50 fpm for light activity in a fixed position, and particularly when the individual is seated at a desk or bench. The maximum velocity around the worker should not exceed 200 fpm for continuous exposure. With a high work level and intermittent exposure (relief stations), velocities of 1000 to 2000 fpm have been used successfully. Great care must be exercised in using such high velocities, however, to avoid the undesirable effects of air at high temperature.

Ordinarily the temperature of the air supplied to the worker for convective cooling should be about 80 F. Evaporative cooling ventilation systems will usually provide this. Preferably, the air should be directed to the front and torso of the body. Impingement on the back of the head, neck, and shoulders should be minimized. The supplied air may require tempering in winter to raise it to an acceptable temperature. However, in areas of high heat load, the temperature of the air supplied during the winter may have to be lower than room temperature to provide adequate relief for the worker.

People vary considerably in their tolerance to air motion, temperature, and humidity, and this tolerance varies with the season. It is essential, therefore, that the air supply outlets for most local relief ventilation systems be adjustable in direction, and permit reduction in outlet velocity. A level of air motion which feels comfortable and refreshing in hot weather may feel disagreeable and drafty in the winter.

Types and Design Requirements of Systems

The supply air can be provided by local man-cooling fans; by outdoor air introduced directly or after dehumidification or cooling (evaporative or mechanical); and by combinations of outdoor and recirculated air either direct or after conditioning, as required.

Local man-cooling fans should be used with caution other than in light heat-load areas where the ambient temperature is below the skin temperature. In particular, where there is an elevated ambient temperature with or without high radiation load, the high velocity may add considerably to the convective heat load and thus seriously increase the demand for sweating and evaporative cooling.

A relief system employing outdoor air is to be preferred over man-coolers and will provide excellent relief in many industrial areas. However, when the outdoor air temperature exceeds the skin temperature, the direct supply of outdoor air is obviously reduced in effectiveness. Such a system is properly used only in geographical areas where the periods of hot weather are of short duration.

In geographic areas where outdoor humidities do not exceed 50 percent relative humidity at high daytime temperatures an evaporative cooling system offers greater relief for the worker in that the discharge air temperature can be lowered (within five degrees of the wet-bulb temperature) to obtain adequate convective body cooling. The sensible heat gain by the discharge air (through mixing) in a properly designed system will be sufficient to reduce the relative humidity (and vapor pressure) of the supply air and thus permit the necessary evaporative loss from the worker's skin. Generally the supply of evaporatively cooled air should not exceed 20 to 50 percent of the total ventilation through the building. So limited, the relative humidity will be kept low enough to avoid distress to the workers and rusting of equipment under most weather conditions in the United States. For information on the design of evaporative cooling systems, see References 5 and 6 and Chapter 41.

An air supply with mechanical refrigeration offers the greatest relief. Such systems are expensive in first cost and this has retarded their use. However, air supply with mechanical refrigeration is finding greatly increased use in precision work and testing areas, in areas requiring constant ambient conditions for product uniformity or control, and where the increased efficiency of the worker is reflected in a reasonable return on the investment.

It is essential that the outdoor air, (with or without cooling) be brought as directly as feasible to the proximity of the work station. Impingement upon hot equipment or mixing with hot ambient air should be minimized. Supply ducts passing through hot areas should be insulated. The use of aluminum ducts will minimize heat gain from radiant sources. For large work areas provided with a high rate of ventilation the local relief can best be obtained by locating the outlets as close to the floor as possible, consistent with the work and structural interferences.

Design of Outlets for Local Relief

In the design of outlets for local relief it is of great importance to consider the following: location, discharge velocity, discharge volume, and control of direction. The influence of these items will be discussed in the paragraphs which follow.

Location. The outlets should be kept as close to the worker as possible in order to minimize mixing with the warmer air in the space. In most areas the outlets can and should be brought down to the 7-ft level. Outlets at floor level can be used with success in many cases.

Discharge Velocity. The discharge velocity may be as high as necessary to obtain the desired velocity at the work station, as outlined above. Outlet velocities of 3000 to 4000 fpm may be necessary for remotely located outlets. Velocities of 1000 to 2000 fpm are the most frequently used for low outlets (at the 7-ft level). When the supply air is cooled, the velocity through an outlet directly at or over the worker must be kept low (around 50 fpm). It should be kept in mind that these recommended velocities are for conditions of maximum heat load. For more moderate weather and ambient conditions the workers will desire to reduce the velocities. Outlet dampers for velocity control (in the direction of the worker) should always be provided. The control must be designed so as not to reduce the ventilation for the space.

Discharge Volume. The outlet volume required will vary widely, depending upon whether the system is designed to provide highly localized *spot cooling* or is to provide general ventilation throughout a sizeable work area. Generally 1500 to 2000 cfm per station will be adequate for moderate loads, and 3000 cfm per station for higher loads such as at hot metal furnace stations. With remote outlets large air volumes are required to insure adequate relief because of the mixing of the supply air with the warmer surrounding air through which it is projected. The air stream from a large outlet will maintain an appreciable core of air at the original supply air temperature for a considerable distance from the outlet. Small outlets and slot outlets have small cores which are rapidly dissipated through induction. In small enclosures or semi-enclosures (shields against radiant heat, for instance) perforated panel supply outlets are very effective for mechanically cooled installations, because of their low induction characteristics. For further information on outlet design and the throw and induction characteristics, see Chapter 20.

