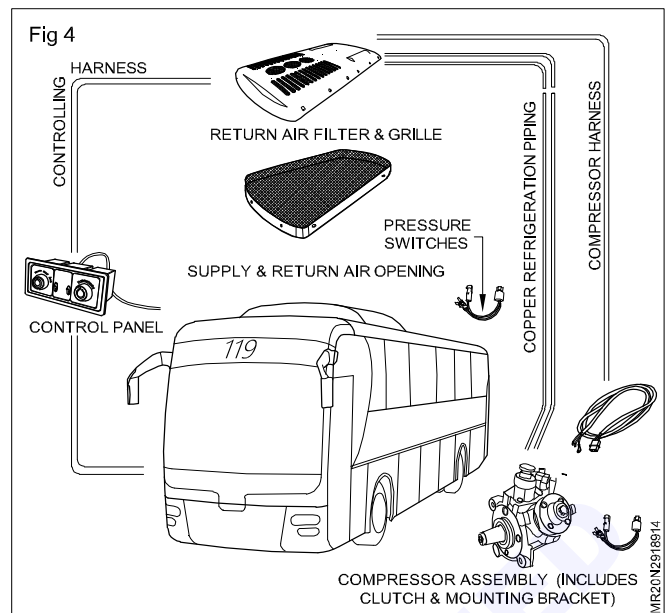
The condenser is mainly divided into new design Multi-flow-condenser (micro channel condenser) and traditional copper and fin condenser, the condenser fan blows the air through the condenser coil, in order to aid the heat dissipation better.

Working Principle of Bus Air Conditioning System (Fig 4)

When you press the ON/OFF button on control panel of bus air conditioning in the driver's cabin, relying on an inter connecting electrical system, the compressor is driven by the electromagnetic clutch via the belt which connected to driven pulley of engine, then the compressor circulates refrigerant through the internal connecting hoses system. Refrigerant, as gas, we use the R134a refrigerant in our bus a/c system, together with the heat from the passenger compartment, which is pumped by the compressor to the high-temperature high-pressure gas, and entering the condenser coil via the high-pressure air-conditioning pipeline.

Since the temperature of refrigerant entering condenser is higher than outside temperature, condenser fans cooling the condenser coil, and taking away a lot of heat energy which contains refrigerant existing as a hot gas.

The refrigerant undergoes the liquefied exothermic reaction, from high-temperature high pressure gas to medium-temperature, high-pressure liquid. Now, the refrigerant exists as a cool liquid, passes the reservoir, cut-off valve and enter filter drier which removing moisture and foreign materials, containing the filter, desiccant. Then the filtered refrigerant enters the sight glass, a device which can visual inspection of the refrigerant like water. Then cooled liquid refrigerant flows into the evaporator through expansion valve, which controls the volume of refrigerant into the evaporator coil and decrease the pressure of refrigerant. Evaporator absorb the hot air energy form passenger compartment through a return air grille device which includes an fresh air system which removes particulate matter without influencing cooling effect, then the evaporator blower blows the cleaned and cooled air into the passenger compartment through the evaporator coil. The refrigerant under a change-of-state from a liquid to a gas, and a corresponding change of pressure from high to low, which called evaporation. During evaporation, due to its throttling effect, the cool liquid through the expansion valve becomes gas, and the gaseous refrigerant absorbs a lot of heat energy, containing the passenger compartment hot air, so as to achieve the purpose of the cooling. Warming air passing the evaporator



coil, due to cooling effect, moisture condensation, then it is collected and discharged to the outside of the bus. The hot gas in passenger compartment is then suctioned by the compressor, where it is compressed and refrigeration cycle repeats.

Major Components Used in Air-conditioning in Railway coaches

Objectives: At the end of this lesson you shall be able to
• **the components used in railway air-conditioning.**

The components used in Railway air-conditioning

- Compressor.
- Condenser Unit.
- Evaporator Unit.
- Air Duct.
- Refrigerant piping & joints.
- Gauge Board.
- A/C control panel.
- Wiring.

Compressor

The refrigerant vapour drawn from the evaporator is compressed by means of a multi cylinder reciprocating compressor and compressed to a pressure ranging from 142 to 213 psi according to the load. The work done due to compressor raises the temperature and pressure of the refrigerant vapour to circulate it through the system and for obtaining desirable impact.

Condenser

The condenser serves the function of rejecting the heat absorbed by the refrigerant vapour in the evaporator, suction line, compressor body, and the heat absorbed during the compression process. The condenser consists of a heat exchanger, which is forced-air-cooled by means of two or three axial flow impeller fans. The refrigerant vapour is condensed when ambient cool air is passed through the heat exchanger. The refrigerant liquid leaving the condenser is led into the liquid receiver from where it moves to the evaporator through expansion valve. The liquid receiver is a cylindrical container which contains a reserve of the refrigerant liquid. A dehydrator and filter are also provided to ensure that the refrigerant is free from moisture and dust particles.

Evaporator Unit

The evaporator unit consists of a thermostatic expansion valve, a heat exchanger, a heating unit (resistance type) and centrifugal blower driven by a motor. The thermostatic expansion valve controls quantity of liquid refrigerant at a lower pressure after expanding it from high pressure to low pressure, corresponding to the load demand. The low pressure low temperature refrigerant passes through the distributor into the heat exchanger consisting of finned copper tubes. The return air from the air conditioned compartment, is mixed with fresh air and this mixture is blown through the heat exchanger, where heat in the air is transferred to the cool refrigerant causing cooling of the air and the evaporation of the refrigerant inside the tubes.

The cooled air is led through the ducting to the various compartments and diffused by means of air diffusers. Filters are provided in the fresh air and return air path to eliminate dust. When the outside ambient temperature is very low, heater is switched on according to the setting of the thermostats

Gauge Board

Gauge panel consists of pressure gauges (HP, LP, and OP) and pressure cutouts to protect the compressor against, (i) High pressure, (ii) Low pressure and (iii) low oil pressure.

High pressure cutout

It is a safety device against excessive discharge pressures and protects the compressor and piping system from damage. It is a pressure operated switch which cuts off the compressor drive motor when the pressure exceeds a preset value (241psi). The plant cannot be restarted unless the cutout is reset manually or the pressure drops below the preset value.

Low pressure cutout

It is also a pressure operated switch similar to the H.P. cutout switch, but it shuts down the compressor if the suction pressure drops down below 10 psi. It protects the system against disproportionately low evaporator temperatures and formation of frost on the evaporator. The compressor starts automatically if the suction pressure rises above the preset value.

Low oil pressure cutout

It ensures adequate lubrication of compressor to avoid piston capture due to less lubricating oil or failure of oil pump. This cutout is set at 35 psi.

Air duct

The air conditioning system includes three air ducts as follows

- Fresh air duct.
- Main air duct.
- Return air duct.

Actually there is no separate return air duct provided in A/C coaches. In the case of A.C. two tier coach and A.C. chair car, the return air is drawn through the return air filters directly from the nearest compartment. In 1st class A.C. coach, the corridor acts as return air duct and the return air is drawn through return air filters located at the corridor ceiling near the first compartment.

Fresh air duct

This is provided at the rate of two per AC plant. It is mounted on the side wall just below the roof evaporator unit. There is an opening in the side wall with louver hinge door arrangement and with the provision to house a fresh air filter. The fresh (inlet) air duct has been designed with damper valve to control the quantity of fresh air to be drawn into the compartment. This arrangement has been standardized for all types of air conditioned coaches.

Main air duct

The conditioned air from the evaporator unit is blown into the main air duct by means of two centrifugal blower fans driven by a motor with double extended shaft. The air is distributed to each compartment in the case of 2 tier sleeper coach and full AC first class coach through adjustable diffusers. In the case of a c chair cars, the conditioned air from the main air duct is distributed along the hall through longitudinal apertures suitably set at factory. The main air duct has been provided with central diagonal partition making it two independent taper ducts so that each compartment is influenced by the diffused air of both plants. Further air distribution to the entire compartment is maintained at constant velocity. In order to reduce turbulence and noise due to air motion in the duct the cross section of the main air duct has been designed in such a way that air velocity inside the duct shall not be higher than 300 m/min. The aperture of air diffuser has been designed to deliver the required quantity of air into the compartment at a velocity not greater than

250M/min. This diffuser is provided with a knob to deflect the air to the required angle. By the above arrangement the air velocity inside the compartment obtained is between 6M/min. to 12M/min. at the face level of the passenger.

