ENGINEERING GUIDE FOR VENTILATION AND AIR CONDITIONING REFRIGERATION SYSTEMS

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1. GENERAL

1.01 This section provides information on the various types of refrigeration equipment that are used in mechanical systems. This information is applicable for use in the design of new buildings and building alterations including those buildings that are intended to house telephone equipment. Ventilation, air-conditioning, and refrigeration systems are used in office and administrative buildings to provide personnel comfort. They are also used in data processing and telephone equipment buildings to provide the environmental conditions necessary for proper equipment operation.

1.02 Due to the level and scope of changes to this section, change arrows have been omitted. This section is being reissued to:

(a) Include considerations of energy conservation

(b) Include new equipment availability.

2. ROOM AIR CONDITIONERS

2.01 ***Description:*** Room air conditioners, commonly referred to as window units, are small self-contained units usually air cooled and located in windows or in building walls. These units have cooling capacities ranging from 4,000 to 36,000 British Thermal Units per hour (BTU/hr).

2.02 ***Application:*** These units are used to provide simple, free delivery of conditioned air to an enclosed space, room, or segregated zone. Typically, this type of unit includes a refrigeration system for cooling and dehumidification and a means for circu-

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lating and cleaning the air. Room air conditioners may be used in existing buildings or in new construction.

2.03 ***Advantages:*** The advantages of using these units are as follows:

(a) These types of units are easy to install. The variety of models available are adaptable to most windows. If required, they may be installed with wall sleeves. The air-cooled units require no water and, generally, do not require drains. Provision for properly-sized electrical connection is usually all that is required.

(b) Each space can maintain its own temperature independent of adjacent spaces.

(c) Failure or maintenance of one unit does not cause a whole area to lose air conditioning.

(d) Easily adapted for local high-heat release areas to supplement the main building system provided the unit can be located in an exterior wall for heat rejection.

2.04 ***Disadvantages:*** The disadvantages of using these units are as follows:

(a) These units provide low initial cost cooling. They have often been applied to the cooling of large areas, but it is not recommended. Though the cooling function may be entirely satisfactory, these units do not provide results comparable to central units in terms of noise level, air distribution, dust removal, and positive ventilation.

(b) The protrusion of units on the exterior wall is usually unsightly.

(c) Operation of these units in accordance with recommended temperature conditions is difficult to control.

(d) The physical location of the unit may cause drafty conditions.

2.05 ***Energy Efficiency:*** Room air conditioners should be as energy efficient as possible. The greater the number of either of the following ratios, the higher the energy efficiency.

(a) Energy Efficiency Ratio (EER) =

$$\frac{\text{BTU/hr Capacity}}{\text{Watts Input}}$$

(b) Coefficient of Performance (COP) =

$$\frac{\text{BTU/hr Capacity}}{\text{Watts Input} \times 3.14}$$

3. UNITARY AIR CONDITIONERS

3.01 ***Description:*** Unitary air-conditioning equipment, sometimes referred to as packaged equipment, consists of one or more factory-assembled components designed to provide ventilation, air movement, air cleaning, cooling, and dehumidification. It may also be equipped to provide heating and humidification. The medium used for heat rejection may be either direct refrigerant to air heat transfer (air cooled) or condenser water. The equipment may be self-contained within one assembly, or it may be split into separate components (split system) which are designed to be used together. Unitary equipment is available in refrigeration capacities ranging in size from 2 to 15 tons for light commerical units to the heavy commercial and industrial equipment of 120 tons.

3.02 ***Applications:*** Unitary equipment should be evaluated for use under the following circumstances:

(a) The space to be air-conditioned can be served by a single unit(s).

(b) A part or an entire floor of a building can be air-conditioned separately.

(c) Areas within the building have varying load requirements.

3.03 ***Advantages:*** The advantage of using these air conditioners are as follows:

(a) Units are compact and require less floor space than a built-up central station system of comparable capacity.

(b) Units have a wide range of capacities and can be placed in many locations throughout the building including the roof.

(c) These units are preengineered and designed with components matched to perform satisfactorily as a complete system.

(d) Depending upon occupancy, a section of a floor or building can be air-conditioned separately from other areas. Unoccupied areas can be turned off.

(e) Unitary or packaged equipment can produce the same environmental conditions as a central system.

3.04 ***Disadvantages:*** The disadvantages of using these air conditioners are as follows:

(a) Units may be limited in their ability to meet specific job requirements.

(b) On an overall basis, there will be more motors, controls, fans, coils, compressors, and moving parts to be serviced. If units are located in occupied spaces, the maintenance work may disturb the occupants.

(c) Using many small horsepower motors can result in an increase in energy costs as compared to a single, high-horsepower central station installation.

(d) Many units located throughout a building may require more total space than one or more central station units of the same refrigeration capacity.

(e) The air distribution is usually unsatisfactory due to ceiling heights, lights, and obstructions when package units are used without duct work. This will result in drafty conditions in some areas and stagnant air in other areas. This type of application is not generally recommended.

(f) Package units located in occupied spaces may cause noise problems and frequent complaints.

(g) Generally, these units are difficult to maintain when they are located in central office equipment spaces.

4. CENTRAL STATION EQUIPMENT

A. Reciprocating Compressors

4.01 Reciprocating compressors should be considered for refrigeration units for cooling loads of up to 100 tons. Most reciprocating compressors in use today use R-12 or R-22 refrigerants and must be combined with heat rejection equipment such as an air-cooled, water-cooled, or evaporative condenser.

4.02 ***Description:*** The function of the compressor in the refrigeration cycle is to remove heat-laden refrigerant vapor from the evaporator and to increase the pressure of this vapor to a point at which this vapor can be condensed at the temperature available in the condensing medium. Reciprocating compressors may be classified as to their cylinder arrangement (vertical, horizontal, or radial) and as either open or hermetically sealed machines.

