found that for 360 rpm the static deflection required for a ratio of f/f_n of 3 to 1 (line *EF*) is 2.5 in., and for a ratio of 5 to 1 (line *GH*) it is 7 in. For these values of deflection the only choice of material is the coil spring. This is also true for speeds up to about 700 rpm. In consideration of the transverse spring constant (so as to maintain good ratios among the various degrees of freedom) experience has shown that the spring should be designed with a *working height* equal to 1.0 to 1.5 times the outside diameter. A long spring of small outside diameter has very low transverse rigidity, and therefore requires some additional means of preventing side drift of the unit, and on very sensitive applications this may tend to destroy the isolation efficiency. For speeds of 700 to 1200 rpm the required deflections range from 0.22 in. to 1.75 in. For these conditions rubber in shear serves as a rather satisfactory material if protected from oil. For speeds higher than 1200 rpm cork specially made for vibration damping can be applied with good results. These limitations are by no means absolute, because certain liberties may be taken without impairing the result if all possible degrees of freedom have been taken into account in the design of the installation.

When a machine unit is properly isolated it will have a definite amount of movement which is determined by the ratio of the unbalanced forces to the total mass of the machine. If this resultant machine movement is too great for the necessary connections or the satisfaction of the customer, it can be reduced only in two ways without destroying the quality of the isolation; first, adding mass or dead weight to the machine (such as concrete) common in the application of low speed, partially balanced machinery; second, accurately balancing (both statically and dynamically) all moving parts so as to eliminate the vibration at the source. This latter method is the best engineering practice and is the modern trend. However, even with well balanced machinery, installed in the vicinity of quiet offices, it is usually necessary to isolate properly the equipment to prevent the transmission of vibration likely to cause complaints.

Where limitation of machine movement is desired during the starting and stopping periods, the application of friction or hydraulic damping will serve without seriously interfering with the efficiency of the isolation.

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CHAPTER 42

ELECTRIC HEATING

Resistors, Heating Elements, Electric Heating Units, Applications of Electric Heat, Types of Electric Heating Systems, Equipment and Installation Methods, Calculating Capacities, Heating Water by Electricity, Induction and Dielectric Heating, Power Problems

ELECTRICITY as a source of heat represents thermal energy in a refined form, easily applied to space heating by a variety of methods, and readily distributed and controlled. However, it usually is more expensive on a direct-heat-equivalent basis than heat from conventional fuels, and for 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. For special applications and particularly when used to supplement heating systems of other types, the compactness, simplicity, responsiveness, accuracy of control, safety, and other characteristics of electric heating may carry greater weight in choice of method, than operating expense or initial investment.

The basis of all electric heating methods and devices, except so-called heat pumps, is in the power-to-heat conversion constant: 1 kilowatt equals 3413 Btu per hr. Because ratings of electric heating equipment are expressed in terms of watts input and volts at the terminals, heating capacity calculations are translated directly to electric power requirements without the necessity of considering ampere currents or ohm resistances.

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

It is strongly recommended that compliance with the National Electrical Code and approval by *Underwriters' Laboratories Inc.*, or other recognized certifying agency, be required in the specifications for all equipment, materials, and construction used in electric heating systems.

RESISTORS AND HEATING ELEMENTS

Electric resistors usually are composed of metal alloys such as nickel-chromium wire or ribbon, or non-metallic compounds containing carbon formed into rods or other shapes. Heating elements may have resistors either in the form of exposed coils mounted on insulators or of metallic conductors embedded in a refractory insulating material, encased in a protective sheath of metal. Fins or extended surfaces may be used to add heat-dissipating area. Elements are made in many forms, such as wires, strips, rings, tubes, plates and panels. Strip elements are used for clamping to surfaces requiring heat transfer by conduction, in some types of convection air heaters, and in 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 applied, usually in the form of panels. Tubular elements may be immersed in liquids, and when cast into metal or formed into coils, are used in water heaters, electric ranges and air heaters.

Cloth fabrics, woven from flexible resistor wires and asbestos or glass