Refrigerant piping and joints

The refrigerant piping consists of the suction line (from the evaporator out let to compressor inlet) discharge line (from compressor outlet to condenser inlet) and liquid line (from the liquid receiver to the inlet side of expansion valve), connections to the gauge panel from the compressor delivery side (high pressure side), low pressure side and from the compressor crank case. The lubricating oil connections are also part of the piping system Main pipelines are jointed with couplers or elbows by means of silver brazing, whereas joints to various components like gauges pressure cutouts, hand shut off valves, expansion valve, strainer etc. are connected by means of flare joints to facilitate easy removal of the above elements for replacement and inspection.

Temperature setting

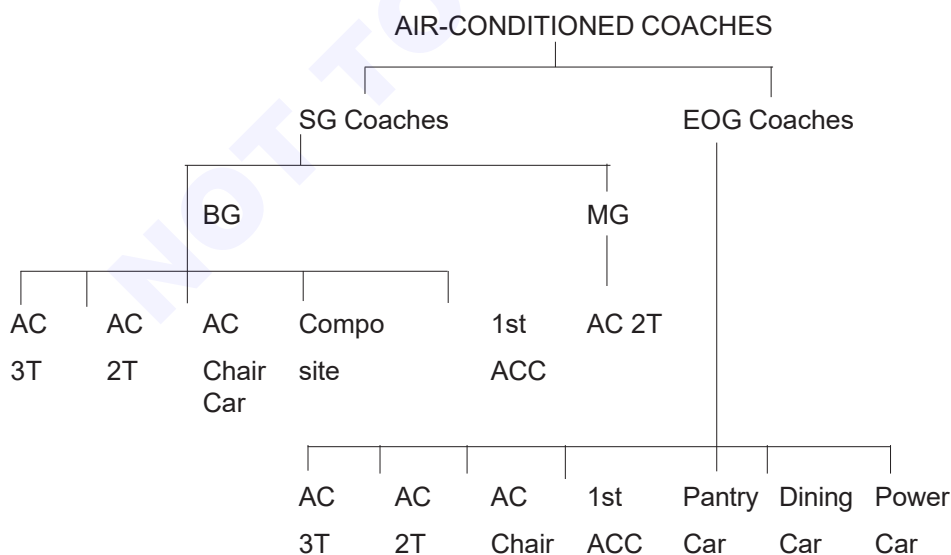
The temperature inside the air-conditioned compartment is controlled by electronic thermostats with one setting each for cooling at 24OC and for heating at 20OC. Operation of cooling or heating takes place in accordance with ambient conditions. The temperature control thermostats are fitted in the return air passage. Two types of thermostats are used, one for controlling the cooling and the other for controlling the heating.

Railway coaches

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

- classification of air-conditioned coaches
- power supply in the coaches.

Classification of air-conditioned coaches.



Power supply in the coaches.

SG Coaches: The electrical power for the self generating type of coaches is derived from the alternator mounted on bogie of the coach and driven by the axle through 'V belt drive as long as the coach is in motion at the minimum full load output (MFO) speed of the alternator. During stationary or when the coach is running at less than MFO speed the entire coach load is met by the battery of 800 AH capacity. Provision for charging and precooling the coach from external supply has been made by means of battery charger, 200A rating mounted on the coach under frame. Two numbers of 415 V, 3 ph, ac, precooling sockets have been provided diagonally on the end walls. The alternator gives an output of 18 KW at 130 V, DC in the unders lung type of AC coach, whereas the alternator capacity is 25Kw in the RMPU AC coach. One alternator set per AC plant has been fitted in the self generating type AC coaches.

EOG Coaches: The electrical power supply for end on generation type AC coaches is derived from separate generator cars arranged at the ends of the train formation,

Description of Railway Air-conditioning

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

- description of RMPU
- salient features of RMPU
- technical Details of RMPU
- air circulation System.

Description of RMPU

The roof-mounted AC equipment for AC coaches of Railways would provide more comfortable journey and also help attach more coaches in the superfast trains. These roof-mounted AC units are more efficient and lightweight. Two high capacity packaged air-conditioning units of minimum of 7.0 TR of cooling in 40°C to 45°C atmospheric temperature i.e. 14.0 TR for one coach, has replaced the open type AC system of capacity 5 TR each (Total 10TR) for each coach. Two packaged units are used in one coach each mounted above the toilets on both ends supplying conditioned air into a tapered duct to serve the coach end to end. The units (two in each coach) are fitted with 4 compressors but operate under normal with 3 compressors and the 4th one acts as standby and works only during peak days of the summer.

Compressors are started in sequence with time delay to reduce the peak demand of electricity during startups. These units are thus more energy efficient and are more reliable. This units can work on E.O.G. systems in addition to S.G. systems . The roof mounted unit needs approximately 11.5 KW, 20 ampere at normal condition. Modular type AC units for rail coaches is a major breakthrough in rail-coach technology. The units are extremely energy efficient and reliable. They use two hermetically sealed compressors of half capacity in each packaged unit.

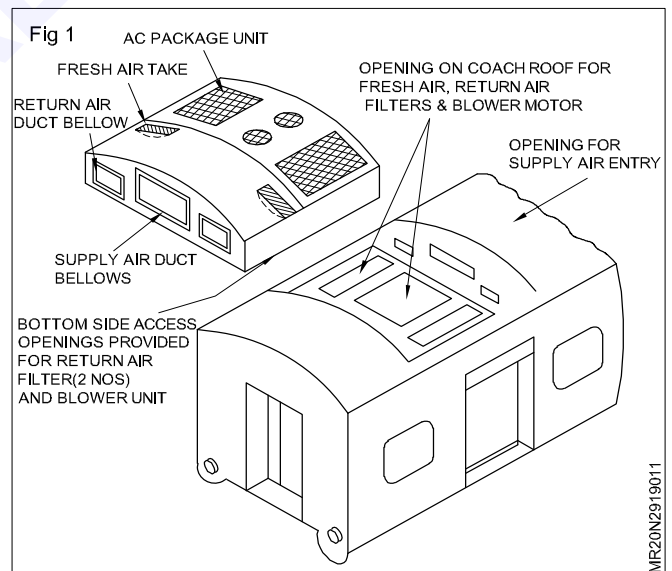
with generation and transmission voltage of 415 V, 3 ph, AC. The power for individual coaches is tapped by means of rotary switch from any one of the double feeders running along the coach leading from the power cars, and coupled between coaches by means of inter-vehicular couplers. The air-conditioning equipment works at 415V, 3 phase AC supply and train lighting equipment work at 110V, AC, obtained between phase and neutral derived from a 3 KVA,415/190V, 4 wire step down transformer.

Driving Equipments

Driving equipments consist of motors for driving the compressor, condenser impeller fans and the evaporator blower fans. The driving motors in self generating type coaches are all of

D.C. machines needing more care for attention of commutator and brushes. The E.O.G. type coaches are provided with 3 phase AC squirrel cage induction motors for driving the AC equipments.

The roof mounted unit is a factory assembled, gas charged and hermetically sealed refrigerant system. The general diagram is shown in Fig 1.



It has two hermetically sealed three phase reciprocating compressors, two vertical flow condenser fans and one blower unit as evaporator fan. There are two independent refrigerant circuit in each PAC unit having a compressor, condenser coil and evaporator (cooling) coil. The condenser fans and evaporator blower are common. Each circuit has its own fresh air and return air filters. Each evaporator (cooling coil) fits in its own drain pan. Each

drain pan has its own drain outlet. The condenser fans and compressors can be accessed from the top of the unit where as the return air filters can be pulled out from under the unit inside the coach in corridor. The blowers, heaters and safety controls can be accessed by opening the access door at the bottom of the unit. The fresh air filters can be reached by opening return air access doors on each side at the bottom of the unit. The terminals are located inside a junction box under the unit and can be accessed by opening the cover of this junction box or termination box.