4.03 ***Open-Type Machines:*** The compressor requires an external drive (ie, an electric motor, internal combustion engine, or a steam turbine). The compressor and the driver may be directly driven through a coupling or a belt drive. The compressor is cooled by the ambient air in the mechanical equipment room. A means of ventilation is usually required to dissipate this heat of compression. Open-drive motors consume more power than the hermetically sealed type. Figure 1 shows a refrigeration unit with dual compressors of the radial type. It is noted that the system shown is of the open type. This type of compressor requires a very efficient shaft seal to prevent refrigerant from leaking at the shaft exit.

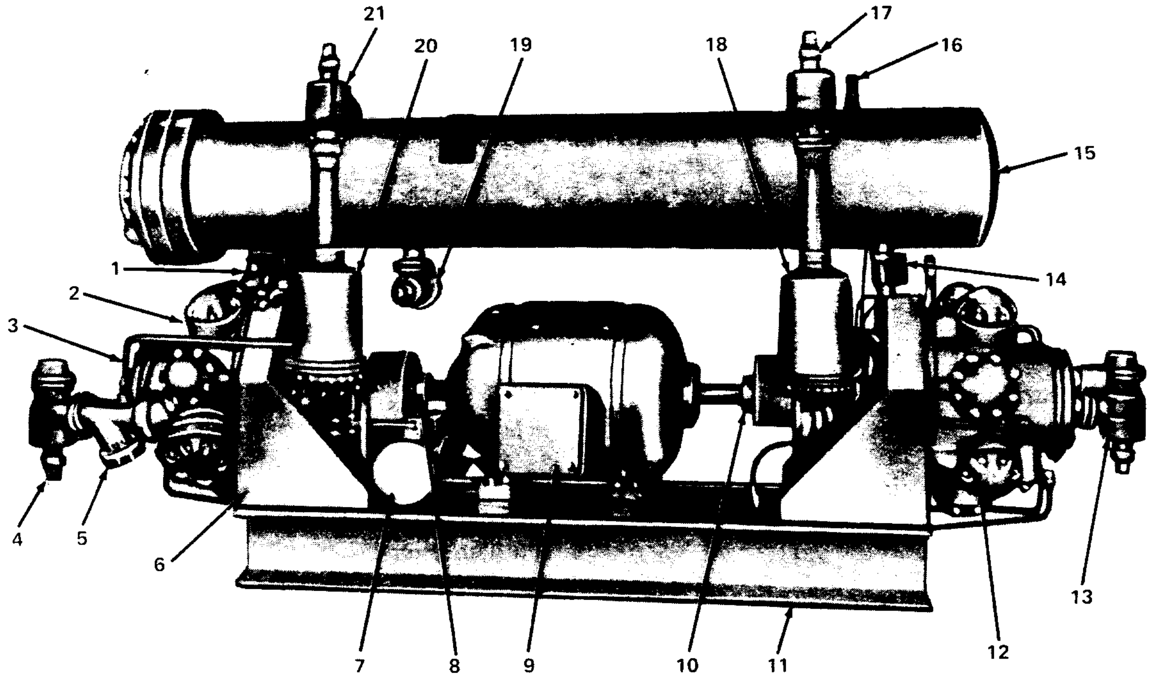
4.04 ***Hermetic Machines:*** The compressor and the electric motor drives are built into one common unit. Most units have the electric motor cooled by refrigerant gas passing through the windings. The heat of this compression must be discharged at the condenser. In addition to the building heat load, the advantages of a hermetic machine are as follows:

(a) Eliminates problems with motor mountings and coupling alignments between the motor and compressor.

(b) Eliminates motor lubrication and refrigerant leakage at the shaft seal.

4.05 One disadvantage of a hermetically sealed unit is that a motor burnout will foul the entire refrigeration side of the system which then requires careful cleaning and costly replacement of the refrigerant.

4.06 ***Safety Features:*** Safety features found on reciprocating refrigeration units are as follows.



1. HIGH AND LOW PRESSURE SWITCH
2. NO. 1 COMPRESSOR
3. PRESSURE RELIEF VALVE TUBE
4. SUCTION SHUT-OFF VALVE
5. SUCTION STRAINER
6. COMPRESSOR SUPPORT
7. OIL TANK
8. MOTOR COUPLING
9. MOTOR
10. MOTOR COUPLING
11. FRAME
12. NO. 2 COMPRESSOR
13. SUCTION SHUT-OFF VALVE
14. DIFFERENTIAL PRESSURE SWITCH (USED IN CONJUNCTION WITH OIL PRESSURE SAFETY SWITCH CONNECTED TO NO. 1 COMPRESSOR ON BACK OF UNIT)
15. CONDENSER
16. PRESSURE RELIEF VALVE
17. DISCHARGE SHUT-OFF VALVE
18. OIL SEPARATOR
19. LIQUID SHUT-OFF VALVE
20. OIL SEPARATOR
21. DISCHARGE SHUT-OFF VALVE

Fig. 1—Radial Condensing Unit

(a) ***Oil Safety Switch:*** Stops the compressor if there is a failure in the lubricant system.

(b) ***Low-Suction Pressure Switch:*** Stops the compressor if the suction pressure drops low enought to produce freezing conditions in the chiller.

(c) ***High-Pressure Switch:*** Stops the compressor if the condenser pressure rises too high due to inadequate condensing or other reasons.

(d) ***Chilled-Water Low Limit:*** Stops the compressor (on chilled-water applications) if the chilled-water temperature approaches the freezing point.

(e) ***Time Delay Relay:*** Prevents the compressor motor from restarting for a specified period or time after a shutdown due to a safety or operating control.

(f) ***Motor Temperature Switch:*** Stops the compressor on hermetic units when the motor windings become too hot.

(g) ***Motor Overload:*** Stops the compressor if the motor draws excessive current.

4.07 ***Controls:*** Reciprocating compressors should include capacity controls to match compressor output with the cooling load for energy efficiency. Some of these methods are as follows.

