A high-pressure cutout is normally required to shut off the compressor if the head pressure should rise above normal working limits. A rupture disk or pressure relief valve may also be required. Protection from excessive pressure due to fire is required in the form of a fusible plug, soft solder joint in the refrigerant piping, or similar temperature-sensitive safety device.

2. *Protective Controls.* The control system normally contains at least some of the following protective devices to prevent damage to system components due to abnormal operation:

(a) Compressor Motor: Amperage overload protection, locked-rotor protection, and motor winding protection.
(b) Low-Pressure Cutout: Prevent freeze-up, operation on low charge, and excessive oil foaming.
(c) Fan Motor Overload: Electrical overload protection.
(d) Wiring: Short circuit protection.

3. *Capacity Control.* On larger units capacity control is provided to match fluctuating load conditions. This is accomplished by one of several means, including multiple circuit systems, compressor unloaders, and suction-pressure regulators. Head-pressure control is also used in this sense, particularly with air-cooled equipment where internal loads vary independently of extremely low outdoor ambient temperatures.

Compressor unloaders are discussed in Chapters 13 and 38, suction pressure regulators in Chapter 45. Multiple circuit systems are units designed with two or more independent refrigeration cycles, each powered by its own compressor, and operated in steps in accordance with load requirements.

Heating System

Integral heating components of unitary air conditioning equipment include:

(a) Steam or hot water coils using an auxiliary boiler.
(b) Electric resistance heaters.
(c) Direct-fired heating elements using either oil or gas.

Steam and hot water coils must be of the non-freeze type where outside air for ventilation will be handled. See Chapter 33 for heating coil design. Direct-fired heating components (oil or gas) resemble duct heaters in basic design. See Chapter 51 for design details.

The use of the refrigeration system as a heat pump, thus eliminating the need for a separate heating component, is also common practice. Heat pumps as such, are not included within the scope of unitary air conditioner equipment, but rather fall in the category of unitary heat pump equipment. See Chapter 66 for further information on heat pumps.

Mechanical Design

Since the design objectives of unitary air conditioners differ widely, depending upon size and intended application of the unit, the following check list for design and specification work obviously refers to some special problems only:

1. *Cabinet Design.* Consider appearance as suitable to location of unit either in the air-conditioned space or hidden from view. Location of unit will also affect cabinet design with respect to shape, size, weatherproofing, sound-proofing, and finish.

Adequate ventilation of compressor and control compartments must be provided. For outdoor installation, ventilation must be accomplished without rain or dust getting at control wiring or contacts.

2. *Crating and Shipping.* The packaged unit must be designed to withstand the ambient temperatures and handling it will receive when shipped by rail or truck. Maximum ambient temperature for shipping and warehousing is generally accepted as 150 F. Where additional strength or rigidity is required for shipping purposes only, it is sometimes less expensive to strengthen the unit itself than to build the added protection into the crate.

Shipping requirements for unitary air conditioners have not been established. However, a general set of shake and impact test qualifications have been set up by the National Safe Transit Committee and published in the National Safe Transit Program. The applicable sections of this program can serve as a guide for unit design, unit packaging and shake and impact testing. Other considerations include suitability of the package for handling and stacking during both shipment and warehousing. During shipment, the unit package may have to support other products, as well as multiple stacking of the same product. Column loading and maximum permissible stacking heights for warehousing purposes must also be considered.

Stacking heights of corrugated carton design will be affected by loss of carton strength due to high humidity conditions; or wet floors.

3. *Cabinet Insulation Requirement.* Insulation is required to minimize conduction of heat, both into and out of the unit cabinet. Insulation is also required to prevent sweating on the outside surfaces of the unit.

ARI Standard 210-64, Sub-Section 5.40, lists insulation efficiency requirements at specified test conditions. Condensation is not permitted to drip, run or blow off unit casing. This design detail is of particular importance in units destined for attic or furred ceiling locations.

4. *Condensate Disposal.* On larger units, the evaporator coil condensate is generally piped to a waste drain. Condensate fittings and piping should be generously sized to prevent plugging due to the introduction of lint and dirt in the incoming air stream.

For smaller, self-contained air-cooled equipment, condensate is sometimes disposed of by distributing it over the hot condenser surface for re-evaporation to the outside air. Performance requirements for this type of condensate disposal are listed in ARI Standard 210-64, Sub-Section 5.50.

5. *Service Access.* This is of primary design importance, particularly for equipment to be installed in cramped equipment rooms, attics or crawl spaces.

6. *Field Assembly and Installation Considerations.* Problems to be considered include (a) limitations of material handling equipment at the job site, (b) maximum size of doors, elevators, and stairways, and (c) weight limitations due to maximum floor and ceiling loadings. Other installation considerations affecting design are minimum ceiling heights, normal equipment room size, clearance from combustible materials (heating equipment), and accessibility for field installation of condensate drain piping, interconnecting refrigerant piping, leak testing, and electrical wiring.

7. *Weatherproofing.* For outdoor units, protection must be included against water and snow as well as wind-blown sand and dust in arid sections. Outdoor equipment also is subject to the problems of safety hazards due to inquisitive children and unauthorized tampering.

PERFORMANCE TESTING

Minimum standards for the performance of unitary air conditioners have been agreed upon by the industry and are published in ARI Standard 210-64. The approved test procedure for the determination of compliance with these standards has also been summarized in ASHRAE Standard 37-60. Certified capacity ratings for unitary air conditioners up to 135,000 Btuh are supervised by the Air Conditioning and Refrigeration Institute. Details of this program and the method of certification are outlined in the bulletin, *Unitary Air Conditioner Certification Program Operational Manual*, dated December 1962.