Since the PAC unit is a modular hermetically sealed type, it requires minimum maintenance. The refrigerant system is Hermetically sealed and has fitting or gauge ports. The safety devices are provided to protect against abnormal operating refrigerant pressures, loss of air and over heating of heating elements. Over current, single phasing, voltage fluctuation.

Salient features of roof-mounted AC package units

- 1 Light in weight, saves fuel for hauling.
- 2 Keeping in view the low price and light weight, the unit pays for itself in one year operation.
- 3 Low cost of installation at the coach building factory since the system is factory made, assembled, gas charged and tested for performance prior to delivery.
- 4 The installation requires simply to lower the unit in the false ceiling above the toilets on both ends of the coach and connection of wiring, drain pipe and flexible duct.
- 5 In case of failure, replacement of the unit with new unit can be done in less than a few hours by simply lifting the defective unit by a crane and lowering the new one in place.
- 6 The A.C unit remains outside the partition wall and therefore, no chance of water leakage on passengers.
- 7 Fresh air is taken from the roof through condenser area which gives a relatively clean air free of the smells of toilets which are common in conventional A.C. coaches.
- 8 Hermetically sealed system with no fittings or openings, thus it presents little potential of gas leakages and break-downs.
- 9 The unit is almost maintenance free since it uses 3ph AC motors which have no commutators or brushes to wear out.
- 10 Uses refrigerant R-22 and very small quantity less than 3 Kg.
- 11 Mounted on the roof, thus dirt or dust collection in condensers is negligible and therefore, requires practically no maintenance or water spraying on condenser coils.
- 12 No chance of damage due to flash floods during the monsoons.

13 Energy efficient - uses less electricity, saves fuel for generation.

14 Humidity control in monsoons possible through use of micro processor - based control system. It will also provide optimum use of all equipments and even wear to compressors through rotation of operation.

Technical details

The A/C unit shall be capable of maintaining inside conditions as under:

	DBT (°C)	WBT (°C)	RH (°C)
Outside (Dry Summer)	45	25	-
Outside (Wet Summer)	40	28	-
Inside (Dry & Wet Summer)	24	-	40

Each coach shall be provided with two roof mounted A/C units each with a minimum cooling capacity 20,000 K.Cal/ hr (6.6TR).

Refrigerant Compressor

Hermetically sealed compressors working with Freon 22 (monochloro difluoro methane) are provided in the A/C package unit. The compressor motor is rated for 415V, 3Ph, 50 HZ, AC Power Supply.

Power Consumption	-	5. 20KW +/-20%
Current (Amps.)	-	8.25 +/- 20% at 415V, 3Ph,50HZ,AC
C.F.M.	-	13

Refrigerant Condenser

Condenser Coil	-	Fin-on-Tube
Face Area	-	0.7 M2 x 2
Material of tube	-	Copper
Tube O.D.	-	10 mm
Fin material	-	Aluminium
Fin Thickness	-	0.2 mm
No. of Fins/cm	-	4 - 5
Refrigerant	-	R22, Less than 3.0Kg each circuit
Condenser Fan	-	Propeller type (2 Nos)
Air Flow (CFM)	-	5000 min. x 2
Speed (RPM)	-	1400 +/- 10%
Motor size	-	1 H.P x 2
Current consumption (Amps)	-	1.8 +/- 10%x2 at 415V, 3 Ph, 50 HZ, AC
Power Factor	-	0.7

The condenser motor shall conform to 15:325-1970 with IP 55 protection conforming to 15:4691-68.

Evaporator Unit	-	Fin-on-tube type
Face Area	-	0.3 M2 x 2
Material of tube	-	Copper

Tube O.D.	- 10 MM (3/811)
Fin Material	- Aluminium
Fin Thickness	- 0.2mm
No. of fins/cm	- 4.3 +/- 1
Evaporator Fan	- Centrifugal type blower
Air Flow (CFM)	- 2000 (3400 cu Mtr/Hr.)
Speed (RPM) Motor size	- 1400 +/- 10%
Speed (RPM) Motor size	- 1.5 Hp
Current consumption(A)	- 2.2 +/- 10% at 415V, 3ph, 50HZ, AC
Power Factor	- 0.7

The main duct carrying conditioned air is so designed that the air velocity inside it does not exceed 360 m/min. The air distribution system is so designed as to ensure that the max. air velocity at 150 mm below duct/diffuser is 10m/min. and at 1.2 m from floor level is 15m/min

Four types of diffusers are used in the conditioned compartment for distribution of cool air. Type 'A' larger diffuser and type B smaller diffuser are provided on the main duct. Type 'C' and type 'D' diffusers are provided on the branch ducts for transverse and longitudinal berths respectively. Branch ducts of size not less than 50 mm is brought down near the window from the main duct on both sides. The diffusers on both the branch ducts are mounted in the inclined position to direct cool air towards lower berths. The branch diffuser on the longitudinal berth's side is provided with adjustable vanes to control quantity of cool air. The diffuser on branch ducts for transverse berths is made in two parts, each part directing cool air towards the lower most berths of the bay. These are also provided with variable vanes.

Air circulating system

The AC system is designed to introduce fresh air at the rate not less than 0.35 M3/min/ person into the A.C. compartment. Keeping in view the above requirement of fresh air, quantity of fresh air per package unit will not to be less than 11.7 Cu.M/min.

Trouble shoot in Automobile A/C

Objectives: At the end of this lesson you shall be able to
 • **problems and troubleshoot related to automotive A/C.**

A/C system is noisy

The noise heard when the A/C system is first turned on is not due to a defect. In the event of persistent noise, check

for the presence of one of the following malfunction causes and apply the corresponding solution.

Cause	Solution
1 Belt worn or slipped	1 Check the wear and tension of the belt.
2 Belt idler pulley is noisy	2 Replace it.
3 Electric clutch plate slipping	3 Make sure that the distance between the compressor pulley and electric clutch is 0.3-0.5mm.
4 Vibration and resonance of the compressor support plate.	4 Make sure the bolts are tight and the plate is properly positioned.
5 Expansion valve "whistles".	5 If the noise persist, replace the valve.

In The following instances, a few defective components of the A/C system create an incorrect inlet and outlet pressure. This phenomenon causes noise in the compressor that is actually due to one of the causes listed below and NOT to the compressor itself.

- Incorrect amount of refrigerant (30-35% more or 70-75% less).
- Expansion valve stuck shut or blocked.
- Compressor displacement regular valve defective (for variable-displacement compressors only).
- Clogging in the A/C system circuit

- Filter saturated with moisture.

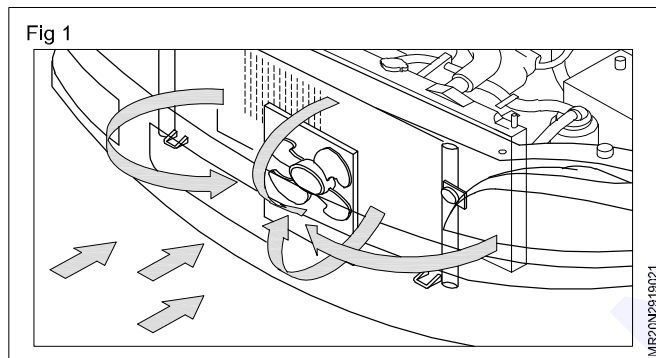
A/C system emits unpleasant odours (Fig 1)

Under certain conditions, moulds and bacteria (normally present in the air) may form on the surface of the evaporator core, causing an unpleasant odour inside the vehicle.

- Use an antibacterial product to treat the evaporator.
- Advise the customer to turn off the A/C system a few minutes before shutting off the vehicle, leaving the blower fan running (this will dry the evaporator core from the moisture that encourages bacteria growth).