(a) ***Suction Valve Lift Unloading:*** The suction valves of certain cylinders are unseated so that compression cannot take place. This is the most efficient method of capacity control.

(b) ***Cylinder Head Bypass:*** Various cylinders may be made ineffective with the bypassing of refrigerant gas from the cylinder discharge to the intake port.

(c) ***Compressor Speed:*** If the speed of the compressor is varied, the capacity will change almost in direct proportion to the speed change. This can be done by using a multispeed motor or a variable speed motor or drive.

(d) ***Multiple Units:*** Multiple compressor units may be controlled by thermostats or pressure stats to start and stop units to match the load variations.

B. Centrifugal Compressors

4.08 Centrifugal compressors should be considered for use on projects of 100 tons or greater. These machines are known for their reliability, ease of operation, long service life, and low noise levels.

4.09 ***Description:*** The principle that governs the functioning of any centrifugal refrigeration system is the same principle that is basic to all refrigeration systems. The evaporating and condensing temperature of refrigerants can be varied by changing the pressure exerted upon them.

(a) The refrigeration cycle (Fig. 2) starts at the evaporator or cooler. The media to be cooled (eg, chilled water) flowing through the tubes is warmer than the refrigerant in the shell surrounding the tubes. Consequently, heat is transferred from the chilled water to the refrigerant. This heat evaporates liquid refrigerant at a low temperature due to the low pressure maintained in the evaporator by the compressor.

(b) The evaporated refrigerant vapor (gas) flows through the prerotation vanes into the compressor where it is partially compressed by the first stage impeller. The rate at which the vaporized refrigerant is drawn into the compressor is controlled by the degree of opening of the prerotation vanes. It then mixes with the stream of gas which comes from the economizer through a hermetic motor. The mixture of suction and economizer gas enters the second stage impeller where it is compressed and discharged into the condenser.

(c) The refrigerant discharged by the compressor condenses on the outside of the condenser tubes at a temperature corresponding to the condenser pressure. This temperature is higher than that of the water in the tubes so the heat is transferred into the condenser water.

(d) The liquefied refrigerant drains into the condenser float chamber. The rising refrigerant level in this chamber opens the float valve and allows liquid to pass into the economizer chamber when so equipped. The cooled liquid collects in the economizer float valve sump. The rising level in this sump opens the economizer float valve and allows this liquid to pass into the cooler. As the pressure in the cooler is lower than the economizer pressure, some of the liquid is evaporated, thereby cooling the remainder to the temperature of the cooler. The vapor formed from the evaporation of the liquid refrigerant passes to the compressor along with the vapor that is continuously formed by the cooling of the chilled water passing through the cooler. This completes the cycle.

4.10 Since compression of the refrigerant is accomplished by means of centrifugal force, this type of compressor is inherently suitable for large volumes of refrigerant at low-pressure differentials. Two or more stages are usually required, and high speeds are necessary to obtain good efficiency. The evaporator is usually constructed as an integral part of the centrifugal-type condensing unit to chill water which is then circulated to the air-conditioning system. This is done because it would not be economical to pipe these large volumes of refrigerant any distance. One important advantage of this type system is its flexibility under varying heat loads. In some cases, units can be designed to operate efficiently at capacities as low as 20 percent of normal load. The two main categories of centrifugal machines are defined by the type of compressors used.

4.11 ***Open-Types Machines:*** The motor or driver is located outside the compressor housing. The driver may be an electric motor, steam turbine, or diesel engine. An open machine may prove to be more flexible than the hermetic because various types of drives and speed changing gears may be used to suit the application.

