age due to nails driven for hanging pictures or from building alteration, most codes prohibit such panels in the United States. Interference with radiation caused by furniture and interior decorations reduce the desirability of wall panels.

### Radiant Convector Wall Panel

Glass electric heating units, sometimes designated as radiant panels, depend on the heating effect produced by passage of current through a thin coating of conductive material fused to one face of a panel of ¼-in. thick special glass. The conductive layer may be sprayed-on aluminum or *printed* metallic oxide patterned to form a grid several thousandths of an inch thick, or fused-on material to give a uniform coating less than 0.0001 in. thick over the entire active face of panel. Normal glass operating temperatures are 300 to 400 F, with maximum permissible temperature around 650 F.

Electric wiring connections are made by a variety of means to the panel, with leads provided for easy field connection. The panel is supported on insulators within a metal frame, with a reflector behind the glass arranged to provide space for air circulation. Protective guards are usually provided to reduce hazards to a minimum.

Glass units are usually rated between 600 and 3000 watts, for standardized voltages of 120, 208, or 240 volts. Starting current for some types exceeds running current by 10 to 50 percent. However, there are types with substantially no current surge. Frame sizes vary from about 30×24 in. for 1000 watt size to 42×6 in. for baseboard models, and are arranged for recessed or for surface mounting. Thermostats integral with the unit are optional. Portable units with cord are available.

Radiant panels using tubular elements welded to or cast into extended aluminum panels have emissivity characteristics similar to glass panels.

### Electric Floor Panels

Resistor cables of the same type used for ceilings may be used for panel systems in concrete slabs. Precautions to be observed in construction of slabs for panel heating are generally furnished with the cable. Cables may be laid in assemblies prefabricated as integral units of cable laced in wire mesh with provision for grounding of mesh. Such prepared assemblies may be suitably located within forms and concrete poured in as a single monolithic slab. Special or heavy-duty cables for concrete installation are available.

Without prepared assemblies, non-insulating cement finish 1¾ in. thick is poured and troweled above cables fixed to a minimum 3 in. slab. In some areas, cables may be stapled to wood nailing strips fixed in the surface of the rough slab. When the slab is made of light-weight insulating concrete, cables may be stapled directly to the slab. Alternative special anchors are available to hold the cable at proper spacing during pouring, and are held by nails driven by hand or power impact drivers. Otherwise, periodic temporary fastening with daubs of cement, plaster of Paris, strips of masking tape, or other nonconductive material must be used.

Provisions of the *National Electric Code* prohibit fastening of cable to reinforcing rods or mesh as a means of holding the cable in place during pouring. To secure monolithic pour, nailing strips are sometimes omitted and the cable is strung on frames with nail spacers; frames are removed when enough concrete has been poured to hold the cable in place. If desired, magnesite flooring, ceramic tile flooring, asphalt tile, or wall to wall carpeting may be used on the floor. Insulating-type concrete may be used below cable, but must not be used around or over cable.

Some floor heating installations employ reinforcing grids energized at low voltage, through dry type transformers, as a heat source.

### Central Hot Water Systems

Heating systems of hot water type using radiators or convectors, discussed in Chapter 8, may be operated using an electric hot water boiler containing immersion elements (resistors). Resistors may be interlocked to prevent energizing when the circulating pump is not operating. The boiler water holding capacity should be sufficient to minimize cycling.

For off-peak operation where electric rate considerations justify, a water heating tank of large storage capacity may be employed. The system may be designed for a water temperature of 250 to 275 F at pressures up to 75 psig, with suitable piping systems for this pressure. An automatic valve may provide 140 to 160 F water at the pump by mixing hot water from the tank with cooler water from the return main. Another method employs the *flash* principle, withdrawing water at high storage temperature into a low-pressure separating chamber where steam is obtained as a result of the pressure reduction; however, power for pumping is substantially greater with this steam-accumulator method. Thermal insulation on boiler tank and piping must be adequate to minimize losses. High investment, space required for equipment, and loss of much of the convenience and economy of operation available with other forms of electric heat, tend to limit the application of this type of system.

### Central Warm Air Systems

Electric furnaces consisting of resistance heating coils housed in an insulated cabinet and equipped with a blower are available in sizes ranging from 5 kw to 30 kw for use with ducted warm air systems. Furnaces are not readily adaptable to individual room control. They are recommended when central cooling is planned or when circulating, filtering and humidifying the heated air; or when positive fresh air supply is desirable. Electric furnaces are compact and require no flue connections or piping, making them adaptable for installation in separate zones. They are also used for converting existing warm air systems.

Individual room control may be obtained in a warm air system by means of duct heaters fitted into branch ducts leading to the various heated spaces. In addition to providing individual room control of heating, these heaters provide a means of local reheat for summer control of humidity, when combined with air conditioning.

## CALCULATING CAPACITIES

The procedure outlined in Chapter 25 of the 1961 Guide and Data Book for calculating the heating load may be used for electric systems. Load expressed in Btu per hour is converted to kilowatts by the divisor 3413 Btu per kilowatt. The National Electrical Manufacturers Association has published the *NEMA Manual for Electric House Heating* describing methods and giving heat loss factors for calculating load directly in kilowatts. All the energy applied to a resistor is transformed into heat, and will dissipate to surrounding air and surfaces receiving conducted or radiated heat. The resistor will attain whatever temperature is necessary to effect this heat transfer. 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 valued, while at 208 volts the shortage is 25 percent. See Table 2.