The condenser doesn't dissipate enough heat

Cause	Solution
1 Air flow blocked by dirt accumulated on the heat exchangers; water radiator, condenser.	1 Clean the radiator and condenser thoroughly.
2 The pressure switch or water temperature bulb are tripped at the correct pressure and temperature levels	2 Cut out the controls using the appropriate electrical not connection. Replace the defective part if necessary.
3 The electric fan does not work	3 Power the electric fan directly. replace if it still does not work.
4 Incorrect functioning by the electric fan (incorrect rotation direction).	4 The fan must be "suction" type when placed between the heat exchangers and the engine, and "blowing" type if placed between the heat exchangers and outside air intake.
5 Engine water overheated	5 Make sure the original engine cooling system is working properly.
6 Condenser not positioned correctly.	6 Make sure that the distance between the radiator and condenser is 15-20mm, if present the air ducts must be correctly positioned.



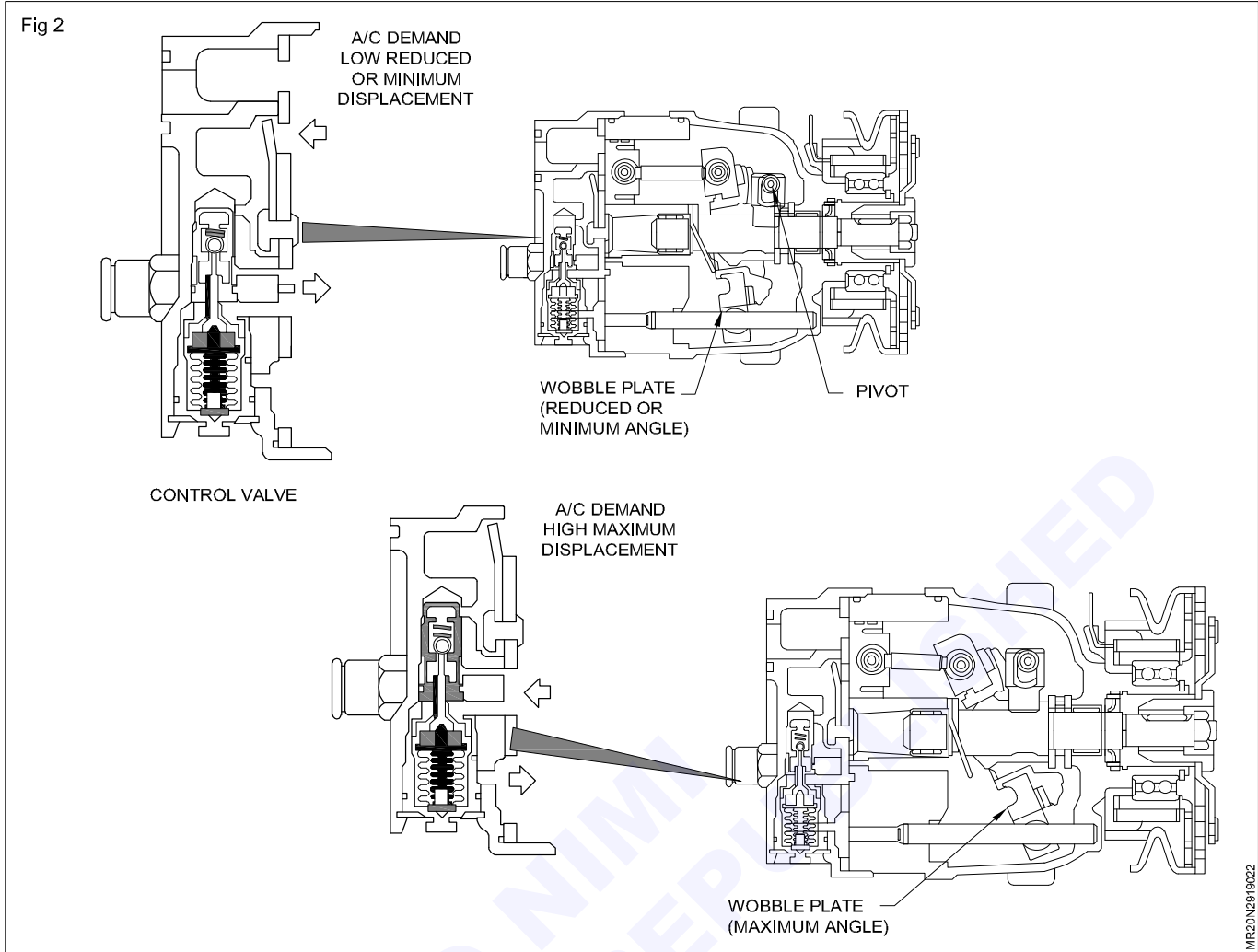
Incorrect refrigerant amount

Air or incondensable gases or moisture in the A/C system

Cause	Solution
1 Incorrect refrigerant amount (30-35% excessive or 70-75% lack).	1 Recover refrigerant from the A/C system.
2 Contaminated refrigerant.	2 Replace the A/C filter (if filter is saturated with moisture).
3 Filter saturated with moisture.	3 Evacuate the incondensable gases and moisture from the A/C system. Run the vacuum pump for at least 30 minutes.
	4 Check the vacuum seal using a pressure gauge control.
	5 Restore the recommended amount of refrigerant to the system as well as any oil recovered together with the refrigerant.

Compressor displacement regulator valve defective (only for variable-displacement compressors)

Cause	Solution
1 Valve blocked by impurities (the evaporator tends to freeze)	1 Recover refrigerant from A/C system.
2 Regulator springs of the valve improperly set (Fig 2)	2 Replace the displacement regulator valve located in the compressor rear cover.
	3 Evacuate the incondensable gases and moisture from the A/C system by letting the vacuum pump run at least 15 minutes.
	4 Restore the recommended amount of refrigerant to the system as well as any oil recovered together with the refrigerant.



Expansion Valve Defective

Cause	Solution
1 Thermostatic capillary of the valve is defective.	1 Recover refrigerant from the A/C system.
2 Mechanics of the valve are jammed. (Fig 3&4)	2 Replace the expansion valve.
	3 Evacuate the incondensable gases and moisture from the A/C system by letting the vacuum pump run for at least 15 minutes.
	4 Restore the recommended amount of refrigerant to the system as well as any oil recovered together with the refrigerant.

Expansion Valve Diagnosis

If when carrying out pressure gauge diagnosis it is found the TX valve is at fault, ie.

Jammed fully open - high/low pressure to high, or Jammed fully closed - low pressure zero to a vacuum; then follow the resting procedure below.

Testing

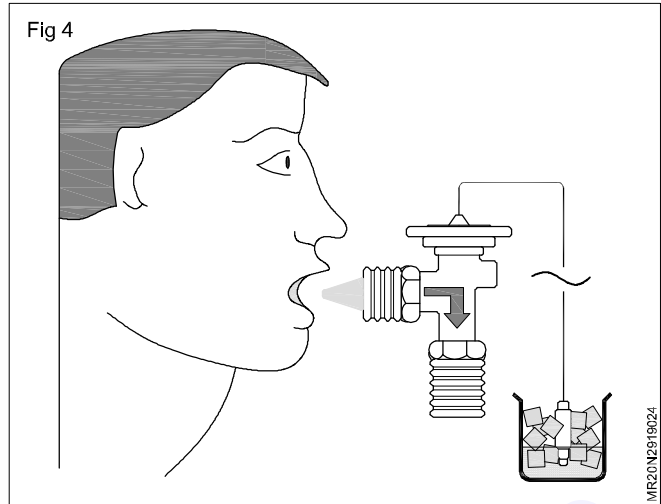
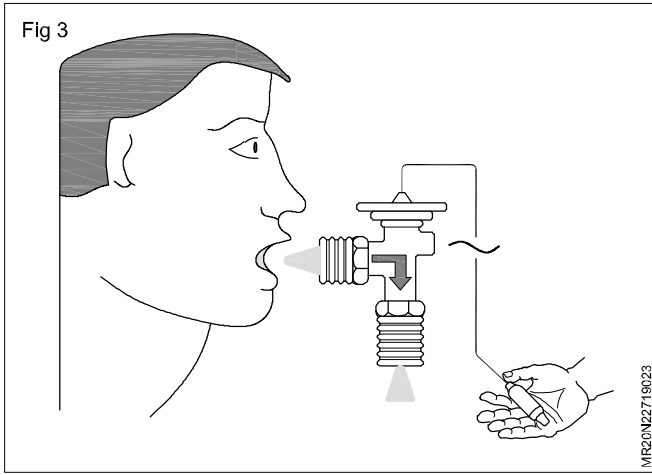
- Remove the evaporator case and dismantle,
- Detach the TX valve pressure compensating tube and temperature sensing bulb from the evaporator outlet side; Mark the area on the outlet tube where the sensing bulb is clamped when replacing a TX valve. This sensing bulb must be fitted in exactly the same position.