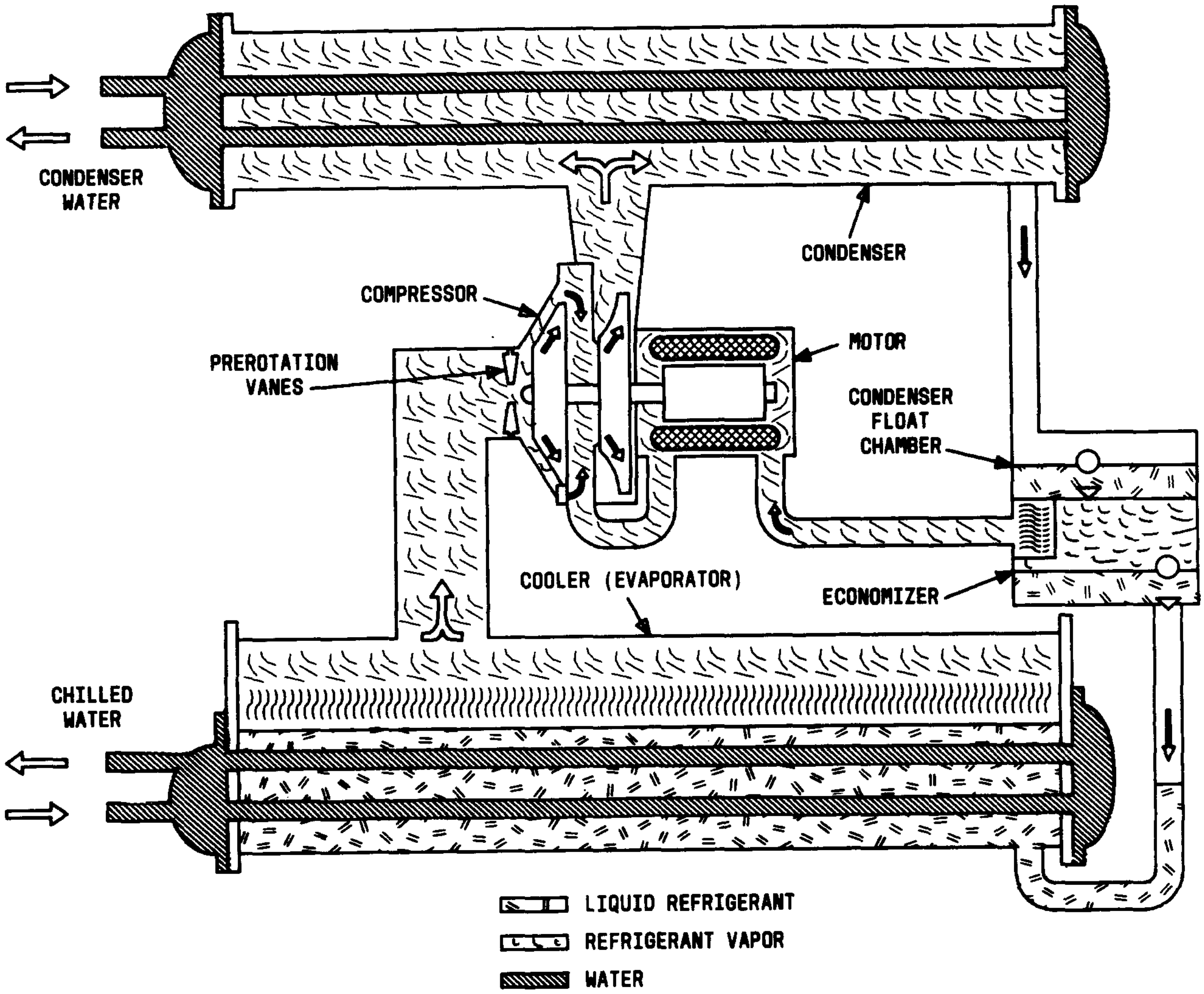


Fig. 2—Refrigeration Cycle Diagram (Carrier Corporation)

4.12 ***Hermetic Machines:*** Hermetic machines are used for the majority of the installations in the 100- to 1200-ton range. In this type machine, the compressor and the motor are built into one common casing with the motor being cooled by the internal flow of refrigerant gas. The induction motor is the only type of motor suitable for use in the presence of gaseous refrigerants. A brush-type motor will cause a refrigerant breakdown due to arcing from the brushes.

4.13 ***Safety Features:*** Safety controls for the open- and hermetic-type centrifugal compressors are as follows.

(a) ***Open Machine:*** Typical safety controls for open machines are as follows:

(1) ***The condenser high-pressure cutout switch*** will stop the compressor when the condenser pressure becomes too high.

(2) ***The low refrigerant temperature cutout*** will stop the compressor when the evaporator pressure becomes too low.

(3) ***The chilled-water, low-temperature cutout switch*** will stop the unit when the temperature falls below a set point.

(4) ***The low oil pressure cutout switch*** prevents the unit from starting until the oil pressure is high enough. In addition, it will stop the unit if the pressure falls during operation.

(5) ***The chilled-water flow switch*** prevents the unit from starting until chilled-water flow is established. It will shut down the unit if, for any reason, the water flow stops.

(b) ***Hermetic Machine:*** In addition to the previously listed controls, the typical safety controls for a hermetic machine would include the following:

(1) ***The bearing high-temperature cutout switch*** will shut down the unit if the bearings become too hot due to an oil system failure.

(2) ***The motor high-temperature cutout switch*** will shut down the unit if the temperature of the motor coils exceeds a set point.

4.14 *Controls:* Centrifugal chillers include a capacity reduction system to match compressor output with the cooling load for efficient energy utilization. This capability is important because of the wide daily and seasonal fluctuations of the building requirements. Chillers can be equipped with the following controls:

(a) ***Chilled-Water Control:*** This control regulates the chilled-water temperature and prevents compressor motor overload by positioning the prerotation vanes through a motor operator.

(b) ***Demand Limiter Control:*** This control limits the travel or opening of the prerotation vanes. The control setting limits the motor amperage drawn based upon a percentage of the nameplate rating.

(c) ***Hot Gas Bypass Control:*** The hot gas bypass artifically adds an additional load on the machine to stabilize the flow of refrigerant from the impeller at lower cooling capacities. The use of hot gas bypass is inefficient.

(d) ***Microprocessor Based Controls:*** The controls furnished with centrifugal machines can adequately control the chillers within the parameters of holding a set point at a fixed load. However, they have a tendency to drift from set point at changing loads, causing excessive energy use and necessitating routine operator correction. Microprocessor-based control methods that react to the actual load instead of anticipated load requirements are now available. They automatically vary the chiller capacity by sensing building load conditions by measuring the temperature of the return chilled water, thus conserving energy.

(e) ***Solid-State Electronic Speed Control:*** Centrifugal chiller motors are presently designed to run at a constant speed on all load conditions. There are controls available which are capable of modulating the flow of current to the motor and to control the opening of the prerotation vanes. Speed control is accomplished with an inverter to affect a variable frequency.

C. Absorption Machine

4.15 *Application:* The largest percentage of refrigeration equipment now being manufactured (in sizes greater than 100 tons) is the centrifugal compressor. Absorption equipment was used in the past when low-cost utility steam or fuel was available. Absorption equipment being manufactured today is more efficient and has application with consideration of the following:

(a) Replacement of existing absorption equipment.

(b) In installations where the electrical service facilities are inadequate and expensive, an absorption unit requires less than 10 percent of the electrical power as compared with compression-type equipment.

(c) In localities where an absorption installation can eliminate the need for a conventional compression machine that would require a full-time operating engineer.

4.16 *Description:* The basic principles of absorption refrigeration system is not different in operation from the more familiar mechanical compression refrigeration system. Both machines accept heat to evaporate a refrigerant at low pressure in the evaporator, thereby, creating a cooling effect. Also, both condense the vaporous refrigerant at a higher pressure and temperature in the condenser in order that the refrigerant can be reused in the cycle.

4.17 In both cases, the capacity of the machine depends upon the pressure that exists in the evaporator since this determines the evaporator temperature.