Shipping and rough handling tests in accordance with the National Safe Transit Program are the generally accepted method of qualifying units and packaging for safe shipment.

REFERENCES

[1] Air Conditioning and Refrigeration Institute, Standard 210-64 *Unitary Air-Conditioning Equipment.*

[2] Air Conditioning and Refrigeration Institute *Directory Certified Unitary Air Conditioners*, current issue.

[3] ARI Unitary Air-Conditioner Certification Program *Operational Manual*, December 1962.

[4] Unitary Air Conditioner Specifications Issue—*Air Conditioning, Heating and Refrigeration News* (Published Annually, March Issue).

[5] The unitary approach to air conditioning (prepared by a Committee of ARI) (*Air Conditioning, Heating and Ventilating*, October 1962, p. 57).

[6] R. F. Crossman and I. B. Faigen: Predicting operating costs for residential air conditioning (*American Artisan*, March 1955).

CHAPTER 66

HEAT PUMPS

Basic Circuits; Fundamentals; Types; Heat Sources and Sinks; Performance Characteristics; Temperature Levels; System Balance; Components; Heat Storage

THE term *heat pump*, as applied to a year-round air-conditioning system, commonly denotes a system in which refrigeration equipment is used in such a manner that heat is taken from a *heat source* and given up to the conditioned space when heating service is wanted, and is removed from the space and discharged to a *heat sink* when cooling and dehumidification are desired. The thermal cycle is identical with that of ordinary refrigeration, but the application is equally concerned with the cooling effect produced at the evaporator and the heating effect produced at the condenser. In some applications, both the heating and the cooling effects obtained in the cycle are utilized.

The heat-pump principle is also applied for purposes other than air conditioning, such as: supply of domestic hot water in residences and commercial buildings, recovery of low-temperature heat as a useful byproduct in industrial operations, and disposal of heat from processes involving evaporation of water or other fluids at depressed temperature and pressure. Defrosting of evaporator coils in refrigerating systems by intermittently admitting hot gas directly from the compressor is another application of the heat-pump method. Descriptions and diagrams of various heat-pump systems and criteria for feasibility are given in this chapter.

Present Status

Even though the heat-pump principle is not new, extensive use of this principle in practical devices has been accomplished only since about 1947.

The activities of several industry committees has led to the publication of information on the technology of heat pumps,[1,2] bibliographies,[3,4] and installation statistics.[5]

Large central heat pumps of modern design, within the capacity range of about 100 to approximately 1000 horsepower of compressor-motor rating, are now operating in a substantial number of buildings. Detailed information on their design and performance has been presented in ASHRAE papers[6-8] and in technical magazines.

Compressor types employed in large central systems vary from one large centrifugal unit to as many as eight multi-cylinder reciprocating units. A single or central system is generally used throughout the building, but in some instances the total capacity is divided among several separate heat-pump systems to facilitate zoning. Both well water and air are used as heat sources. Compression is accomplished in two stages for a few recent projects. Frequently, provision is made for heating and cooling service to be supplied simultaneously to separate zones of the building.

Unitary heat pumps, available from or under development by many manufacturers, account for the large majority of residential and small commercial installations. Outdoor air is the heat source in the majority of installations, but models are also built for well water. Capacities range from 2 to about 25 horsepower. Both hermetic and open-type compressors are used. The entire heat-pump circuit may be charged with refrigerant and sealed at the factory, or individual factory-sealed subassemblies may be connected in the field. Some models are arranged for remote location of the outdoor-air heat exchanger that serves alternately as evaporator and as condenser. In appearance and dimensions, casings of unitary heat pumps closely resemble those of conventional air-conditioning units having equal capacity.

Minimum industry performance standards of unitary heat pumps are covered by *ARI Standard 240-64, Unitary Heat Pump Equipment*, revised in 1964 by the Air-Conditioning and Refrigeration Institute. It applies to factory-made heat pumps and to matched assemblies, as defined in the Standard, for residential, commercial, and industrial service, but it is not applicable to field-modified cooling units converted to heat-pump operation, or to room air conditioners. The Standard requires that both heating and cooling capacity be expressed in Btu per hour under specific conditions, and includes minimum performance standards such as the ability to operate under maximum load conditions or adverse power and temperature conditions. It also describes safety codes to which such equipment should be designed and outlines several performance requirements that are considered good practice in the design of either unitary heat pumps or built-up systems. This standard includes methods of testing as established by ASHRAE Standard 39-61, *Methods of Testing for Rating Unitary Heat Pump Equipment.*

Window-type, or in-the-wall type heat pumps, now in factory production in ½ to 2 hp size range, resemble conventional units for summer air conditioning, similarly installed. Heretofore, the capacity of these units on heating service has generally been less than that required in extremely cold weather to maintain the required temperature within the space served adequately by the same unit in summer. Except in regions having a mild climate, they were useful principally for intermediate-season operation or to supplement the main heating system of the building. Some recently introduced models, however, have characteristics more suited to complete year-round operation.

BASIC CIRCUITS

Fundamentals

Since, from the refrigeration standpoint, a heat pump is similar to a conventional refrigeration system, its basic circuit may be represented by Fig. 1. Changeover between heating and cooling services may be accomplished by, (a) actuating valves in the refrigerant lines, so as to interchange the positions of heat exchangers constituting the evaporator and the condenser, respectively, in the refrigerant flow circuit; or (b) by switching the paths of air, water, or other fluid that convey heat from source to evaporator and from condenser to sink, respectively. The interchange function inherent in heat-pump control led to use of the term *reversed-cycle refrigeration* during the early development period of the heat pump, but this inaccurate name is now obsolete.

The operating principle of the heat pump is identical with

The general responsibility for this chapter is assigned to TC 8.4, Heat Pumps.