Opening Test: Warm the temperature sensing bulb by hand, the TX valve should now be fully open. This can be verified by blowing through the valve.

Closing Test: Into a container of water and crushed ice, place the temperature sensing bulb and gently stir, the TX valve should now be fully closed. This can be verified by blowing through the valve.

If any of the above tests fail, replace the TX valve with the correct type i.e. (tonnage and super heat). ensure new "O" rings are used and that the temperature bulb is covered with insulating material to ensure no false temperature readings are obtained.

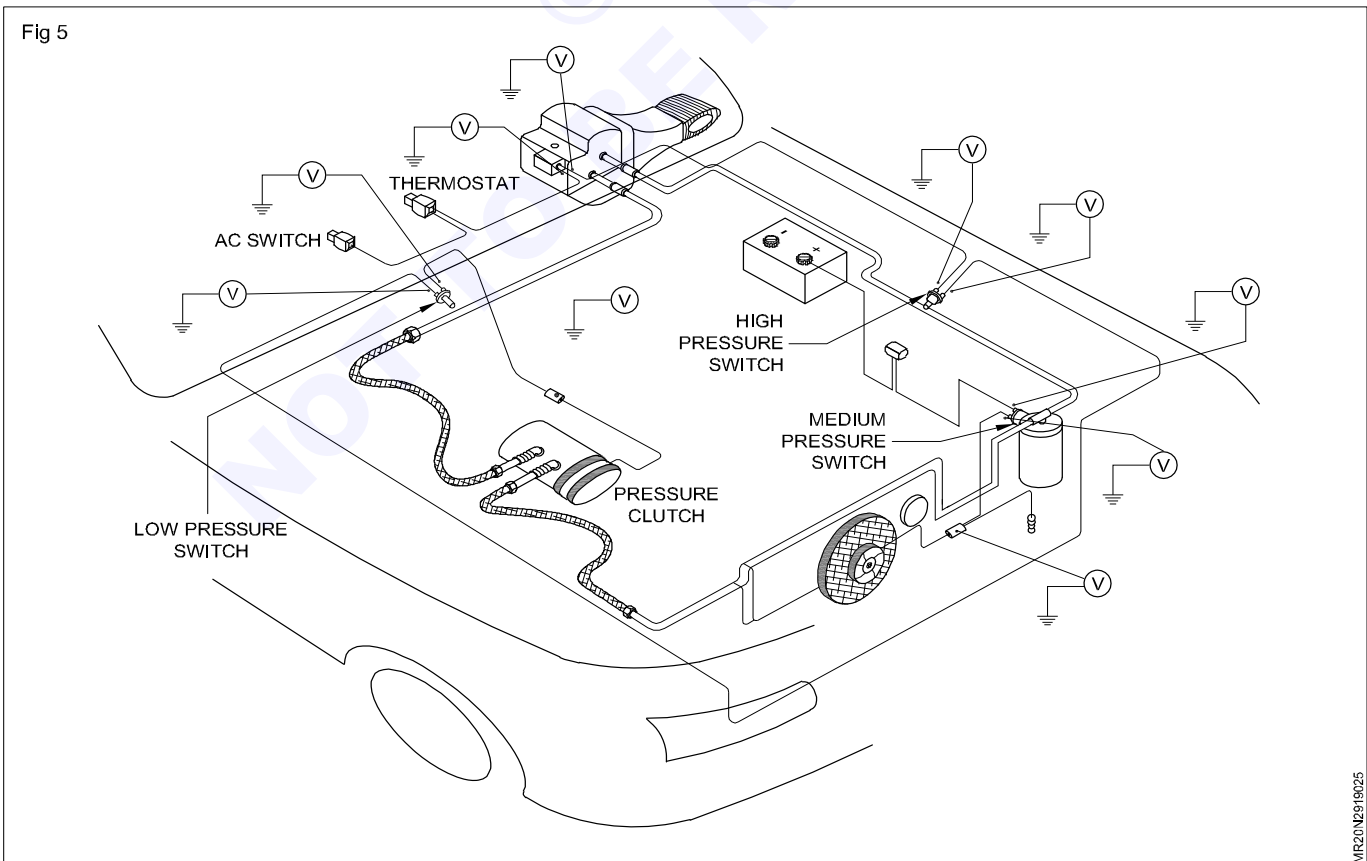
Caution - when bending the temperature sensing tube to fit, care must be taken not to break it as this tube is hollow and contains refrigerant.



The Electric Compressor Clutch Slips or Does Not Engage

Note: For valves equipped with automatic control (ECC), go to self-diagnostic or software control.

Cause	Solution
1 Shortage of refrigerant (70-75% lack)	1 Search for the refrigerant leak
2 Electric clutch coil de-energized or intermittent energized (Fig 5)	2 Disconnect the electrical clutch wire from the electrical system and connect it to the positive pole of the battery using a 7.5A fuse. If the clutch does not engage, it must be replaced. If it does engage, check the pressure switch, thermostat, A/C control switch, and miscellaneous electrical connections.
3 Incorrect distance between compressor pulleys and electric clutch plate.	3 The distance must be between 0.3-0.5mm



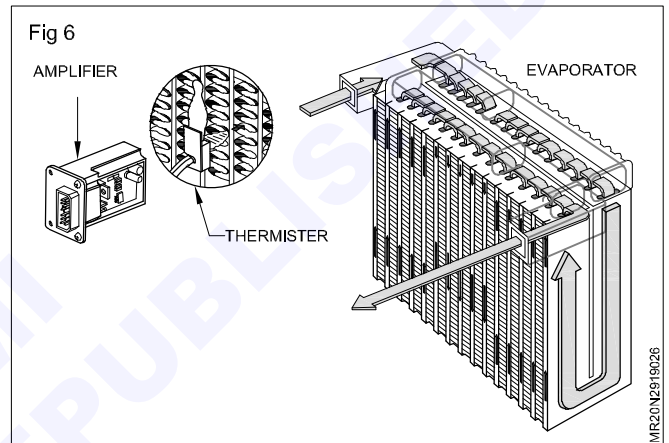
Ice on the Evaporator Core

Cause	Solution
1 Malfunction by the thermostat or "no- frost" probe (if present) (Fig 6)	1 Make sure the electrical connection of the thermostat or of "no-frost" probe is in good condition, and that the sensor is properly positioned. Replace any defective parts as needed.
2 Malfunction by the blower fan	2 With the A/C system running, at least the first ventilation speed must work. Otherwise, make sure the electrical system is properly connected.
3 Compressor displacement regulator valve is defective (only for variable displacement compressors)	3 Check the operation of the compressor displacement regulator valve.

Note:

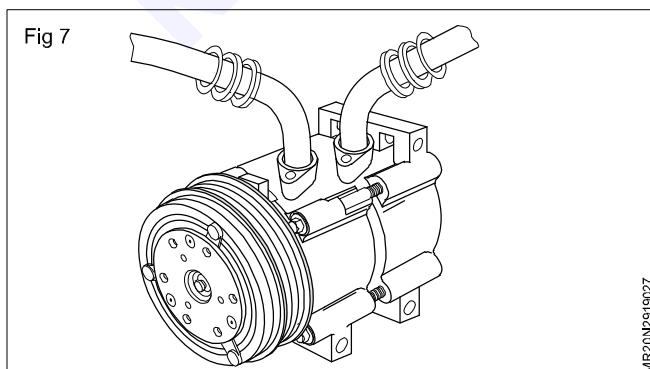
- This may occur even after a few minutes of operation, causing a progressive drop in the air flow at the vents.-
- For valves equipped with automatic control (ECC), go to self-diagnostic or software control.