Table 2 . . . . Relation of Resistor Voltage to Heat Delivery

| Condition | Volts | Heat Delivered % |
|---|---|---|
| Electric system, nominal value | 120/240 | 103.3 |
| For design of equipment, at terminals | 118/236 | 100 |
| Range, as basis for design | | |
| Minimum | 110/220 | 86.8 |
| Maximum | 124/248 | 110.5 |
| On secondary distribution system | | |
| Favorable zone, as to voltage conditions | | |
| Minimum | 110/220 | 86.8 |
| Maximum | 125/250 | 112.0 |
| Tolerable zone | | |
| Minimum | 107/214 | 82.2 |
| Maximum | 127/254 | 116.8 |
| Emergency conditions | 90/180 | 58.3 |

The arbitrary addition of a percentage *safety margin* on the calculated heating load is not recommended. Such practice would increase the peak electric demand and often the cost of electric service.

The most economical electric heating systems from an operating standpoint are of decentralized type, with a thermostat provided on each unit or for each room. This permits each room to compensate for heat contributed by auxiliary sources such as sunshine, lighting, and appliances. This arrangement also gives a better diversity of the power demand due to non-coincidence of electric load from all units of an installation. Manual switches are often provided to permit cutting off heat or reducing temperature in rooms when not in use. When such operation is practiced, consideration should be given to provide adequate capacity for warm-up as compared to a system maintaining a constant temperature.

For the sake of economy, buildings intended to be heated electrically should be well constructed, have adequate thermal insulation and storm windows or multiple glazed windows and storm doors to minimize heat loss, and weather stripping to minimize infiltration.

Adequate thermal insulation may have different interpretations depending on climatic conditions, cost of heating energy, design and type of construction, characteristics of occupancy, living habits of occupants and other factors. In residential construction, the 1960 "Minimum Property Standards" of FHA limit the allowable heat loss to 40 Btuh (11.7 watts) per sq ft of occupied floor area. Most electric heat authorities recommend limitation of overall heat transmission coefficients ($U$ values) to a maximum of 0.05 for ceilings, 0.07 for frame walls and 0.07 for floors (above vented crawl spaces). The National Mineral Wool Insulation Association specifies a minimum resistance ($R$ value) of 19 for ceilings, 11 for walls, and 13 for floors.

In some severe climates, consideration is being given to more insulation and use of triple-glazed windows for reduction of heat loss and increase of inside surface temperatures so that higher inside relative humidities can be used without excessive condensation.

A 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 0.15 and 0.25. Heat factors are also expressed in Kwh per square foot per thousand degree-days.

## POWER CONSIDERATIONS

The cost of electricity for space heating will vary throughout the country. Rates are determined by the utility companies' costs and sales policies. Generally, those companies having large air conditioning loads which cause summer peaks are apt to have special heating rates. Special low rates sometimes are available during certain hours when the load is low. Information should be obtained from the local utility company before operating cost estimates are made.

Many utility companies serve their commercial and industrial customers on a rate which includes both demand and energy charges. When this type of rate applies, it is desirable to keep the user's kilowatt demand as low as possible, by provisions in original design of the installation and by judicious methods of operation. Excess heating capacity should be avoided, but without jeopardizing satisfactory performance in cold weather. A variety of control methods can be applied to minimize both demand and consumption. Decentralized control with a thermostat in each room or on each heating unit, is one method.

### Operating Costs (Residential)

With increased numbers of electric heating installations, operating cost estimates and experience records are accumulating. Experience records and comparisons would indicate that actual consumption is usually less than conventional calculations. This is particularly true with thoroughly insulated structures or for applications having short hours of maintained temperatures and long reduced temperature periods.

The *NEMA Manual for Electric House Heating* applies the following formula for estimating the annual energy use of residential electric heating systems:

$$\text{Annual kilowatt-hour consumption} = \frac{HL \times DD \times C}{TD}$$

*where*

$C$ = constant (see text below).
$HL$ = heat loss of building, kilowatts.
$DD$ = annual degree days for area.
$TD$ = difference between indoor and outdoor design temperature, Fahrenheit.

The constant C depends on a number of variables such as weather conditions in the locality, orientation, design and construction of the building, living habits of the occupants, design of heating systems, and internal sources of heat. To be applicable, the method of calculating heat loss must be in accordance with Chapter 25 of the ASHRAE Guide and Data Book (1961) or the procedure specified in the *NEMA Manual*. The *NEMA Manual* (NEMA Pub. No. HE 1-1957, June, 1957) reports that based upon experience with many thousand electric heating installations, the value recommended for C is 18.5 unless local experience of a statistical nature has established a more reliable value for the particular area concerned. REA Bulletin 142-1 Electric House Heating suggests correction factors for degree-days to be applied to the NEMA formula when the annual degree-days are less than 1800.

The FHA *Minimum Property Standards* (FHA No. 300, General Revision No. 3, December, 1960) recommends use of a C factor in the NEMA formula of 17 for dwellings (a) having a floor area of 1200 sq ft or less and located in any area, or (b) having a floor area of more than 1200 sq ft and located in an area having a design temperature difference (indoor-outdoor) of 65 deg or less. The same publication also recom-