Centrifugal compressors are used for large installations, and usually where the indirect system is required. The driving mechanism can be a steam turbine or electric motor. The steam-jet system is used where steam is available and cooling water can be had in large quantities.

It will be noted by referring to Fig. 16 that all systems using compressors have a common characteristic, namely, that the capacity varies with the evaporating temperature. Not only can the equipment be selected to produce a given result, but the performance can be predicted under varying load conditions by the simple expedient of using the variable of evaporating temperature as the abscissa, and the load or capacity as the ordinate in a series of curves.

Manufacturers of compressors and cooling coils furnish performance data for apparatus that can be plotted in the form of curves similar to those shown in Fig. 18. The performance of a compressor is plotted as a series of curves, each curve being drawn for a given condensing pressure. The performance of a direct-expansion coil at two different air velocities is plotted on the same graph. The operating point will be, of course, where the two curves cross.

Data given in Table 9 illustrate two types of conditioned enclosures having the same total load of 148,000 Btu per hour, but with two different ratios of sensible to total heat. In the case of the office with a ratio of 82 percent sensible to total heat, the operating point *A* in Fig. 18 is found to be 42.2 F evaporating temperature, with a face velocity of 500 fpm. In the case of the restaurant, with a ratio of 69.5 percent sensible to total heat, the air velocity is lowered to 300 fpm, and the evaporating temperature is lowered to 34.4 F as shown in point *B* of Fig. 18. In order to obtain the same capacity, a larger condensing unit is used. This illustration assumes zero pressure drop through the suction line. The pressure drop can be taken into account by shifting the compressor performance curves by the amount of pressure drop expressed in Fahrenheit degrees.

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CHAPTER 39

THE HEAT PUMP

History and Development; Basic Circuits; Fundamentals; Types; Heat Sources and Sinks; Performance Characteristics; Temperature Levels; System Balance; Seasonal Performance; Annual Operating Cost; Components; Application; Criteria for Feasibility; Design and Selection; Systems for Larger Buildings; Sensible, Latent, and Low-Side 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 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 concerned alike with the cooling effect produced at the evaporator and with the heating effect produced at the condenser. In some applications, both the heating and the cooling effects obtained in the cycle are employed simultaneously.

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 later in this chapter.

HISTORY AND DEVELOPMENT

Over a century ago, William Thomson (Lord Kelvin)[1] suggested the use of a compressor as a *warming engine* to heat buildings, as an alternate for combustion of fuels. Somewhat prior to 1910 Dr. S. Z. Ferranti, Prof. J. Perry and Mr. T. V. Morley, in England, strongly advocated the undertaking of development in the design and application of heat pumps, but the economic outlook, then unfavorable, deferred further investigation. It was not until a paper on the principles and economics of heat pumps, prepared in October 1928 by T. G. N. Haldane, was presented before the British Institute of Electrical Engineers in December 1929,[2] that development was started in the United States. Haldane reported the trial results from early installations made in Scotland. Application for water heating was then as prominent abroad as use for space heating.

Dr. A. R. Stevenson, Jr. was an early advocate in this country, having first presented the possibility to the Refrigeration and Gas Committee of the American Gas Association in April 1926, and later to the Franklin Institute.[3] The concept held in this country today, that heat pumps for the large majority of space-heating applications should be regarded essentially as *year-round* air-conditioning devices, did not become generally accepted until about 1950.

History in the United States

Pioneering work on heat-pump development in the United States was conducted through the early 1930's mainly under sponsorship of a few investor-owned electric utility companies, with the objective of promoting wider use for their service. The seasonal character of electric load from summer air conditioning, after a record of steady growth, was then already making evident its likelihood of creating new peak demands on utility systems. This prompted the investigation of methods whereby such load could be made more favorable both to the customer and to the electric company.

The first major installation in the United States was made about 1931, for a new 3,800,000 cu ft office building of Southern California Edison Company in Los Angeles. Refrigeration equipment of the already existing air-conditioning system was modified to permit heat-pump operation with outdoor air in a conventional cooling tower serving as heat source. An installation made in Salem, New Jersey[4] in 1934 was the first commercial heat pump in this country designed for complete heating and cooling. A number of buildings occupied by subsidiaries of American Gas and Electric Company in Ohio, West Virginia, Virginia, and Kentucky were equipped during the middle and late 1930's. The home office of Louisiana Power and Light Company at Algiers, Louisiana was equipped in 1936, using purchased city water as source of heat. An office building[5] of United Illuminating Company at New Haven, Connecticut, erected in 1939, was equipped with a water-source heat pump. It utilized as a standby heating system a large water storage tank equipped with immersion electric heating elements. Throughout this early period all installations were custom built, employing standard equipment components modified where necessary to suit the dual-purpose functions. After World War II the use of heat pumps increased, particularly with the introduction of unitary equipment, in which the refrigeration system, fans, pumps, and the necessary automatic controls were assembled within a single housing.

In recognition of the status attained by heat pumps and their growing engineering importance, the American Society of Heating and Ventilating Engineers appointed a Technical Advisory Committee on the Heat Pump in 1947. An independent group from the electric utility industry, known as Joint AEIC-EEI Heat Pump Committee, was founded in February 1947. This body has worked closely with equipment manufacturers, giving advice on matters related to suitability of equipment types and control methods, to experience resulting from trial installations, and especially to the characteristics of electric loads. It has also under-