heat, effective temperature, and body heat balance. For buildings with low ceiling heights, the possibility that heated air may accumulate under the ceiling or that the ceiling may absorb heat and become a radiant heating panel should be explored. (See Chaps. 5 and 24.) Such radiant heat loads may represent other heat loads considered but not dissipated to the outside. In addition to the pertinent chapters in The Guide, the designer should refer to the articles by Small[1], and Haines and Hatch[2] on the subject of heat relief in industry, in evaluating the above factors.

2. Consider the practicability of reducing the heat loads imposed on the area and worker by:

a. Designing a building structure of adequate height, reducing the glass area exposed to sun radiation, and utilizing heat-absorbing glass to shield the high intensity radiant sources.

b. Changing the process in such manner as to provide lower operating temperatures, thereby lowering the heat release to the area.

c. Providing air cooled booths, possibly in conjunction with remote operating controls and visual aid devices, so that the hot areas may be avoided except for short exposures.

d. Insulating all surfaces above 125 F in temperature where these surfaces are extensive enough to add appreciably to the ambient air temperature or mean radiant temperature.

e. Using canopy hoods for hot equipment or providing local hoods at flues and doors of furnaces and similar hot equipment to reduce the heat dissipated to the work area.

f. Shielding hot equipment (often used in conjunction with hoods) so as to reduce sources of radiant heat.

3. Give careful consideration to the type of clothing used by the workers.[3] Lightweight, open-weave fabrics in white, will frequently reduce the heat received by the worker to a small extent and will materially increase the workers' ability to lose heat by convection and evaporation. Also, reflective clothing can be provided, as noted hereinafter under the heading Radiation Shielding.

4. Heat removed from exchangers, motors, generators and similar equipment can be used to temper necessary make-up air or to heat the building in the winter. This heat can be discharged outdoors in warm weather.

Physiological Considerations

In hot environments, the major physiological considerations are the degree of activity of the occupants (this affects their metabolic rate or rate of heat production), the length of the period of activity and occupancy, and the ambient environmental factors (dry-bulb temperature, mean radiant temperature, humidity and air motion) which control the dissipation and reception of heat by the occupants. The subjects of work activity, and the correlated effective temperature limitations are covered in detail in Chapter 6. While effective temperature is a good index for hot areas (when mean radiant temperature effects are included), it must be realized that the allowable effective temperature which can be considered for a particular area must be dependent upon the degree of activity or work rate, and, consequently, on the body heat balance. It is essential that body heat balance (metabolic rate plus heat received by the body, versus the heat dissipated by the body) be maintained except for relatively short exposures to hot environments. The subject is treated to some extent in Chap. 6, but Haines and Hatch[2] have recently provided detailed data for estimating the maximum heat removal that can be expected for various environmental conditions. These data and calculations will also provide a means of estimating the maximum practical work rate for the area under consideration, and will indicate the best means for providing relief for the worker.

Too little information is available on the effect of air motion (draft) on human comfort. An understanding of the subject is of great importance in designing areas for local cooling. The comfort reaction to a draft is a function of (a) the physiological factors of work activity: position, age, sex, health and acclimatization; and (b) the environmental conditions of temperature, air movement (over the body), and humidity. In hot atmospheres with high mean radiant temperatures and with high degrees of activity, a draft may be pleasant. In cooler conditions with less active work, a draft may be unpleasant. The body extremities are sensitive to draft and the head, neck, and shoulders have been found particularly sensitive if subjected to continued or excessive air movement in conjunction with low humidity, sweating, and the impingement of low temperature air.

The position of the worker is important. A person sitting, at rest, will produce less heat than a person standing, but because of the increased convection and evaporation surface exposed, the latter can lose more heat. Likewise, a person whose job requires him to stay at a fixed point, cannot be comfortable under the same conditions of air movement as a person who is moving about and exposed intermittently to the same air movement. Yaglou[4] among others, has pointed out that minimum body stress occurs with uniform cooling or heating over the body area. On the basis that the maximum work rate which can normally be maintained for an 8 hr day is 88 Btu per (sq ft)(hr) or 1700 Btu per hr for a surface area of 19.5 sq ft, the following stress factors may be used as guides in determining the design of local relief areas in hot industries.

1. The effective temperature should be maintained below 85 F. (See Ref. 2 also.)
2. The relative humidity should not exceed 80 percent for normal temperatures nor should the wet bulb temperature exceed 83 F. (See Chap. 6, Fig. 9.)
3. The skin temperature should not exceed 95 F.
4. The pulse rate should not exceed 125 beats per minute (from an initial rate of 70 to 80).
5. The rectal temperature should not exceed 100 F (from an initial level of 98 to 99 F).

These are neither rigid nor exact limitations but do provide guides for design purposes. Generally, the designer will do well to stay reasonably below these limits. If the limits of paragraphs 3, 4, and 5 are not exceeded within the first two hours of work they probably will not be exceeded during the work day provided there is no change in the rate of work or the environmental conditions.

Radiation Shielding

Shielding is an all-important method for reducing radiant heat exposures and the one technique that has been largely neglected in industry.

A shield consists of a sheet of suitable material placed between a hot object, such as a furnace, and its cooler surroundings. The closer it is placed to the hot object, the greater the effective coverage. Hot surfaces emit infra-red waves which reach all objects within visible range. Essential to all shielding is the presence of an air space between the hot object and the shield to avoid conduction to the shield or a thermal short circuit.

Radiation shields in the following forms are very effective:

1. Sheets of reflective metal or insulating board, either semi-permanently attached to the hot equipment (such as furnace buck stays) or arranged as semi-portable floor stands.

2. Aluminum foil faced cloth curtains which can be raised or lowered on spring rolls.

3. Transparent shields, including heat absorbing tempered plate glass, reflective metal chain curtains and close mesh wire screens. These have lower efficiency than opaque shields described in preceding paragraphs 1 and 2.

4. Reflective garments, such as aprons, or in the form of a sandwich in cases of