used and on the type of heat distribution system and its controls. In general, the conditions most favorable to heat pumps occur where, due to climate or operating requirements, the compressor capacities needed both for heating and for cooling service are the same, or nearly so. Customary methods of conveying the heat output from heat pumps to the space served are indicated in Table 1. The main types of heat pumps and the characteristics of heat sources utilized are discussed in Chapter 37.

Some recent models of window-type air conditioners are being equipped for operation as heat pumps. They have refrigerant reversing valves and controls, provided either at the factory or optionally by the installing contractor. Such units are intended for between-season or convenience heating only, since they do not give good performance when the outdoor temperature falls below 35 to 40 F, and they lack means for defrosting the evaporator coil.

In the case of heat pumps using air as heat source, it is shown theoretically and found in practice that heat delivery capacity falls off rapidly as outdoor temperature decreases, whereas the heat requirement increases directly with indoor-outdoor temperature difference. Deficiency at temperatures below the *balance point* can be made up by supplementary electric resistance elements, but this adds disproportionately to power demand. Moreover, seasonal energy consumption by such resistance heating, per kilowatt of demand established, is much less than for the heat-pump cycle itself, and the combination gives load characteristics unfavorable to the utility company for rendering low-cost electric service. An alternative provision for cold-weather peaks is thermal storage in chemical salts and by other devices; such processes are still in the development stage.

The installed cost of residential heat-pump systems is two to three times that of resistance types. However, in practically all cases the summer air-conditioning service obtained with conventional heat pumps is as valuable to the user as the winter heating. Resistance heating systems, except the minority using mechanical air circulation through ducts, do not lend themselves to consolidation with summer air conditioning features, and consequently, an independent cooling installation is necessary. Heat pumps thus have an advantage over such dual systems.

CALCULATING CAPACITIES

The procedure outlined in Chapter 12 for calculating the heating load should be used for electric systems. Load expressed in Btu per hour is converted to kilowatts by the divisor 3413 Btu per kilowatt. All the energy applied to a resistor transforms itself into heat, unaffected by temperatures of the surrounding air and of surfaces receiving radiated heat. However, both electric power input and heat output are directly affected by voltage at the resistor terminals, being proportional to square of the voltage. Thus, a resistor rated 1000 watts at 240 volts, if used on a circuit at 220 volts, delivers 840 watts or 16 percent under the rated value, while at 208 volts the shortage is 25 percent.

Selection of proper indoor and outdoor temperatures for design of electric heating systems is more critical than for those using fuel, since in case the installed heating capacity is found deficient, the only recourse is to add more electric heating units or to bring the supply voltage up to the permissible maximum. On the other hand, fuel-operated systems ordinarily permit raising the rate of combustion somewhat above the nominal rating, although there may be some penalty on efficiency, operating or maintenance expense, or overall performance.

Indoor temperatures usually specified are shown in Table 2 of Chapter 12, subject to the indicated notation concerning effect of radiant or panel heating. Moreover, allowance is required for radiation effect of cold surfaces if there are large windows, and for the continuing trend toward adoption of higher indoor temperatures. Concerning outdoor temperature for design, attention is directed in the case of electric heating systems to the cautionary remarks relating to winter climatic conditions in Table 1 of Chapter 12. Judgment must be exercised in choice between values *In Common Use* and *TAC 97.5 Percent Basis*, which show differences as large as 15 deg for some cities. If indoor temperature is taken at 70 F, it may be inadvisable to select outdoor temperature as high as the TAC 97.5 percent value.

The arbitrary addition of a percentage *safety margin* on the calculating heating load or on the specified rated capacity of heating units to be installed, is not recommended, especially in case the outdoor temperature for design is taken at or near the *In Common Use* value instead of *TAC 97.5 Percent Basis*. Such practice increases the peak electric demand and usually the cost of electric service. It also tends to produce excessive on-and-off cycling, impaired temperature regulation, and needless voltage variation or *flicker* disturbances with bad effect on lighting and other electric devices.

Many electric heating systems are of decentralized type, with a thermostat provided on each convector or for each room as recommended by manufacturers of such heating equipment. This practice compensates for variability of heat contributed by auxiliary sources such as sunshine, lighting and appliances. It also gives opportunity for *diversity* of power demand, *i.e.*, the non-coincidence of electric load from all the convectors, panels or heating units of an installation. Manual switches are also commonly provided in such decentralized installations to permit cutting off heat or reducing temperature in rooms when not occupied. Such decentralized operation, advocated as an economic measure with electric heating, requires that consideration be given to adequate capacity for warm-up, as against the uniform-temperature operation with a fully centralized system.

It is essential that buildings intended to be heated electrically should be well constructed, with adequate thermal insulation having impervious vapor barriers, and with storm windows or double-glazed window units and weather stripping to minimize heat loss and air infiltration. Open fireplaces should be eliminated wherever possible, because they induce excessive infiltration. The relatively high electric cost for thermal energy, about $6.00 per million Btu at $0.02 per kwh, for example, as compared with about $1.20 for oil at $0.12 per gal when utilized with 70 percent efficiency, gives economic justification for substantial expenditure to reduce heat consumption. The large majority of dwellings heated economically by electricity have heat factors (quotient of seasonal energy consumption in kilowatt hours, divided by degree-days and by volume of gross heated space expressed in thousands of cubic feet) between 0.2 and 0.3. The features necessary to hold consumption within these limits result in construction that for 5000 degree-day climate with 0 F outside design temperature, gives a calculated heating load of 4000 to 5000 Btu per hr per 1000 cu ft gross volume. Heat factors up to 0.4 are not uncommon, but