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 41

ELECTRIC HEATING

Resistors, Heating Elements, Electric Heaters, Unit Heaters, Central Heating and Air Conditioning, Electric Boilers, Electric Hot Water Heating, Heating Domestic Water Supply, Calculating Capacities, Induction and Dielectric Heating, Power Problems

ELECTRIC heating deals with the conversion of electrical energy into heat and the distribution and practical use of the heat so produced. In certain regions, where the cost of electricity is favorable, electric heating is used extensively. Its use is also frequently dictated by special conditions.

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

RESISTORS AND HEATING ELEMENTS

Commercial electric heating elements usually have solid resistors such as metal alloys or non-metallic compounds containing carbon. In some types of electric boilers, water forms the resistor which is heated by passing an alternating electrical current through it.

In one type of heating element, the resistors are exposed coils of nickel-chromium wire or ribbon, or non-metallic rods, mounted on insulators. This type is used extensively for operation at high temperatures for radiant heat, or at low temperatures for convection and fan circulation heating.

Some elements have metallic resistors embedded in a refractory insulating material, encased in a protective sheath of metal. Fins or extended surfaces add heat-dissipating area. Elements are made in many forms, such as strips, rings, plates and tubes. Strip elements are used for clamping to surfaces requiring heat by conduction, in some types of convection air heaters, and in low temperature radiant heaters. Ring and plate elements are used in electric ranges, waffle irons, and many small air heaters. Tubular elements may be immersed in liquids, cast into metal, and, when formed into coils, used in electric ranges and air heaters.

Cloth fabrics, woven from flexible resistor wires and asbestos thread, are used for many low temperature purposes such as heating pads, aviators' clothing and radiant panel heating installations.

Special incandescent lamps are used as heating elements in certain applications where radiant heat is desired. These use carbon or tungsten filaments as resistors, and are designed to produce maximum energy in the infra-red portion of the spectrum.

ELECTRIC HEATERS

Conduction electric heaters, which deliver most of their heat by actual contact with the object to be heated, are used in such applications as aviators' clothing, hot pads, soil heaters, and water heaters. Conduction