4.18 In mechanical compression systems, the vapor formed when the liquid refrigerant absorbs heat to provide the refrigerant effect is drawn to a lower pressure area created by the mechanical movement of the pistons. In an absorption machine, this vapor is also removed to a lower pressure area. The low pressure inside an absorption machine is the key to its refrigerating ability. However, the low pressure area in the absorption machine is created by controlling the temperature and concentration of the water/lithium bromide solution (Fig. 3).

Note: Lithium bromide, a nontoxic salt with a high affinity for water, is the absorbent.

4.19 A list of terms that is used in absorption refrigration is given in Table A.

4.20 ***Characteristics of an Absorption Machine:*** An absorption unit produces chilled water by using water as a refrigerant and a solution of lithium bromide as an absorbent. The absorption cycle consists of four major components:

(a) ***Evaporator Section:*** Chills water by the evaporation of refrigerant (water) and sprays it over the chilled-water tubes

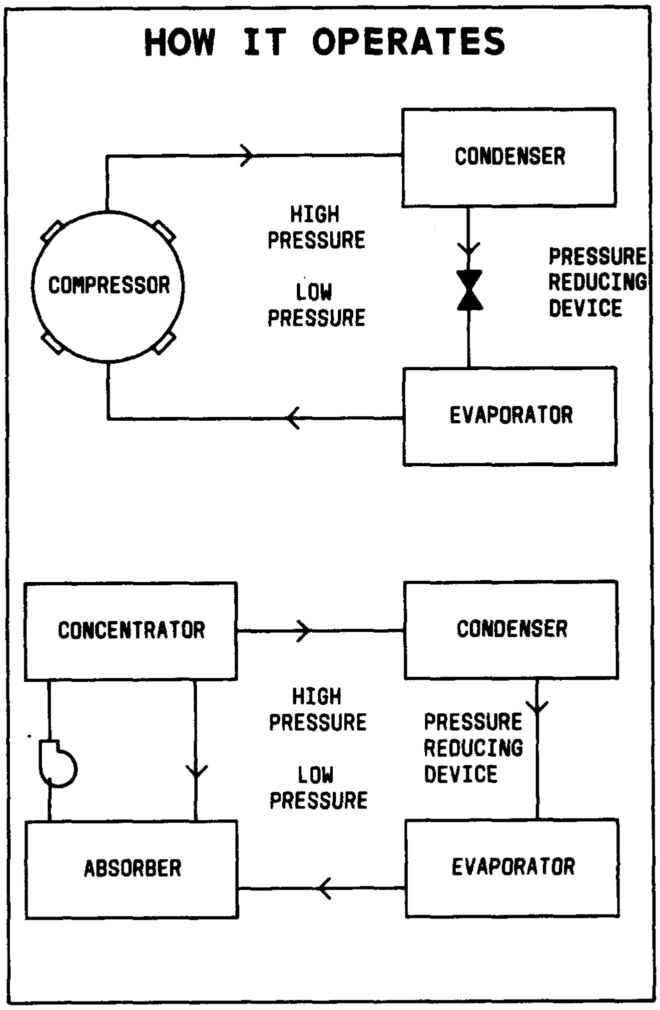


Fig. 3—Comparison of Mechanical Refrigeration Cycle and Absorption Refrigeration Cycle

TABLE A

GLOSSARY OF TERMS FOR ABSORPTION REFRIGERATION

TERMS	DEFINITION
Absorbent	A substance readily capable of taking in and retaining moisture from the atmosphere.
Absorber	A vessel containing liquid for absorbing refrigerant vapor.
Concentrated Solution	A solution with a large concentration of absorbent and only a small amount of refrigerant.
Concentrator (also referred to as the Generator)	A vessel containing a solution of absorbent and refrigerant to which heat is supplied for the purpose of boiling away some of the refrigerant.
Condenser	A vessel in which vaporized refrigerant is liquefied by removal of heat.
Dilute Solution	An absorbent solution diluted by a large amount of refrigerant.
Evaporator	A vessel in which refrigerant is vaporized to produce a refrigerating effect.
Heat Exchanger	A device used to transfer heat between two physically separate fluids.
Heat of Condensation	The heat released when a vapor condenses to a liquid.
Heat of Dilution	The heat released when two liquids are mixed. This is sometimes referred to as the heat of absorption since one liquid may absorb the other in the mixing process.
Sensible Heat	Heat used to raise or lower the temperature of a substance.

(b) ***Absorber Section:*** Where the evaporated refrigerant (water) is absorbed by the lithium bromide

(c) ***Concentrator Section:*** Boils off the refrigerant (water) from the lithium bromide by use of steam or hot water coils

(d) ***Condenser Section:*** Condenses the water vapor produced in the generator section.

4.21 The various solutions are pumped from one section to another using small horsepower pumps. As an example, a machine with 1000 tons of capacity may require only 20 horsepower pumps.

4.22 ***Safety Controls and Limits:*** Absorption units require the following safety controls:

(a) ***Chilled-Water, Low Limit Control:*** Shuts down the absorption unit when the chilled water falls below a preset minimum temperature. This is to prevent tube damage due to ice formation in the chiller.

(b) ***Pump Interlock Control:*** If the solution pump or the evaporator pump becomes inoperative, then the machine will automatically shut down.

(c) ***Water Flow Switch Control:*** If the chilled water or condenser water pumps shut down for any reason, then an interlock through a water flow switch will shut down the machine.

4.23 ***Controls:*** Absorption units require the following controls:

(a) ***Condenser Water Temperature Control:*** Condenser water inlet temperature should be maintained at a predetermined setting by use of a bypass valve installed on the inlet header to the cooling tower. The bypass must be designed and sized to bypass the total condenser water flow around the cooling tower.

