Where close control of relative humidity is desired, heating coils or electric heaters for reheat may have to be added. The use of air-conditioning psychrometric techniques is only required for accurate humidity control.

Cooling equipment is usually rated on the basis of the overall room-to-refrigerant temperature differential instead of using the intermediate average coil-surface temperature. If the tentatively selected unit cooler does not possess the proper capacity, it may be possible to adjust the fan speed to a new air volume. At the new air volume and the new overall differential, the cooler may be able to deliver the necessary cooling capacity. If not, the procedure must be repeated with another size of unit cooler, the final selection being based on the proper balance between unit cooler and the condensing unit to maintain the Btu per hour heat removal and temperature difference at design room temperature.

Procedures for rating and testing room coolers are given in an ASRE Standard[3] which establishes four groups of conditions (numbered I to IV) under which units may be rated. Many manufacturers establish and publish their ratings in accordance with this standard in which forced circulation air coolers are classified according to air side surface conditions as (1) dry coil, (2) sprayed coil, and (3) spray (no coil); or according to type of air delivery to room as (1) free delivery fan, or (2) pressure fan. Natural convection air coolers are classified according to type as (1) external baffle, (2) built-in baffle, and (3) without baffle.

Arrangement and Operation

The refrigerant is usually supplied to the evaporator through a thermostatic expansion valve, thus obtaining dry expansion in the evaporator. In other designs, float-valve feeding is used as a means of metering the refrigerant into the evaporator. The refrigerant circuit in the coil may be of the continuous-flow type from inlet to outlet, or it may have means for internal recirculation of the refrigerant. The coils having the *dry-expansion* or *continuous flow from inlet-to-outlet* circuits may be of the upward feed or the downward feed arrangements. Upward flow is generally regarded as producing more refrigerant holding capacity and more effective use of the surface. However, with some refrigerants and in some systems, the downward-feed system has been found to produce better oil-return characteristics. Many direct-expansion installations use liquid-vapor heat exchangers to increase the coil utilization without undue risk of returning liquid refrigerant to the compressor.

Where two or more evaporator coils are to be attached to a single condensing unit, and different evaporator temperatures are desired, a back pressure valve may be installed to limit the minimum evaporating temperature of the warmer coils. This valve also finds application where fluctuation in the evaporator temperature prevents accurate control of air temperature and humidity.

Except in product precooling, the objective of air distribution is to absorb the heat load as it comes into the room while maintaining a desirable degree of ventilation-air movement through hygroscopic cargoes that are not encased by vapor-barriers. In cold storage practice, this generally requires the securing of as uniform an air distribution as possible to every part of the product zone, with employment of diffusion of air over the product and the prevention of direct blasts against the product. These requirements must be recognized when selecting the unit coolers and their outlets and when selecting the locations for the unit coolers. It is important to note that the quantity of air in motion in the refrigerated space is not only that passing through the coils. A quantity of air many times in excess of the air handled by the units is always set in motion by the induction effect of the moving cooled air. Therefore, in evaluating the velocity for any given area, the total air set in motion must be considered. It is a function of the type of outlet, the discharge air velocity, and the unit location relative to restrictive walls and product.

Unit location is also important from the standpoint of occupant comfort, low-velocity outlets being preferred for floor type units. High-velocity outlets are acceptable in fur storage vaults, ice cream hardening rooms, and other spaces where air motion is not an important factor.

In general, unit air coolers should not be suspended in front of door openings, or close to them where moist warm air will be drawn directly into the unit each time the door is opened, thereby causing excessive frosting and loss of capacity. Better performance will be obtained by placing the unit air cooler where the air will be discharged toward the door. If the shape of the space is such that this location would result in excessive air velocity over the product, then the location of the unit air cooler should be changed so that the air is discharged parallel to the wall in which the door is located.

Control of Unit Air Coolers

Although most unit air coolers can be adapted to any control cycle, continuous fan operation is recommended to avoid stratification and wide fluctuations in space temperature. Should the unit be completely self-contained, control of the direct-expansion refrigeration unit may be obtained from the temperature of the recirculated air and from suction pressure. In the case of multiple unit systems supplied with refrigerant or chilled water from a central source, a valve in the supply to each cooling coil may be controlled thermostatically from space temperature.

REFERENCES

[1] Joint Committee of the American Society of Refrigerating Engineers, AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Refrigerating Machinery Association, National Electrical Manufacturers' Association, and Air Conditioning Manufacturers' Association: *ASRE Circular* No. 13-42.*

[2] Joint Committee of the American Society of Refrigerating Engineers, AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Refrigerating Machinery Association, National Electrical Manufacturers' Association, and Air Conditioning Manufacturers' Association: *ASRE Circular* No. 16.*

[3] *ASRE Standard Methods of Rating and Testing Forced-Circulation and Natural Convection Air Coolers for Refrigeration* (*ASRE Circular* No. 25-44).

[4] *Room Air Conditioners* (*Air-Conditioning and Refrigeration Institute Standard* 110-56).

[5] *National Electrical Code* (*National Board of Fire Underwriters Pamphlet* No. 70, Paragraph 195).

[6] *American Standard Safety Code for Mechanical Refrigeration* (American Standards Association, B9.1-1953).

[7] *Standard for Room Air Conditioners* (Underwriters' Laboratories, Inc., UL484, September 1957, 2nd ed.).

