stats are sometimes used to de-energize the heaters if the heater temperatures become excessive for any reason such as a reduction in air flow. Heaters must be de-energized on fan shutdown. (See Chapter 13 of the 1961 GUIDE AND DATA BOOK, for general information on controls.)

TYPES OF ELECTRIC SPACE-HEATING SYSTEMS

The inherent adaptability of electric energy for transmission, conversion, and regulation, and the relatively high unit cost in terms of thermal equivalent, as compared with fuels traditionally used for space heating, necessitates and justifies greater attention to efficient utilization.

Types of electric heating equipment and complete heating systems in current use are listed in Table 1. The sequence shown is for convenient reference only, and does not indicate the relative extent of use, quality of performance, or installation cost and operating expense. Installations of all types listed are in successful operation, but performance and cost depend largely on proper application to local conditions.

EQUIPMENT AND INSTALLATION METHODS

Convector with Metallic Resistors

Heating units for wall mounting, recessed or surface type, are made with resistors of incandescent bare wire or lower temperature bare wire or sheathed elements. An inner liner or reflector is usually placed between resistors and casing to provide a secondary air passage promoting circulation and minimizing rear casing temperature. Part of the heat is distributed by convection and part by radiation. The proportion of each depends on the construction of the unit.

Ratings usually are from 1000 to 8000 watts (3400 to 27,300 Btu per hr) although some models have ratings down to 500 and up to 15,000 watts. Voltages are the standardized values of 120, 208, 240, 277, and 480. Similar models equipped with air circulation fans are available, giving convection heat delivery up to 90 percent. Other types, using similar components but without a fan, are arranged as *floor furnaces* to be installed between floor joists. A manual switch and thermostat integral with the unit are usually provided.

The location of electric convectors should be governed by the same principles that determine arrangement of steam or hot water convectors with respect to air movement.

Small portable units are available with ratings up to 1650 watts for operation at 120 volts. Higher wattage units are made for 208 or 240 volt application, and require suitable heavy duty receptacles.

Unit Ventilators

Unit ventilators with electric heating elements of the metal sheath type with extended surface are used to provide heating and ventilating of school classrooms. Overheat switches are usually provided for each element in the heating section to de-energize the elements in case of interrupted fan operation. Ratings are available up to 36 kw in the larger sizes of classroom units. Auditorium unit ventilators of the same type are rated up to 150 kw. The total capacity of the unit ventilator is made up by numerous smaller heating elements so temperature control can be accomplished by energizing or de-energizing the elements one at a time. The application of unit ventilators is described in Chapter 45, Unit Ventilators and Unit Heaters, in the 1961 GUIDE AND DATA BOOK.

Unit Heaters

Electric unit heaters include a suitable built-in fan which circulates room air over heating elements; they are employed

Table 1 . . . . Principal Types of Electric Space Heating Systems

A. Convectors, Radiant Convectors, Unit Heaters—Built-In and Portable
  1. Convector with metallic resistor, high or low temperature
  2. Unit ventilator
  3. Baseboard-type convector
  4. Convector with fan, including unit heater
  5. Resistor unit placed in room-type air conditioner
  6. Resistor with focusing radiation reflector
  7. Radiant convector wall panel
  8. Steam radiator with immersion electric element
  9. Floor furnaces

B. Panel-Type Installations
  1. Ceiling panel
     a. Electric conductors embedded in plaster on lath
     b. Electric conductors embedded in plaster or similar material between two layers of plaster board
     c. Rigid composite panels containing electrically conductive component
     d. Flexible composite sheets containing conductive component or embedded metallic filaments
  2. Wall panel
     a. Radiant-convector panel
     b. Rigid panels, as for ceilings
     c. Flexible sheets, as for ceilings
  3. Floor panel
     a. Electric conductors embedded in concrete slab
     b. Reinforcing mesh in concrete used as resistors with high current, low voltage, power supply

C. Central Hot Water Systems
  1. Water from electric heater pumped to radiators or convectors in rooms
  2. Same, with thermal storage for off-peak operation
  3. Fuel-fired boiler converted to electricity
  4. Heat pump systems—See Chapter 4 of this volume and Chapter 58 in the 1961 GUIDE AND DATA BOOK

D. Central Warm Air Systems
  1. Duct heaters
  2. Central electric furnace
  3. Heat pump systems—See Chapter 4 of this volume and Chapter 58 in the 1961 GUIDE AND DATA BOOK

for the same uses as other forms of unit heaters (steam, hot water, gas, oil), where conditions are favorable to electric heating. They are especially adaptable for supplemental heating, for small occupied rooms in otherwise unheated buildings and for unattended equipment enclosures in which temperature must be maintained above freezing. Location and arrangement of such unit heaters are discussed in Chapter 45 of the 1961 GUIDE AND DATA BOOK.

Large high-wattage unit-type heaters are available for ceiling or high wall mounting. These are similar to steam and hot water unit heaters in appearance and function. Resistors may be placed in room air conditioners to permit operation as forced air heaters when desired.

Baseboard-Type Unit

A metal casing, proportioned to resemble and replace conventional baseboard along walls, contains one or more resistors placed horizontally.

Resistors may be bare wire, sheathed element, cast grid, finned, or ceramic extended surface. The vertical dimension is usually 9 in. or less and projection from face of wall from 3½ in. or less. Location follows the same principles applying

to hot water type baseboard installation described in Chapter 46 of the 1961 GUIDE AND DATA BOOK.

Baseboard-type units using glass panels are available in various heights and lengths.