(b) ***Chilled-Water Temperature Control:*** Exiting chilled-water temperature must be controlled to match capacity when the loading on the chiller is reduced. This can be accomplished by steam throttling, control of condenser water flow in the absorber, or control of the reconcentrated solution. These methods control the ability of the machine to reconcentrate the solution which is returned to the absorber. As the concentration is diluted, the ability to chill water is reduced.

(c) ***Steam Pressure Control:*** When using steam to heat the solution, the boiler or service steam pressure must be held to within one pound of the design pressure either by direct boiler control or a pressure-reducing valve if high-pressure steam is used.

(d) ***Hot Water Control:*** If hot water is used for heating, a control valve is necessary to control the hot water through the machine.

D. Rotary Screw Compressor

4.24 ***Application:*** The rotary screw compressor is a positive displacement machine applicable for use in a central station chilled-water system. Capacities are available in numerous configurations (horizontal, vertical, and multiple compressor) from 20 to 750 tons of refrigeration. Equipment is available for water-cooled, air-cooled, or evaporative condensing and in either the open or semihermetic types. Distinct advantages of the rotary screw compressor are:

(a) Energy efficiency over varying load

(b) Part load performance to 10 percent of capacity

(c) Smaller vertical sizes available for retrofit and replacement that require little or no building work for access.

4.25 ***Description:*** The machine consists of two mating, helically grooved rotors in a housing with suitable inlet and outlet refrigerant gas ports (Fig. 4). The rotors are called the male lobes and female interlobes.

4.26 Operation of the compressor is in three phases:

(a) ***Suction Phase:*** As the lobe of the male rotor begins to unmesh from an interlobe space in the female rotor, a void is created and refrigerant gas is drawn into the compressor.

(b) ***Compression Phase:*** As rotation continues, the gas in the interlobe space is carried circumferentially around the compressor housing. Further rotation meshes a male lobe with the interlobe space on the suction end and compresses the gas in the direction of the discharge port. Thus, the occupied volume of the trapped gas within the interlobe space is decreased, and the gas pressure consequently increased. The relative compression of the refrigerant gas is shown in Fig. 4. The interlobe space V_s is filled with the initial volume of gas entering the compressor. The relative volume of the compressed gas prior to discharge to the condenser is V_d.

(c) ***Discharge Phase:*** At a point as determined by the compressor design, the discharge port is uncovered, and the compressed gas is discharged by further meshing of the lobe and interlobe space.

5. HEAT PUMPS

5.01 ***Description:*** A heat pump is a system in which refrigeration equipment is used for

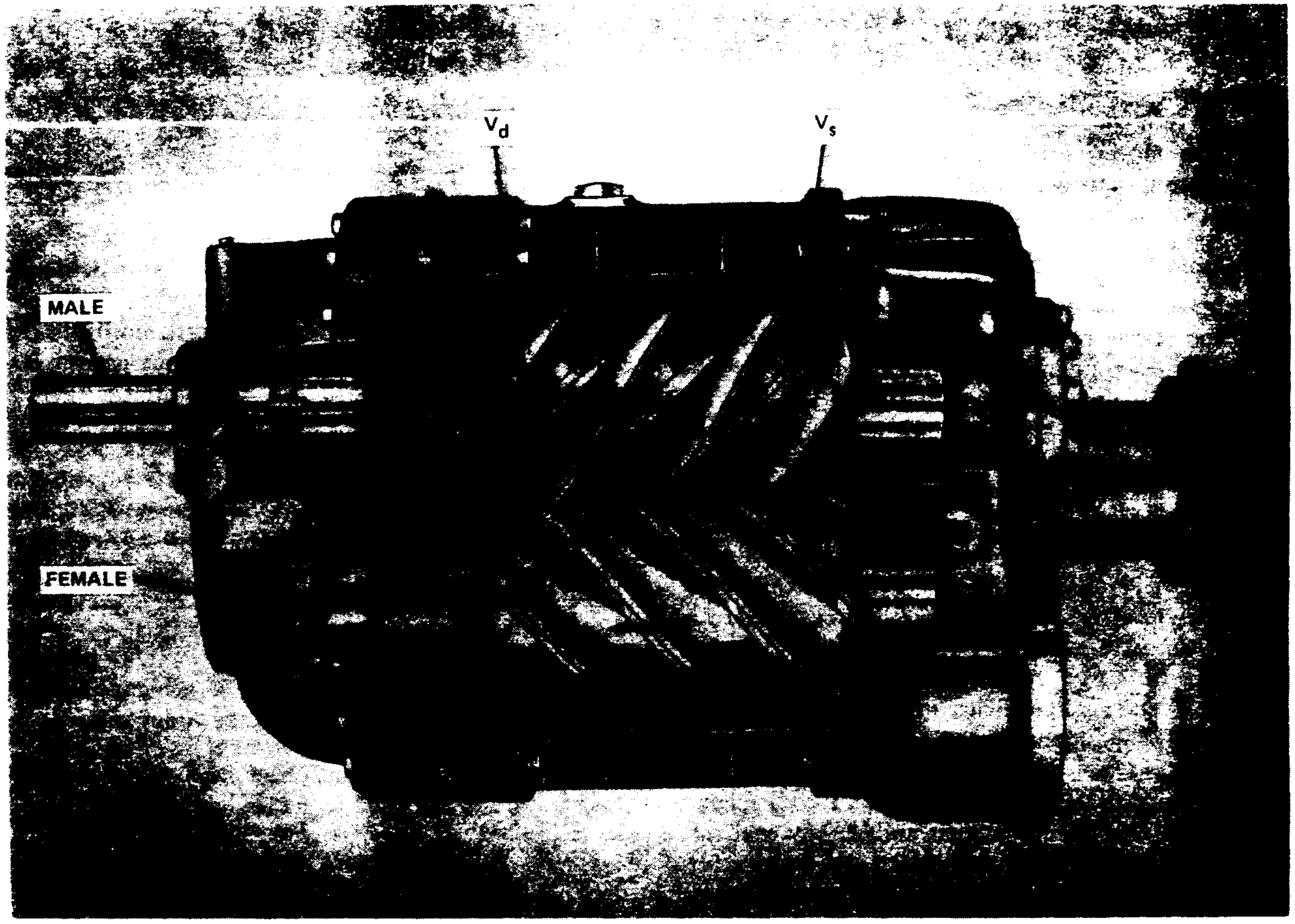


Fig. 4—Rotary Screw Compressor

heating as well as cooling. The thermal cycle is identical to that of ordinary refrigeration.