Amplifier



Compressor Damaged

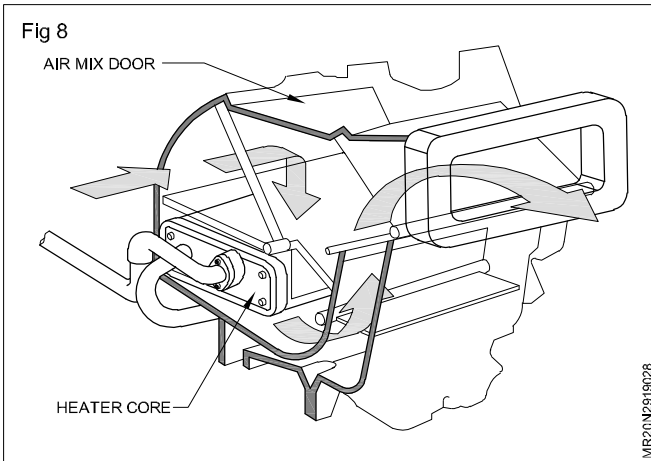
Cause	Solution
1 Valves bent	1 Recover refrigerant from A/C system.
2 Seizing (Fig 7)	2 Replace the compressor from A/C system.
	3 If the compressor is seized, flush the A/C system using a specific product and replace the dehydrator filter.
	4 Install a new compressor.
	5 Evacuate the incondensable gases and moisture from the A/C system by letting the vacuum pump run at least 30 minutes.
	6 Restore the recommended amount of refrigerant to the system as well as any oil recovered together with the refrigerant.



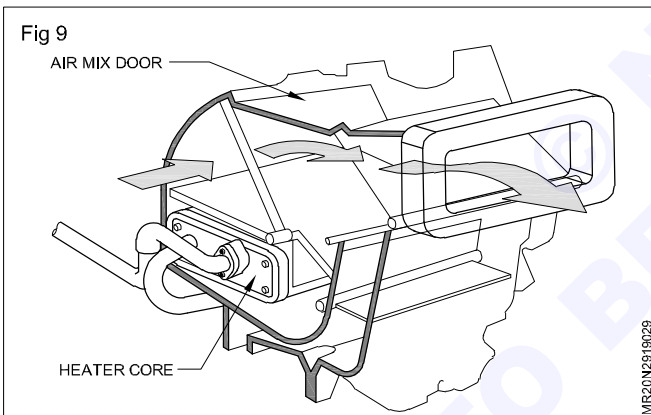
Hot Air Infiltrated in the Passenger Compartment Hot Water Infiltrated in the Heater

Cause	Solution
1 The water valve of the heater (if present) does not close properly. (Fig 8&9)	1 Check the lever mechanisms and/or valve control motor. Cut out the heater if necessary.
2 The air mixing and/or re-circulating flaps are not perfectly sealed.	2 Check the lever mechanisms and/or valve control motors.
3 Sealing of the evaporator unit poorly airtight	3 Make sure the evaporator unit is tightly sealed and the couplings with the original heater are correct, to prevent warm air from infiltration from outside.

Air flow during maximum hot



Air flow during maximum cold



Blockage in the A/C system circuit (Figs 10 to 17)

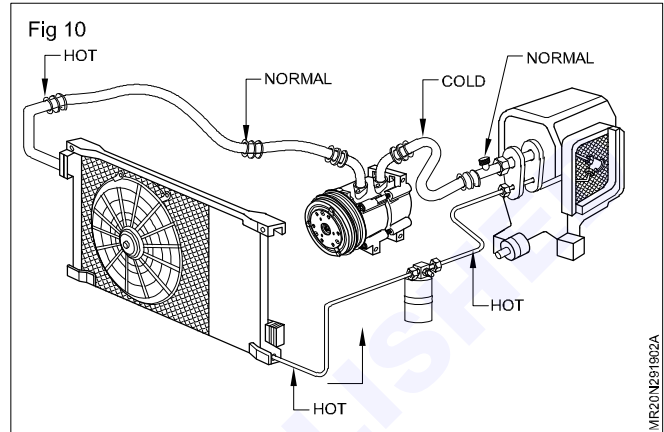
A very useful diagnostic aid is the "Feel Test". As the test implies it is a matter of quite simply feeling tubes and components for temperature drops, indicating possible blockage location.

By this stage you would be aware of what side of the A/C system should be hot and what side should be cold. But what also happens with the pressure gauge reading, sometimes they don't make sense.

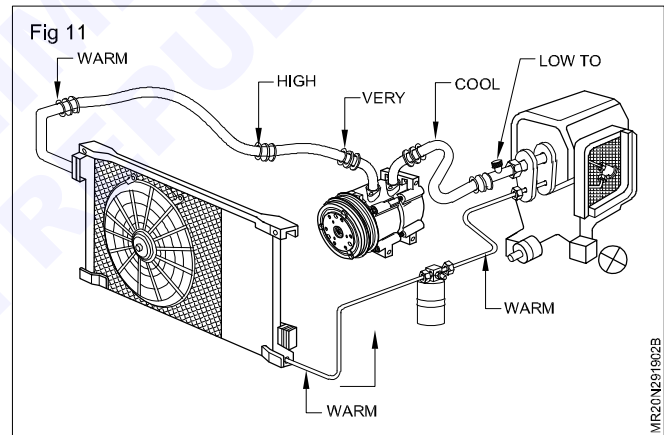
The location of the charging ports in relation to the A/C system MUST be taken into consideration. A pressure gauge reading could be high or low depending on what side of the charge port the blockage is located. Use the "Feel Test" as well as the pressure gauges readings.

Normal System

HIGH SIDE - Hot LOW SIDE - Cold



Blockage - High Side (after charge port)



High side pressure - High

Low side pressure - Low to normal

- High pressure switch will not deactivate the A/C system, low pressure switch might;
- Compressor noisy;
- High Side hose very hot before blockage;
- High side hose very cool to warm after blockage.

Indicates Blockage

Blockage in the A/C system circuit

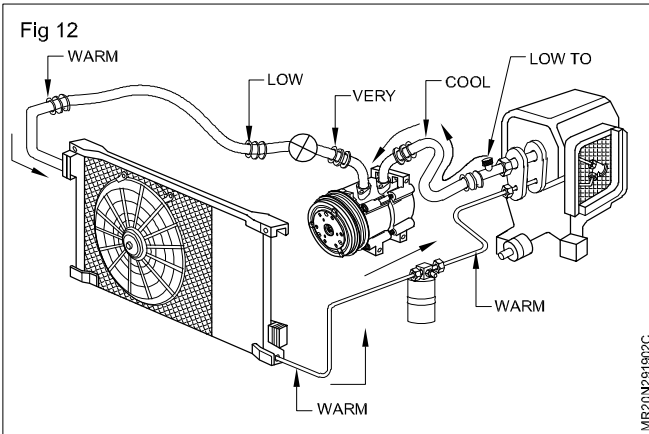
Blockage - High Side (before charge port)

High side pressure - Low

Low side pressure - Low to normal

- High pressure switch will not deactivate the A/C system, low pressure switch might;
- Compressor noisy;

- High Side hose very hot before blockage;
- High side hose very cool to warm after blockage.



Indicates Blockage

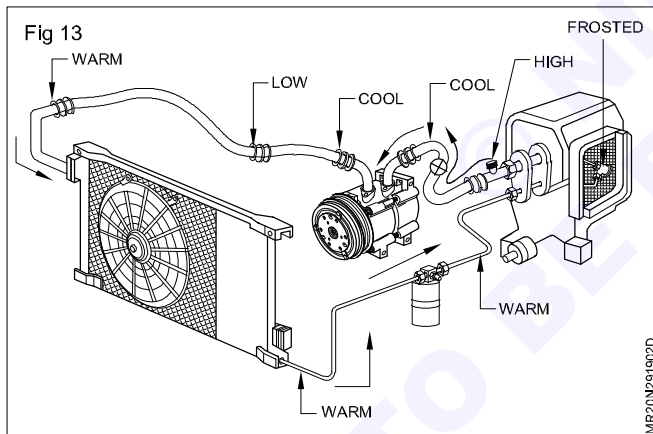
Blockage - Low Side (after charge port)

High side pressure - Low

Low side pressure - High

- Low pressure switch will deactivate the A/C system;
- Frosting of the low side hose/fittings before the blockage.