The 1961 NEMA Standards for electric heating equipment provide that no point on the surface of the heater or in the outlet air stream shall exceed 350 F.

Resistor Portable Heater with Reflector

These units employ an incandescent wire or strip heater backed up by a reflector. They may be equipped with a blower. They are usually thermostatically controlled and equipped with a safety *tip-over* switch or with over heat limit switch. Usual ratings are 500 to 1650 watts for 120 volt use. Heat emitted is 50 to 60 percent radiant.

Infra-red Heaters

Sectional focusing, trough-type reflectors are made with low-temperature resistors, or with metal sheath, quartz tube or quartz lamp elements, to be suspended from the ceiling or bracketed from the wall. Rated capacities are 200 to 1500 watts per linear foot or unit. In buildings with exceptionally high ventilation loads where convection heating is economically impractical, *infra-red* heaters are employed to provide relative comfort despite low ambient temperatures. Installations may be for complete area heating or *spot* heating of only specific areas occupied by personnel. There is growing use of infra-red *spot* heating in outdoor locations. In a modified form, similar units are used for industrial heating and drying.

Steam Radiator with Immersion Element

Radiators equipped with an immersion element screwed into a bottom opening, are usually sealed after charging with water and antifreeze compound. A safety valve or thermal relief plug is provided to protect against excessive pressure and temperature in case heat dissipation is unduly curtailed by obstructions to air convection. The steam-and-water intermediate heat transfer does not affect overall thermal efficiency, but gives the unit operating characteristics adapted for certain applications. Units may be permanently connected by conduit, or used as portable heaters with cords.

Ceiling-Panel Installations with Conductive Rubber

Panels of laminated construction containing electrically conductive rubber, with rating of 22 watts (75 Btu) per sq ft, for 115 and 230 volt service, are built in standard sizes 3 x 4 ft, 4 x 4 ft, and 4 x 6 ft. They consist of a layer of special rubber about 3/64 in. thick sealed between layers of phenolic resin-impregnated electrical insulating paper. The assembly is covered on each side with a sheet of aluminum foil. Overall thickness is 1/16 in.; weight is 0.4 lb per sq ft. Metal strips embedded along edges of the rubber sheet serve as potential leads. Electric terminal blocks are provided on each panel and standard raceway moldings are furnished for wiring connections. An earlier type of construction using asbestos-board backing to form rigid panels ¼ in. thick has been discontinued.

Under normal operating conditions, the surface temperature of an automatically controlled ceiling panel is about 100 F. When panels are turned on in a cold room or with continuous operation, the maximum temperature reached is 120 F.

Since it is not permissible to cut heating panels, the entire pattern for ceiling must be planned in advance, with particular attention to coverage near exposed walls. Attachment to smooth surfaces may be made by a special adhesive applied on the ceiling along a 1½ in. fastening margin provided around the four sides of each panel. A highly sensitive room thermostat with narrow operating differential should be used in each room.

Ceiling-Panel Installations with Embedded Conductors

Resistors or cables for embedding in ceilings to form panel-heating installations are electrically insulated with coverings resistant to high temperature, water absorption, aging effects, and chemical action with plaster, cement, and soil. Cable units identified by a color code are furnished in nominal standard lengths from about 75 to about 1800 ft, and are rated from 200 to 5000 watts for standardized voltages of 120 or 240. The outside diameter of the cables is usually about ⅛ in. Non-heating leads 7 ft long are attached to each unit to connect at thermostat or connection box without running cable beyond the ceiling. The length of cable or leads must not be altered. The identification label showing rating may not be removed. Manufacturer's instructions should be followed regarding installation procedures.

The lath used is of non-metallic fire-resistant type. The cable is secured to the lath with staples spaced not over 16 in. apart. Each cable is tested after fastening on lath, and after first plaster coat has been applied, for continuity of circuit and for insulation resistance of at least 100,000 ohms measured to ground. The minimum spacing between cable passes is 1½ in. and is generally used near cold walls, with up to double that spacing near interior areas of the room. Non-heating leads outside the ceiling should be installed by approved wiring methods. Cables must be kept away from metallic materials and from areas of ceiling additionally heated by recessed or surface mounted lighting fixtures. All general power and light wires should be run above thermal insulation or at least 2 in. above the heated ceiling surface.

For plastered ceilings, non-insulating plaster is applied in two or three coats with the first coat troweled in the same direction in which the cable runs. Ceiling cables, properly engineered, installed, and operated will not cause ceiling cracks. While new plaster is drying out, the system should not be energized and the range and rate of temperature change should be kept low by other heat sources or by ventilation until plaster is thoroughly cured. The use of vermiculite or other insulating plaster is contrary to code provisions since it causes cables to overheat.

For laminated ceiling construction, suitable cables are stapled to non-metallic lath or plasterboard, allowing sufficient clearance at joist location to permit nailing of finish layer of plasterboard. Then a layer of non-insulating plaster or similar material is applied to cover the cable and connections completely, and to provide a smooth surface on which the final layer of plasterboard is applied. The purpose of the intermediate layer is to sandwich the cable firmly in place and improve heat transfer between the cable and the ceiling. Failure to fill the space between the layers of plasterboard may allow cable to overheat in these voids.

Cable embedded in plaster ceilings, or properly installed in laminated dry wall ceilings, should remain operational for the life of the ceiling.

A highly sensitive room thermostat with narrow operating differential is recommended for each room. Chapter 10 includes data on panel heating with electric panels.

Electric Wall Panels

Cable embedded in walls similar to ceiling construction is occasionally found in Europe. Because of possibility of dam-