(a) ***Heating:*** In the heating cycle, cool refrigerant at low pressure circulates in the evaporator (outdoor unit) and absorbs heat from the ambient air. The refrigerant is drawn into the compressor where the temperature and pressure are increased. From the compressor, the refrigerant gas is discharged into the condenser (inside unit) coil. The coil surface rejects the absorbed heat to the cooler ambient air.

(b) ***Cooling:*** In the cooling cycle, the indoor and outdoor units exchange roles as evaporator and condenser.

5.02 Heat pumps are available in varying ranges of capacities from 5 to 45 tons. The heat source for the operation of the heat pump can be air or water, and units have been adapted to use heat energy from the sun.

5.03 ***Applications:*** The following factors should be considered in using heat pumps.

(a) Heating and cooling is available from one piece of equipment.

(b) High coefficient of performance (COP)—The heat output varies between two and three times the energy input.

5.04 ***Disadvantages:*** The disadvantages of using a heat pump are as follows:

(a) The heating capacity is reduced as the heat source temperature decreases (particularly important with the air-to-air cycle). (Unit capacity decreases as the heating requirement increases.)

(b) The power input (kW) per ton of refrigeration (cooling cycle) is higher than a conventional cooling only unit.

6. HEAT REJECTION EQUIPMENT

A. General

6.01 The objective of a mechanical refrigeration system is to remove heat from a space, transport this unwanted heat, and reject it to the environment. Generally, the heat transport medium (refrigerant, water, or fluids) is reclaimed and recirculated to renew the process. Heat rejecting devices used in the refrigeration systems in buildings are air-cooled condensers, evaporative condensers, cooling towers, and coolers.

B. Air-Cooled Condensers

6.02 ***Description:*** An air-cooled condenser consists of a refrigerant coil, casing, fan, and motor. It condenses the refrigerant gas by means of a transfer of sensible heat to air passing over the coil.

6.03 ***Application:*** Air-cooled condensers are available in capacities up to approximately 120 tons. When comparing air-cooled condensers to other heat rejection equipment such as evaporative condensers and water cooling towers, air-cooled condensers have a higher first cost and energy cost for a given capacity. Maintenance costs are greater for evaporative condensers and cooling towers, and when considering the total operating cost, air-cooled condensers may be more economical.

6.04 Air-cooled condensers may be considered for the following:

(a) Locations where there is a shortage of makeup water, drainage facilities, or high water costs.

(b) Multiple compressor installations which can be served by multiple air-cooled condensers or a multiple circuit in a single air-cooled condenser.

(c) There is no danger of winter freeze-ups because air-cooled condensers present no water freezing problems when operation is required at low outdoor temperatures.

(d) The condenser can be located in close proximity to the equipment which it serves.

(e) Air-cooled condensers may be installed indoors as well as outdoors. An indoor installation requires duct work for supply and discharge of air which increases the first cost as well as energy costs for increased fan horsepower.

6.05 ***Physical Characteristics:*** Air-cooled condensers are available for both horizontal and vertical air flow. Horizontal units are available with a choice of either propeller-bladed fans or centrifugal wheels. Fans can be direct or belt driven. Belt drives permit minor capacity adjustments to suit field conditions. Vertical air flow units have propeller-bladed fans only. Units can be obtained with multiple circuits to handle several independent refrigerant circuits.

6.06 ***Controls:*** Air-cooled condensers may be controlled by either air- or refrigerant-side controls. The air-side controls vary the amount of air flowing through the coil sections while the refrigerant side controls change the amount of available condensing surface by flooding portions of the condenser space with liquid refrigerant.

(a) ***Air-Side Control:*** May be accomplished by one or a combination of the following:

(1) Sequence operation of fans when multiple fans are used on a single condenser coil

(2) Volume damper operation in the fan discharge

(3) A bypass damper to bypass air around the coil

(4) The use of a variable speed fan.

(b) ***Refrigerant-Side Control:*** May be accomplished by one or a combination of the following:

(1) An electrically heated surge receiver to keep minimum liquid temperature in the receiver

(2) A pressure-regulating valve in the condenser drain to maintain a minimum pressure in the condenser

(3) A bypass valve to transfer hot discharge gas around the condenser to maintain a minimum receiver pressure.

C. Evaporative Condensers

6.07 ***Description:*** An evaporative condenser consists of a refrigerant condensing coil, fan, motor, water distribution system, water and circulating sump, and casing. The refrigerant vapor to be condensed is circulated through the condensing coil which is continuously sprayed with water. Air is blown over the coil which causes a portion of the sprayed water to evaporate. This evaporation removes heat from the coil and condenses the vapor.

6.08 ***Application:*** Evaporative condensers are available in capacities up to approximately 1400 tons. Considerations for using evaporative condensers are as follows:

(a) Areas which experience low wet-bulb temperature.

(b) Areas which have an ample source of inexpensive water of the proper quality.

Note: Water quality is important because it evaporates on the condenser coils.

(c) The condenser can be located in close proximity to the equipment which it serves.

(d) Evaporative condensers may be installed indoors as well as outdoors. An indoor installation requires duct work for supply and discharge of air. This increases the first cost as well as energy costs for increased fan horsepower but is recommended for year-round operation. An outdoor condenser may be operated during the winter if the water is shut off and the pan drained. The reduced capacity when operating dry may be ample for winter use.

