remove convective heat. Radiation shielding should be used as well to control the larger fraction of the total heat escaping from the process. The design of local exhaust hoods is considered in Chapter X.

B. GENERAL BUILDING VENTILATION

The most common means for heat removal in the hot industries is by general ventilation, making use of wall openings for the entrance of cool outside air and roof ventilation, commonly of the gravity type, for the escape of the heated air.

Although the higher fraction of heat loss from hot bodies is by radiation, this radiant heat is absorbed by building walls and other solid structures. These heated surfaces become sources of convective heat and also act as secondary re-radiators. Eventually, the heat must be removed from the enclosed space by ventilation (except for losses through walls). General ventilation is therefore an essential part of the heat-control procedure; but it does not take care of direct radiant-heat exposures and, even in its secondary role, has failed to function as needed. A principal reason for this failure is that inadequate provisions are made for air ingress. Insufficient area of openings and poor location of inlets result in improper distribution of too little air within the building.

Convection flow around hot bodies is naturally upward. With an ideal system of general ventilation, combined with radiation shielding, the inlet air should be brought in near the floor level, be directed toward the workers, and then flow toward the hot equipment. In this way the coolest air obtainable is received by the workers before its temperature is increased by mixing with warm building air or circulation over hot processes. This air will then flow toward the hot equipment and as its temperature increases it will rise and escape through the vent openings in the roof. The combination of the air motion and the coolest air available will result in the maximum comfort for the worker that can be obtained without some method of artificially cooling the air. Contrary to general practice, provisions for proper distribution of the air supply should receive the same careful consideration as that given to the selection of exhaust equipment. Engineering reference works may be consulted[14] (see Chapter VIII).

C. LOCALIZED VENTILATION AND COOLING AT FIXED WORK STATIONS

Often practical considerations limit the effectiveness of heat control at the source and building size and shape and limitation in air supply make it impossible to bring the heat within acceptable limits throughout the work area. In such cases, local relief may be provided over limited areas immediately around separate work stations. Cool air is introduced in sufficient quantity to surround each worker with an independent atmospheric environment.

The local relief, or so-called spot cooling, system has two different functions depending upon the relative importance of the radiant and convective components in the total heat load. (*1*) If the load is primarily convective in the form of hot air

[14] W. C. L. Hemeon, *Plant and Process Ventilation*. The Industrial Press, New York, 1955.

immediately surrounding the employee, then the only function of the local relief system is to displace the hot air immediately around him with air of an acceptable temperature and velocity. If the air is available at a suitable temperature and is introduced without mixing with the hot plant air, no further cooling will be necessary. Such a system is not one of spot cooling in the sense of cooling the employee, but, rather, one of maintaining an acceptable working atmosphere around him, within the hot building environment. (*2*) When there is a significant radiation load, however, the local relief system must provide some actual cooling to offset it, since the radiant energy will penetrate through the local pool of air surrounding the employee. This means that the temperature of the supplied air will have to be low enough to make the convection component, C, negative in the heat load to offset R, the radiation component.

Air movement within the local relief zone is desirable to maintain adequate evaporative cooling; but, for the reasons outlined earlier, the use of high air velocities and high evaporative cooling to offset radiation is not desirable since the convective load is increased (where $t_a > t_s$) and with it there is a greater sweating demand. This is the objection to simple man-cooling fans, which are so widely used in industry.

A major problem in the design of local relief systems is to introduce the supplied air in such a way that minimum mixing takes place with the surrounding hot air. High velocity jets encourage mixing but are frequently necessary to "throw" the air into the work zone from an offside supply duct. The design of local relief facilities is dealt with in the ASHAE *Guide*[15] and by Small.[16] The performance of air jets blowing through air have been extensively studied,[17-19] and the findings should have useful application in the design of spot-cooling systems.

In situations of extreme heat, employees may be stationed inside an insulated and separately ventilated observation booth or relief room, to which they can return after brief periods of high exposure directly on the job. The practical usefulness of such a protected room will vary with the industry. Air-conditioned crane cabs are now in common use.

V. Supervision of Employees in Hot Industries

Although man's ability to withstand heat decreases sharply with age, experience in the hot industries is often better with older than younger employees. This

[15] *Heating, Ventilating, Air Conditioning Guide, 1954*. American Society of Heating and Air-Conditioning Engineers, New York, 1954.

[16] B. R. Small, Heat relief in industry, *Iron Steel Engr.*, **29**, 71–77 (April, 1952).

[17] G. L. Tuve, Air velocities in ventilating jets, *Heating, Piping, Air Conditioning*, **25**, 181–190 (January, 1953).

[18] L. Helander, S. M. Yen, and R. E. Crank, Maximum downward travel of heated jets from standard long radius ASME nozzles, *Am. Soc. Heating, Air-Conditioning Engrs. Trans.*, **59**, 241 (1953).

[19] A. Koestel, Computing temperatures and velocities in vertical jets of hot or cold air, *Heating, Piping, Air Conditioning*, **26**, 143–156 (June, 1954).