manual switch to cut off any unoccupied room, is one method. Sequence switching whereby electric service to individual rooms or circuits is shifted in rotation by an automatic timing device and sequence is modified by outdoor thermostat or by total electric load, is another.

Load-limiting controls of several types have come into use. These are generally arranged to measure the customer's total power demand, which for a residence may be grouped as lighting and miscellaneous appliances, refrigerator and water heater, cooking range, and the space heating system. When the demand exceeds a preset value, one or more heating circuits are cut off progressively in rooms least affected by the interruption. Experience shows that with electric floor or ceiling panel heating, temperature drop occurs slowly, at the rate of about 1 deg per hour for concrete slabs and 2 deg for plaster construction or rigid panels properly backed with thermal insulation. Moreover, electricity consumed by lighting, appliances and cooking ranges is contributing some useful heat at such times.

Another form of limiting control for 120/240-volt 3-wire circuits provides complete or sequence transfer of space heating units from 240 volts to 120 volts, thereby reducing the electric input to one quarter whenever the total load or general-service component exceeds a preset limit. This method lends itself to use of an outdoor thermostat actuating a relay, whereby in mild weather the entire heating system operates at 120 volts and with lengthened cycles obtains more uniform room temperature. For reducing temperature at night, if desired, a clock-operated master thermostat can be provided to lower the heating-system voltage. On some electric utility systems, centralized control by means of a pilot-wire or carrier-current actuating a relay is applied to house-heating installations.

With any type of control, time-delay relays should be used in order that upon restoration after an emergency service interruption or whenever a master thermostat calls for heat, the individual circuit or units will come on non-simultaneously over a period of a few minutes. This is advisable especially for types of resistor units that have a power input, when cold, as much as 50 percent above the rated value at normal operating temperature.

Operating Costs

With increased numbers of electric heating installations, operating cost estimates and experience records are accumulating. Experience records are indicating that actual consumption may be less than conventional calculations and comparisons would indicate. 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 cost of electric heating:

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

where

C = constant (see text below).
HL = heat loss of building, kilowatts.
DD = annual degree days for area.
TD = difference between inside and outside 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 system and internal sources of heat. Experience with many thousands of electric heating installations has shown that a conservative value for C is 18.5. Values of C as low as 12 have been reported on individual installations. It is recommended that a value of C of 18.5 be used unless local experience of a statistical nature has established a more reliable value for the particular area concerned in the estimate.

For block-type electric rates, multiplying the annual kilowatt-hour energy consumption by the cost per kilowatt-hour indicates the annual cost. For demand rates, the assistance of the local utility should be secured to estimate demand and energy uses by the month on the particular rate involved. It may be pointed out that residences with thermostatic control *in each room* generally establish a maximum of 75 percent of the total calculated heat load as the highest demand requirement for heating.

Table 3. 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

Voltage Requirements

The preferred nominal system voltage at point of electric utilization by equipment, for single-phase 3-wire systems necessary with space heating, is 120/240 volts, as stipulated by standards of the electrical industry (*EEI* publication R-6 and *NEMA* publication No. 117 issued May 1949). For household heating appliances mentioned in the standards, such as air heaters, water heaters, and cooking ranges, the *equipment voltage rating for design* is specified as 118/236 volts, and the range of *voltages to be used as a basis of design* extends from 110/220 minimum to 124/248 maximum. However, naturally variations exist from time to time in the conditions at different points in any secondary distribution system and will affect both voltage level and range of fluctuations. Under emergency conditions on electricity supply systems, voltages of the order of 90/180 may be encountered. Heat delivery by resistors with these voltage values, expressed in percent of rated delivery with the normal 118/236 volts (at terminals) is given in Table 3.

Voltages stipulated for secondary distribution systems are at point of service entrance to the building; the drop of voltage in the house supply wiring to terminals of the heating equipment may be 2 to 3 percent, thus re-