Indicates Blockage



Blockage - Low Side (after charge port)

High side pressure - Low

Low side pressure - Low to vacuum

- Low pressure switch will deactivate the A/C system;
- Frosting of the low side hose/fittings before the blockage.

Indicates Blockage

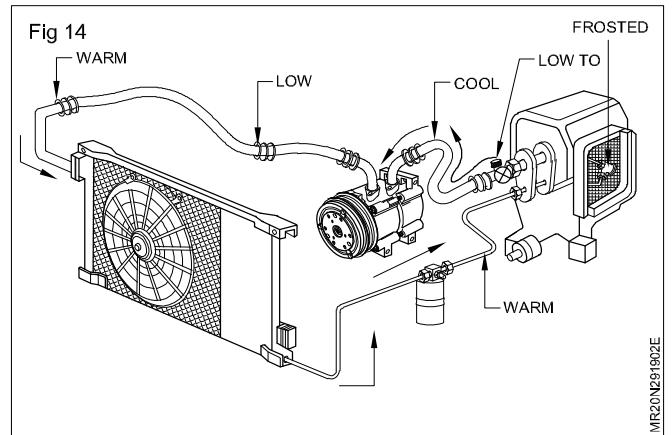
Blockage in the A/C system circuit

Blockage - Orifice Tube (Orifice Tube system)

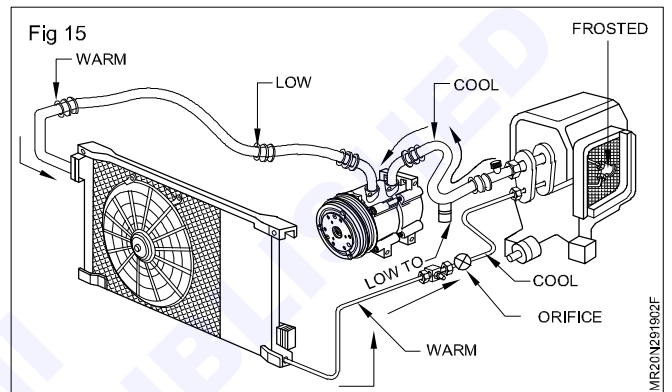
High side pressure - Low

Low side pressure - Low to vacuum

- Low pressure switch will deactivate the A/C system;
- Frosting of the tube after the orifice tube.



Indicates Blockage



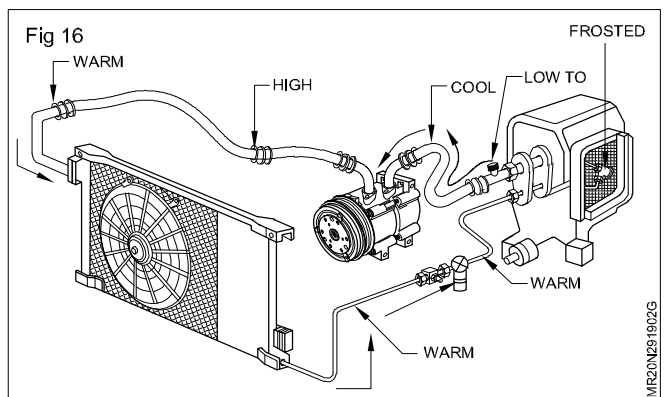
Blockage - Receiver Drier

High side pressure - High

Low side pressure - Low to vacuum

- Low pressure switch will deactivate the A/C system;
- If the blockage is in the receiver drier itself, the outlet tube will be frosted

Indicates Blockage

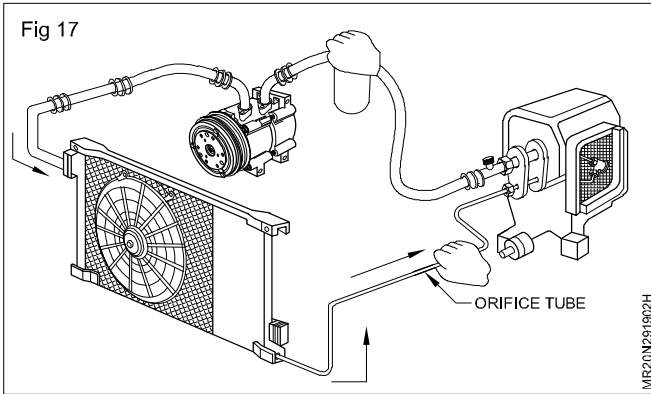


Checking refrigerant charge

(orifice tube system)

Run the A/C system, place one hand at the outlet side of the orifice tube and one hand on top of the accumulator.

If the temperature of the accumulator is higher than the temperature after the orifice tube, then the refrigerant charge is not to specification. Add 150g and recheck.



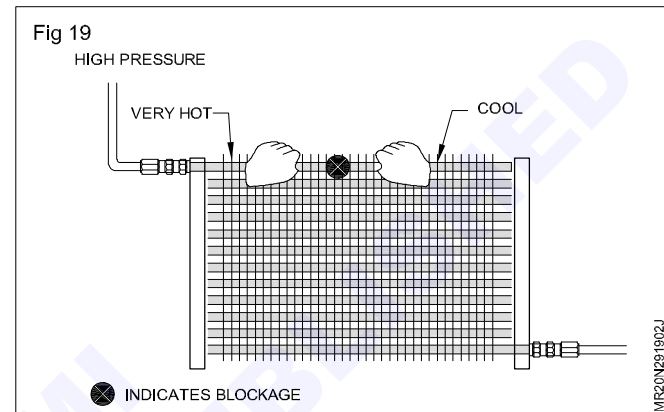
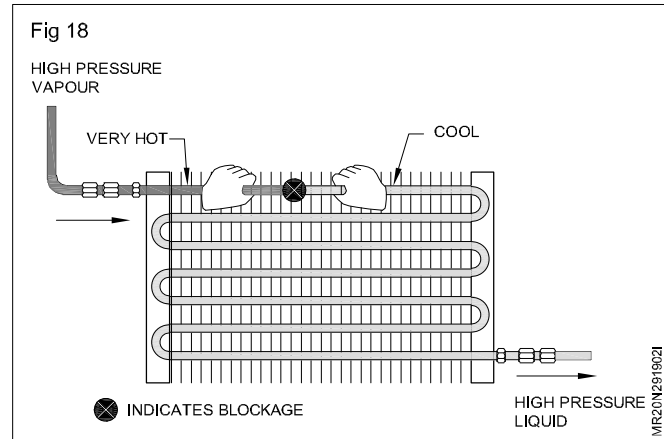
Blockage in the A/C system circuit

Blockage - Condenser (Fig 18&19)

A change of state, where high pressure vapour forms into a high pressure liquid during the movement through the condenser, takes place within approximately the first 1/3 of the condenser. With this change of state a slight (depending on ambient temperature change takes place.

Using your finger, follow the tube(s) of the condenser (avoid burning your skin), you can feel where the change of state takes place. This change will however be quite subtle. But if you feel the difference in temperature before approximately the first 1/3, a blockage maybe present.

With the parallel flow design condenser, refrigerant flows through more than one tube so the possibility exists that the condenser will operate sufficiently in lower ambient. But when the ambience increases and greater refrigerant flow is required, a blockage in one tube will cause problems such as poor performance and excessive discharge pressures.



Preventive maintenance in HVAC plant

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

- operation and routine maintenance
- preventive Maintenance.

Operation and Routine maintenance

Operation of a plant not only includes the starting and stopping of a system, but also needs a continuous observance on the performance of the whole system in routine maintenance. Some minor & negligible problem can turn into a major malfunction. Which will in turn result in costly and time taking repairs. Operator of the plant should be attentive and should detect faults as per early as possible. One of the important aspect of operation is to maintain log sheet or maintenance chart to analyse the performance of the system and to take routine maintenance as and when demand arises.

