requirement. Complete information can best be obtained from a hanger manufacturer.

APPLICATION OF PIPE, TUBE, AND FITTINGS

In the application of pipe, tube, and fittings it is necessary to comply with regulations contained in local codes and ordinances. Table 23 is offered as a guide to current practice in heating and air conditioning. It is based on practice in a number of consulting engineers' offices and information extracted from Reference 7. It should be borne in mind that selection of material to be used will also be influenced by the familiarity of local artisans with methods of using different materials.

REFERENCES

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CHAPTER 32

PIPE AND INDUSTRIAL INSULATION

Industrial Insulation: Uses, Properties, Temperature Range of Use, Temperature Limitations, Forms; Bare Surface Heat Loss; Conductivities; Heat Flow Calculations; Thickness for Application; Economical Thickness; Low Temperature Insulation; Insulation to Prevent Freezing; Application; Underground Insulations

THE PAST 50 years have seen an enormous increase in the use of thermal insulation by industry. Where once it was not uncommon to see hot water and steam lines, and even boiler surfaces, uninsulated, it is now rare indeed to see any surface operating more than a *little* above or below ambient temperature without insulation. Higher costs of fuel, increased efficiency of industrial operations, and the necessity for close control of the temperature of industrial processes are among the factors that have caused this greatly increased usage of thermal insulation.

USES OF INDUSTRIAL INSULATION

Thermal insulation serves five principal purposes: (1) to conserve heat or some other form of energy, for example, electrical energy to operate a refrigeration compressor; (2) to increase the comfort of living spaces; (3) to facilitate control of the temperature of a process; (4) to reduce the temperature of the shell of a pressure vessel; and (5) to control the external temperature of the insulated space in order to avoid danger to personnel, to protect surrounding structural members from damage by high temperature, to reduce the temperature of working spaces, and, in case of equipment operating below ambient temperatures, to prevent sweating or icing at the warmer surface. Depending on the application, one or another purpose may govern the choice of insulation; usually two or more are concurrently of importance.

PROPERTIES OF INSULATIONS

Low thermal conductivity is the property that distinguishes a thermal insulation. Thermal conductivity is defined as *the rate of heat flow through unit area of a homogeneous substance under the influence of unit temperature gradient in the direction perpendicular to the area.* Many units have been used to express thermal conductivity but the most common engineering unit is Btu (hour) (square foot) (Fahrenheit degree per inch of thickness). The usual symbol for thermal conductivity is k.

Reflective insulations, such as aluminum and steel coated with a reflecting coating, depend not upon low thermal conductivity for their resistance to heat flow, but upon the low thermal emissivity of their surfaces and subdivision of the air space. To be effective in retarding heat flow by radiation, the reflective surface must face an air space.

Thermal conductivity values of the most commonly used industrial and pipe insulations are shown in Table 1. These values have been selected as typical and useful for engineering calculations, and may or may not apply to a particular material or application. For accurate values for a particular insulation the user should consult the manufacturer or obtain the results of unbiased tests.

Other properties of thermal insulations that are of more or less importance, depending upon the use, are strength, hardness, density, compressibility, specific heat, resistance to high or low temperature, and thermal coefficient of expansion. The final choice of an insulating material for a given purpose usually involves a compromise with regard to several desirable properties. For example, an insulating firebrick must have considerable strength and must be resistant to the temperature to which it is to be exposed. The desirable properties of low conductivity and light weight must be sacrificed to some extent to achieve these necessary properties of strength and temperature resistance.

TEMPERATURE RANGE OF USE OF INDUSTRIAL INSULATION

Since thermal insulation reduces the exchange of heat energy between an insulated surface and its surroundings, it can be useful at any temperature from the lowest to the highest. Actually insulation is used in industrial processes operating at temperatures from −400 F to +3000 F and higher.

At the low end of the scale are processes involving liquefied gases, usually in vessels or piping, at temperatures from the lowest up to about −40 F. From −40 to normal atmospheric temperatures large amounts of low temperature insulation are used for enclosing freezing tunnels, cold storage rooms, and a great variety of food and industrial processes requiring low temperatures.

At normal and near-normal temperatures insulation in building structures is required for economical operation of heating and air-conditioning systems. Insulation for heating and cooling equipment and for the distribution ducts, piping, etc., is, however, usually considered as industrial. The range of temperatures is from that of chilled water or about 32 F up to steam at 100–125 psig (about 350 F).

Drying and baking ovens, small and large boilers, distillation equipment in oil refineries, and high-pressure and superheated steam piping call for insulation suitable up to 1200 F. Petroleum cracking units, heat treating furnaces, and ceramic kilns may reach 2200–2400 F. Still higher temperatures with surfaces to be insulated up to 3000 F are found on melting furnaces for glass, iron, steel, and metals of all kinds as well as furnace enclosures for combustion spaces for many kinds of heating units.

Above 3000 F the variety of materials physically suited for walls and structural parts decreases rapidly with increasing