Control of Direction. With very few exceptions, directional outlets are necessary in order to maintain ventilation or make-up air to the space even when the workers do not wish to have the air directed into their work zones. In this way, the air can be directed down in the summer when it is needed, and up in the winter for ventilation, heating, and make-up purposes. It will be possible, too, to direct the air toward one or another work station as needed. From the production standpoint, directional control may be necessary to direct the relief ventilation so as not to disturb the product or upset the performance of local exhaust hoods.

Types of Outlets for Local Relief

A few of the different types of outlets are shown in Fig. 3. In most cases, volume control is highly desirable. Directionalizing and damper control should be designed for easy adjustment from the floor by chain, sash cord, or pole. Where

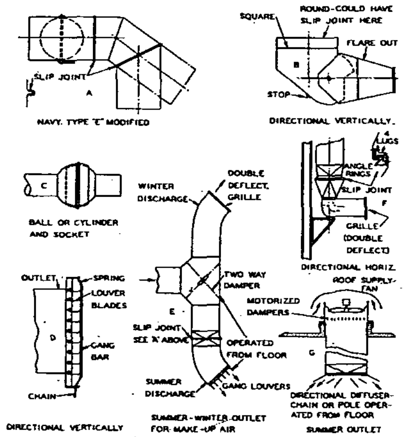

Fig. 3 . . . . Directional Outlets for Spot Cooling

a constant total volume of supply make-up air must be maintained, an outlet similar to *E* will permit volume adjustment to the *work zone* without reducing the total air supply to the building area. A double deflection grille is available with gang-operated, horizontal face bars (similar to *D*) to accomplish the desired objective by directing the air down to the work zone or toward the ceiling. Such a grille could be installed on outlet *F*. Outlets *A*, *B*, and *C* could be used without dampers for these applications. An inexpensive means of supplying summer relief air is shown in *G*. Easily-adjusted diffusers, which will provide a flat or down-blast air discharge pattern, are available.

Where overhead installations are not possible because of structural interferences or other difficulty, outlets near the floor may be used. These may be in the form of grilles located in pilasters, control panels, tables, equipment, or in the floor itself. Such outlets have been quite successful in welding and foundry areas and at the work locations in kitchens.

CONTROL OF ENVIRONMENTAL GASES AND VAPORS, DUSTS, AND FUMES

In general, the systems for the control of these atmospheric contaminants in industrial plants will be of three types:

1. *Local exhaust systems* will be indicated where the contamination originates at concentrated areas and is characterized by low or imperceptible air motion, or where the contaminant is a dust, mist, or fume requiring a capture velocity exceeding 25 fpm. Design of this type system is discussed in Chapter 52, and will not be further treated in this chapter.

2. A system employing the *dilution* method will usually be indicated where the contamination originates at scattered points dispersed generally throughout the area.

3. Combination of local *exhaust* and *dilution* methods is often economical, since well designed exhaust hoods or openings, removing from the space that portion of the contamination load which is susceptible to such treatment, will often reduce greatly the air volumes required for dilution purposes. The choice of the type of system should be made on the basis of economic comparisons.

Design of Dilution Systems

The first step in the design of a system employing the dilution method is to determine as exactly as possible the nature and extent of the contaminating load. This will often be difficult, and may require construction of pilot production models. Often, however, the required data will be available from production records, showing the weight or volume rate of loss of the contaminating agent to the atmosphere, or it may be estimated from parallel operations in other plants, or by applying experienced engineering judgment. However obtained, the determination of the nature and magnitude of the contaminating load is an indispensable step in the proper design of the corrective system. Designs based on number of air changes per hour, or other rule-of-thumb methods, are hopelessly inadequate, and lead either to unsuccessful operation or to excessive and unnecessarily high cost of installation.

1. *Gases and Vapors.* Once having established the nature and magnitude of the contamination load, it is rarely necessary to completely remove contaminating agents from the atmosphere. For cases involving diffusible vapor or gas contaminants, maximum allowable concentrations (MAC) of commonly encountered gases and vapors have been established, and these data are tabulated in Chapter 7. From these data, and the previously established rate of addition of the contaminant to the space, the volume of air required to dilute the addition to a tolerable level can be calculated by the equation:

$$Q_a = \frac{Q_c \times 10^6}{(MAC) - (SAC)} \qquad (9)$$

where

Q_a = quantity of air circulated, cubic feet per minute.
Q_c = rate of generation of contaminant, cubic feet per minute.
(MAC) = maximum allowable concentration, ppm by volume.
(SAC) = concentration in supply air, ppm by volume.

The rate of generation of the contaminating vapor will often be available as a *weight or volume* of liquid evaporated into the space per unit time. These may be converted to the units of Equation 9 by applying the principle that a pound-mol of a