The following day-to-day routine maintenance need to be attended

- 1 Air-filter cleaning: A dirty air filter reduces the efficiency of the plant. The more dirt accumulation results in greater reduction in efficiency. If not cleaned regularly, the filter will become saturated and the dirt can move over to the cooling coil and fins and creates an insulation for heat transfer. Weekly cleaning is recommended. In dusty environments it is recommended to clean it frequently.
- 2 Leak Testing: Leak testing must be done regularly. Weekly once is recommended.
- 3 Low side maintenance: When the plant is to be shut down for a prolonged period or if the low-side of the system need to be open for repair, it is necessary to pump down all the refrigerant from evaporator to the condenser or receiver tank.
- 4 High side maintenance: For carrying out the repairs or any maintenance of the high side of the system, firstly remove the entire charged refrigerant from the system to a cylinder. For this, firstly pump down the system and then use recovery machine to store the refrigerant into the cylinder. Otherwise use a separate compressor to pump out the refrigerant from the system into the empty cylinder.
- 5 Charging: For charging, back seat the compressor suction service valve. Connect a charging hose from the refrigerant cylinder to the compressor suction gauge port of the service valve. Purge out air from the hose pipe. Keep the cylinder in vertical position so that only gas can enter the compressor. After starting the compressor, charge the system slowly. Stop the charging every two to three minutes. Check the suction pressure. Keep charging the system until it gets fully charged.

6 Top up: Sometimes, system needs extra refrigerant charge, in that case do top up. Follow the steps for charging process.

7 Belt Tension of indirect Drive system: Check the tension of the belt and tighten wherever found loose.

8 Check the spray of the cooling tower nozzle.

9 Check the ampere and voltage reading of the system.

10 Ensure that the pressure gauges and thermometers are giving the correct indication of the plant performance. Also analyse them with the previous readings from log sheet/ maintenance chart.

11 Water treatment plant must be checked for resin bed saturation level. Is the hardness of water after treatment is getting less or not?

12 Descaling of the water cooled condenser must be done routine wise. This can be known by measuring the temperature of entering water and leaving water from the condenser. If no or less heat transfer than the normal is there descaling needs to be done.

Preventive maintenance of HVAC Plant

Preventive maintenance and service assume greater importance to improve the efficiency of the system and prevent damage. In energy crises and material shortage, proper and timely preventive service can result in a considerable amount of saving in power and material. Good maintenance and service is only possible if the plant is properly erected and commissioned. The preventive maintenance can help in three ways.

- 1 To anticipate faults
- 2 To improve efficiency
- 3 To save energy

The preventive maintenance schedule as follows

- 1 For improve system performance and decrease power consumption, clean the air filter, clean AHU, lubricate blower motor.
- 2 Check the operation of safety controls periodically.
- 3 Check the refrigerant leak, maintain properly.
- 4 Check vibration and rectify vibration.
- 5 Maintain log back properly.

Reasons for increase in discharge pressure

- 1 Fouling of tubes in water cooled condenser.
- 2 Scale formation in condenser water tubes.

- 3 Pressure of non-condensables in the system.
- 4 Overcharge of refrigerant in the system.

Preventive steps for increases of discharge pressure

- 1 De scale condenser water tuber periodically.
- 2 Clean the cooling lower.
- 3 Purge the non-condensable gasses.
- 4 Remove excess refrigerant.

Reasons for suction pressure reduction

- 1 Fouling of the evaporator surface
- 2 Wrong adjustment of throttling devices
- 3 Reduction of air quantity over cooling coils.
- 4 Clogging suction filters of high capacity compressors
- 5 Shortage of refrigerant.
- 6 Clogged liquid line strainers.

Preventive steps for reduction in suction pressure

- 1 Clean the cooling coil periodically
- 2 Adjust the throttling device correctly.
- 3 Check the damper position, if it is open the plant will have a low suction pressure and will not deliver full capacity when it is required. Therefore, there dampers should be checked for proper fixture and free movement.
- 4 Clean suction filter.
- 5 Check the leakage, rectify leak, add refrigerant.
- 6 Clean liquid line strainer.

Important checks and starting procedures

Pro start-up checks: Confirm that all fans are light on shafts rotate easily and turn in the correct direction. Check the alignment of all drive kits and that pulley set are light on shafts. Check belt's tension. Make sure that all bearings etc, are clean and properly lubricated. Use the control circuit current and verify the sequence of operation of all motor starters, controls and safety devices with reference to detailed winning diagram.

Post start-up checks: Starting and running amperage of all motors suction & discharge pressures/temperatures oil pressure. Air-temperatures chilled water temperature (if applicable) condenser air or water temperatures. Dry bulb wet-bulb temperatures of the ambient air and conditioned, space is free from draughts or stagnant air pockets, stratification etc, all ancillary equipments and complete control circuits functioning correctly. Finally check the log sheets & remarks.

Log sheets: It is desirable that all main operating characteristic, pressure & temperatures to be recorded at set times. The information should be kept on well protected loose-left, log sheets or in bound books.

These should contain columns for time, switched 'on' time switched 'off' and progressive totals of hours run by each compressor or pump with stand-by/changeover facilities. A remarks column to record unusual events such as per failures, and action taken & normal maintenance. The sheet size and lay-out must be suitable to the equipment.

Starting procedure: Always follow the detailed instructions provided by equipment manufactures or system designers. In general - start all motors manually in the correct sequence. Make certain that compressor suction & discharge, liquid line valves are opened, then start the compressor. Start the cooling tower fans and circulating water pumps before starting the compressor. Test the operating and safety controls in condensing unit after starting the compressor. Check evaporator fans & any accessories, air side operating and safety controls. Check and balance systems operating pressure & temperature, check the operating of all operating safety controls.

Planned maintenance

Daily: Check that all equipments are free from noise and vibration. Check operational suction discharge and all pressure check the air- water, refrigerants temperature whenever possible.

Weekly: Check the liquid line sight glass, check/clean/replace air-filters if necessary. Check condensate drums are free from blockage, check running amperage of all most motors. Check if the condensing temperature, inlet & outlet are normal.

Monthly: Lubricate the fan and motor bearings as necessary (Follow the manufacturer's lubricant specification and bearing-care instruction). Check all belts for condition tension and alignment. Tighten all fan sheaves and pulleys if it is loose; check the conditions of the cooling tower sump's strainer screens, clean all water filter, refrigerant liquid line strainers. Check the condition of the duct work and test balancing, service electrical contacts of starters and controls.

Quarterly: Check water cooled condensers for levels of chemical treatment, of the condensing temperature high check if it need de-scaling. If the heat exchangers provided with fins check the surface for freedom from blockages. Lubricate the fans and bearings as necessary, leak test refrigeration system. Inspect humidifiers if necessary clean the sensors of the thermostat.

Yearly: Examine all motors/fans/shaft bearings. Clean all water strainers drain, clean & repair cooling lower, clean or replace spray nozzles, while cooling tower maintenance. Remove the sludge gathered inside the cooling tower sump Fig.1. Cooling tower & condenser water lines surfaces exposed to sun should be cleaned and painted, check all operating all safety controls for correct setting & operation. Maintain a schedule maintenance board and tick the works completed with date.

Operating plant at design efficiency: If we are not given proper attention, it may lead to faulty operation, in results in the long run major problem may occur and it works out to be quite costly, for example, a partially clogged water filter or cooling tower spray nozzles increase the discharge pressure of the compressor, contributing to increased power consumption for much less cooling effect.

As an example increase of a 15 TR plant is given in table below:

Hence we have generalised the important of preventive maintenance & service.

1 Maintain an effective planned schedule to keep the heat transfer surfaces, air filtering and air-handling equipments clean, free of dust, scale and corrosion.

- 2 Lubrication of moving parts at the right time, with quality and correct quantity of lubricants.
- 3 Checking operation of safety and operating controls periodically.
- 4 Periodical checking of the system for refrigerant leak.
- 5 Check for abnormal vibration and noise.
- 6 maintenance of a properly recorded log of readings of the plant.
- 7 It is important to carry out seasonal, periodical, overhaul of components as recommended by manufacturer.

Table 1

Condition	Suction Temperature in °C	Condensing Temperature in °C	Ton of Refrigeration	BHP	Percentage reduction in capacity	Percentage increased in BHP
Normal	7.2	40.6	17	0.93	-	-
High condensing pressure	7.2	46.1	15.6	1.12	8.2	20