6.09 ***Controls:*** Controls are required to maintain a preestablished condensing pressure. Some of the control systems that are installed on evaporative condensers are:

(a) Dampers on the fan discharge which can be modulated to change the airflow across the coil — the dampers may be actuated by a condensing pressure stat located in the condenser.

(b) A system of air discharge and bypass duct work arranged so that wet-bulb temperature of the entering air can be raised.

(c) A variable speed fan motor to vary the airflow across the coil.

6.10 ***Energy Efficiency:*** Evaporative condensers require less electrical horsepower per ton of refrigeration than either the air-cooled condenser or the cooling tower.

(a) Evaporative condenser capacity is a function of ambient wet-bulb temperature while air-cooled condenser capacity is a function of ambient dry-bulb temperature. Since design wet-bulb temperatures are lower than dry-bulb temperatures, system condensing temperatures (using evaporative condensers) can be lower which results in compressor and system horsepower savings.

(b) The evaporative condenser rejects heat directly to the ambient air in one step of heat transfer. In the cooling tower and water-cooled heat exchanger system, heat must first be transferred to the cooling water by the condenser and then to the atmosphere by the cooling tower. The single-step heat transfer in the evaporative condenser provides lower condensing temperature which results in compressor horsepower saving.

D. Cooling Towers

6.11 ***Description:*** A mechancial draft-cooling tower consists of a casing, basin, sump, fan, motor, a water distribution system, and deck or fill material. The water transporting the heat is distributed over the fill by spray nozzels. Air is simultaneously blown upward over the fill causing a small portion of the water to evaporate. This evaporation removes heat from the remaining water. The cooled water is collected in the tower sump and returned to the condenser. Cooling towers are generally used with water-cooled condensers which provide for heat transfer from the refrigerant vapors.

6.12 ***Types:*** There are several types of mechanical draft-cooling towers used for heat rejection. These are the forced air flow and the induced air flow. With regards to the air and water flow, the towers are identified as cross flow or counterflow. In cross flow, the air travels horizontally across the falling water; in counterflow, it travels vertically through the falling water.

6.13 ***Application:*** Mechanical draft-cooling towers range in capacity from 5 to 2000 tons. Cooling towers are generally used in systems with a capacity of 100 tons or greater and with consideration of the following:

(a) It will prove more economical to use water piping than the more costly refrigerant piping when the heat rejection equipment is located away from the refrigeration apparatus.

(b) The use of a cooling tower with water-cooled condensers permits easier installation for future expansion.

6.14 In the selection of a mechanical draft-cooling tower, the following factors should be taken into consideration:

(a) Condensing temperature of the refrigerant in the water-cooled heat exchanger unit.

(b) The tower range is the temperature differential between the inlet and outlet water.

(c) The approach of the tower is determined by subtracting the wet-bulb temperature from the outlet water temperature.

(d) The mechanical draft-cooling tower is more energy efficient than an air-cooled condenser due to lower refrigerant condensing temperatures. However, the tower will require more electrical energy than an evaporative condenser.

6.15 ***Controls:*** Water leaving the cooling tower must be maintained at a predetermined minimum temperature so that the condensing pressure can be maintained. This, in turn, ensures proper operation of the thermostatic expansion valve or the refrigerant float valves. Condenser water temperature may be controlled in several ways:

(a) Use a 3-way valve to bypass the sprays and put the water directly in the basin.

(b) Reduce tower capacity by using a 2-speed fan motor and automatically changing the speed to maintain the leaving water temperatures.

(c) Cycle the cooling tower fans.

(d) Sequence the fans on a multicell tower.

(e) Employ combinations of the water bypass and fan control.

6.16 Safety controls and interlocks found on cooling towers are:

(a) Low water temperature alarms in the tower basin

(b) Vibration switch to stop the fans if ice formation causes an imbalance.

6.17 A cooling tower installation can be operated during the winter season if certain precautions are taken to prevent freeze up. To keep water from freezing in the basin, an auxiliary sump within a heated space can be used. The sump must be large enough to store all the water normally in the tower basin and be elevated enough to provide a pump suction head. In operation, only a small portion of water goes through the sprays while the rest is bypassed into the sump. Another method of preventing basin freeze up is to install a heating coil in the basin using steam, glycol, or hot brine inside the coil.

E. Coolers

6.18 ***Description:*** Coolers are heat rejection devices in which a fluid, contained within a closed circuit, is used to transport heat to the place of rejection. This fluid is generally a glycol and water mixture. Types of coolers are:

(a) ***Dry Air Cooler:*** This unit is identical to an air-cooled condenser. Sensible cooling is used to reject the heat from the fluid to the atmosphere as air is drawn across the cooler coils.

(b) ***Evaporative Fluid Cooler:*** This unit is identical to the evaporative condenser. Latent and sensible cooling is used to reject the heat from the fluid.

6.19 ***Application:*** Coolers are used for applications requiring refrigeration throughout the entire year as computer rooms. Coolers are available with capacities of 10 million BTU/hr. These units combine the advantages of a direct expansion system and of a water-cooled condensing system:

(a) The fluid is circulated in a closed circuit for reduced heat exchanger maintenance.

(b) Increased reliability during winter.

(c) Piping is simplified. Cooler can be remotely located from refrigeration unit.

(d) Adaptable to heat recovery applications.

7. REFERENCES

7.01 Information contained in this section is based on the *American Society of Heating, Refriger-*

ating, and Air-Conditioning Engineers (ASHRAE) Handbook, 1979, the *Handbook of Air-Conditioning System Design,* Carrier Air-Conditioning Company, and the following sections:

SECTION	TITLE
770-240-301	Evaporative Condensers
770-240-302	Cooling Towers
770-250-301	Reciprocating Refrigeration Compressors for Air-Conditioning Systems
770-250-302	Maintenance and Operation of Centrifugal Refrigeration for Air-Conditioning Systems
770-250-303	Absorption Refrigeration Systems.