that give the same sensation of warmth as, say, 75° saturated still air, have an effective temperature of 75° F. Such combinations are easily read from the chart.

The effective temperature scales were derived by a "cut and try" procedure wherein test subjects moved from a control room into an adjacent test chamber and immediately recorded their thermal sensations. By repeated trials combinations of temperature, humidity, and air motion that, subjectively, felt like conditions in the control chamber were identified. Despite its limited subjective basis, laboratory and field experience with the ET scale has indicated that it is useful in defining the thermal comfort zone, and also that it correlates with objective measurements of physiological response to heat. In practice, the ET scale overemphasizes somewhat the influence of humidity in the comfort zone and tends to underestimate its effect in hot environments. It is, nonetheless, a valuable scale, which combines most successfully the several thermal factors of the environment into a single index value. The comfort zone outlined in Figure 4 may be used as the basis for specifying air-conditioning requirements for offices, light industry shops, and so forth. (For a discussion of the heat problem in the hot industries see Chapter XXI.) It is of interest to note the close agreement between the comfortable environmental temperature and the external conditions under which thermal neutrality is maintained, as suggested in Figure 1.

II. Environmental Control

Thermal comfort in the environment is the primary purpose of air conditioning. It has been shown that low temperatures reduce manual dexterity and increase accident frequency;[4] however, comfort, not accident prevention, has been the motivating force behind most heating installations (cf. also page 110).

Most industrial cooling installations have been decided upon because of an expected monetary return on the investment. Many articles have appeared in the literature pertaining to the savings that have been made by the installation of summer air conditioning and it is rapidly gaining acceptance.[5]

Inasmuch as man generates heat and is comfortable at room temperatures below body temperature, it should be remembered that the problem is always one of controlling the heat loss from the body, not of heating the man. To maintain an environment that will regulate the loss of heat from the body, it may be necessary to supply heat or humidity, to cool or dehumidify, or to vary the velocity of the air movement in the area. Many installations will require the consideration of more than one of these to arrive at a satisfactory condition.

A. ADDING HEAT TO A SPACE

The heat loss from a building is usually calculated in order to determine the amount of heat that must be added to maintain suitable inside temperatures.

[4] E. E. Osborne and H. M. Vernon, *Ind. Fatigue Research Bd. (London), Rept.* No. 19, H. M. Stationery Office, 1922.

[5] Is air conditioning worth the investment? *Heating, Piping Air Conditioning*, 26, 119 (August, 1954).

Because of their complexity these calculations will not be discussed here; they are available in the chapter on heating loads in the *Heating, Ventilating, Air Conditioning Guide* published annually by the American Society of Heating and Air-Conditioning Engineers.

Heat may be supplied to a space in two ways: by radiation or by convection.

1. Radiation

Thermal (heat) radiation is the transmission of energy by means of electromagnetic waves of very long wave length. Radiant energy of any wave length may, when absorbed, become thermal energy and result in an increase in the temperature of the absorbing body (see Chapter XXI). The most common method of supplying heat by radiation is with the ordinary radiator or some form of heated panel. These units may be heated by steam, hot water, or electricity and are found in a variety of shapes and sizes. The wall radiator is rapidly becoming extinct since it has a tendency to overheat anyone close to it while not supplying sufficient heat to people farther away.

Much has been written regarding radiant panel heating. The heat source for this system is usually buried in the floor or concealed behind the plaster of the ceiling or wall. It was thought that the use of low temperature radiation would result in comfort even though low air temperatures were maintained. Actually, in most cases, this has been just another way of heating the air. In garages, airplane hangars, and similar buildings where men work on the floor and large doors may be opened, greater comfort has resulted with heated floor panels. However, radiant panel heating has not always been satisfactory in factories because the lag in the controls has been too great to accommodate the rapid increase of temperature caused by a large sun load or the heat gain resulting from manufacturing processes.

When it is not possible or practical to heat the surrounding air at a reasonable cost, comfortable conditions have been provided by means of portable, semiportable, or fixed gas-fired radiant heaters. A receiving dock at a large unheated warehouse is a good example. Figure 5 illustrates an installation of fixed gas-fired radiant heaters used as the only heat source in a partially opened, uninsulated building.

2. Convection

Convective heat transfer is the transmission of heat by either natural or forced motion of a fluid (liquid or gas). In general, any heat source that air circulates around becomes a convector. This may be a wall radiator, a unit heater or furnace, or coils; either mounted so that air moves over it because of the thermal lift created by the increase in the temperature of the air, or fitted with a mechanical fan to move the air over it. The concealed radiator or convector is seldom used in industry because it is difficult to locate, is bulky, and affects only a small area.