[8] *Methods of Rating and Testing Air Conditioners* (*American Society of Refrigerating Engineers Standard* 16-56).

[9] *Cooling Load Estimate Form for Room Air Conditioners* (*Air-Conditioning and Refrigeration Institute Standard* 120-56).

[10] *Air Conditioning Refrigerating Data Book—Applications* (American Society of Refrigerating Engineers, 1956-57, Chapter 34).

* ASRE has combined *Circulars* No. 13-42 and No. 16 in *ASRE Standard* No. 16-56, *Methods of Rating and Testing Air Conditioners.*

CHAPTER 17

ELECTRIC HEATING

Resistors, Heating Elements, Electric Heating Units, Electric Space Heating Applications, Types of Electric Heating Systems, Equipment and Installation Methods, Calculating Capacities, Induction and Dielectric Heating, Power Considerations

ELECTRICITY as a source of heat represents thermal energy in a refined form, easily applied to space heating, and readily distributed and controlled. For many applications, including use to supplement heating systems of other types, the compactness, simplicity, responsiveness, accuracy of control, safety, and cleanliness of electric heating may carry greater weight in choice of method than operating cost and initial investment. Electric heat often is more expensive on a direct-heat-equivalent basis than heat from conventional fuels. Economical service requires careful application in the design of system, adaptation of building structure, choice of control devices, and in method of operation by the user.

Using the power-to-heat conversion constant, 1 kilowatt equals 3,413 Btuh, resistance heating calculations are expressed directly in terms of kilowatt power requirements.

Definitions of *Resistor*, *Heating Element*, and other terms applying to resistance electric heating practices will be found in Chapter 1.

All equipment, materials, and construction used in electric heating systems should comply with the requirements of the *National Electrical Code*, with local codes, and be listed as approved by Underwriter's Laboratories Inc., or other recognized certifying agency.

ELECTRIC HEATING UNITS

An electric heating unit is a frame, casing, or other supporting means containing one or more heating elements, electric terminal connections or leads, and electrical wiring and insulation, all assembled into a unit. There are many varieties of housing, material, and arrangement of heating elements, operating temperatures, ratio of radiant to convective heat delivery, directional control for radiation, natural or forced convection, automatic or manual control, and electric load limiting features. Many specific types of units are discussed in the section Equipment and Installation Methods.

RESISTORS AND HEATING ELEMENTS

Electric resistors usually are composed of metal-alloy wire or ribbons, non-metallic carbon compounds in rod or other shapes, or printed circuits. Heating elements may have exposed resistor coils mounted on insulators, metallic resistors embedded within refractory insulation encased in a protective metal sheath, or a printed circuit encased in glass sheets. Fins or extended surfaces may be used to add heat-dissipating area. Elements are made in many forms. Strip elements are used for clamping to surfaces for heat transfer by conduction in some convection air heaters and some low temperature radiant heaters. Ring and plate elements are common in electric ranges and many small air heaters. Metal or oxide conductive films on glass and ceramics have been used usually in panel form. Tubular elements may be immersed in liquids, may be used bare, may be formed into coils, or may be cast into metal or plastic, and used in water heaters, ranges, and air heaters.

Cloth fabrics, incorporating flexible resistor wires, are employed for many low temperature purposes such as heating pads, sheets, blankets, aviators' clothing, and some radiant panel heating installations.

Special incandescent lamps with tungsten or carbon filaments and glass or quartz envelopes are designed to produce maximum energy in the infra-red portion of the spectrum and applied as radiant heaters.

ELECTRIC SPACE HEATING APPLICATIONS

Complete electric heating systems are now finding wide application not only in residences but also in many commercial and industrial establishments. Auxiliary electric space heating is often used for convenience, for instance: (*a*) for local use when the main heating system is shut down, (*b*) for local use where the main heating system is inadequate, (*c*) for temporary heating, (*d*) for special conditions involving separate or remote control, (*e*) for isolated locations, (*f*) for cases where minimum initial cost is the dominant factor. Portable units readily satisfy some of these requirements.

Compact electric heating units are sometimes installed in main supply or branch ducts of central-fan steam and water systems to provide the final temperatures and relative humidities required for comfort or process air conditioning. Electric heaters installed for use primarily in the heating cycle can also be utilized for reheat in the cooling cycle.

In control of systems, the flow of air over the electric heaters should be constant while the input to the heaters should be varied. This is necessary because of the basic difference between electric heating and other methods such as steam heating. Steam is approximately a constant temperature source of heat at any given pressure, and, consequently, a change in air flow over a steam coil does not greatly alter the coil surface temperature. Hence, the heat output of a steam coil varies in proportion to the air volume, but the surface temperature of the coil remains about the same. With electric heat the energy input and output are constant, and if the electrical energy input remains constant, the temperature of the heating elements will vary inversely with the air flow. Therefore, face and bypass dampers should not be used in electric heating, because the reduction in air flow and the corresponding rise in heater temperature would endanger the operating life of an electric heating element.

Automatic regulation of the electrical input is usually accomplished through a proportional-type step controller that energizes or de-energizes heaters in increments small enough to prevent excessive cycling. The electrical input per heater, or step, is normally determined by the permissible change in supply air temperature per step. High-limit thermostats are sometimes used to de-energize the heaters if the heater tem-