

30. *Vane Ratio*: The ratio of depth of vane to minimum width between two adjacent vanes.

STANDARDS FOR SATISFACTORY CONDITIONS

The object of air distribution in warm air heating, ventilating, and air-conditioning systems is to create the proper combination of temperature, humidity, and air motion in the occupied zone of the conditioned room (floor to 6 ft above floor level). To obtain comfort conditions within this zone, standard limits have been established as acceptable *effective temperatures*. This term comprises air temperature, motion, humidity, and their physiological effect on the surface of the human body. Any variation from accepted standards of one of these elements may result in discomfort to the occupants. The same effect may be caused by lack of uniformity of conditions within the space or by excessive fluctuation of conditions in the same part of the space. Such discomfort may arise due to excessive room air temperature variations (horizontally, vertically, or both), excessive air motion (draft) failure to deliver or distribute the air according to the load requirements at the different locations, or too rapid fluctuation of room temperature or air motion (gusts).

The effect of air motion has been investigated at Case Institute of Technology.¹ The comfort criteria used by these investigators are of interest. Draft was defined as any localized feeling of coolness or warmth of any portion of the body, due to both air movement and air temperature, with humidity and radiation considered constant. The warmth or coolness of a draft was measured above or below the controlled room condition of 76 F dry-bulb temperature at the center of the room, 30 in. above the floor, and air moving at approximately 30 fpm.

To define the difference Δt in effective temperature between any point in the occupied zone and the control condition, the investigators used the following equation proposed by Rydberg and Norback:²

$$\Delta t = (t_a - 76) - 0.07(V_a - 30) \quad (1)$$

where

t_a = local air stream dry-bulb temperature, Fahrenheit.
 V_a = local air stream velocity, feet per minute.

Equation 1 takes into account the feeling of coolness produced by air motion. Equation 1 shows that a one degree temperature change is equal to a 15 fpm velocity change, and is used to establish the neutral line in Fig. 1. In summer, the local air-stream temperature t_a is below the control temperature. Hence, both temperature and velocity terms are negative when the velocity V_a is greater than 30 fpm, and both of them add to the feeling of coolness. If, in winter, t_a is above the control temperature, any air velocity above 30 fpm will subtract from the feeling of warmth produced by t_a . Therefore, it is usually possible to have zero difference in effective temperature between location x and the control point in winter, but not in summer.

Houghton³ presented data which make it possible to interpret statistically the percentage of room occupants who will tolerate or object to a given draft condition. Fig. 1 presents Houghton's data in the form used in Reference 1.

Although the percentage of room occupants who will object to certain conditions may change over a period of years, Fig. 1 gives valuable insight into the possible objectives of room air distribution. The data show that a person will tolerate higher velocities and lower temperatures at ankle level than at neck level. They also prove that conditions in the occupied zone are more critical at seating level than they are near the floor.

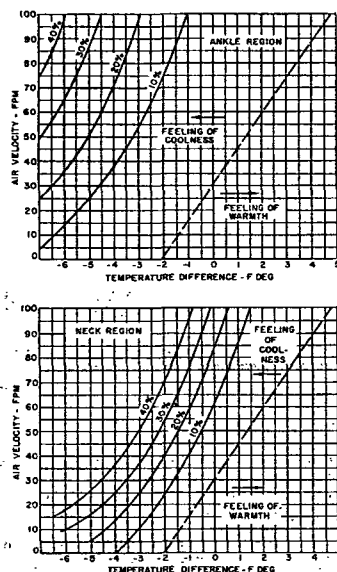


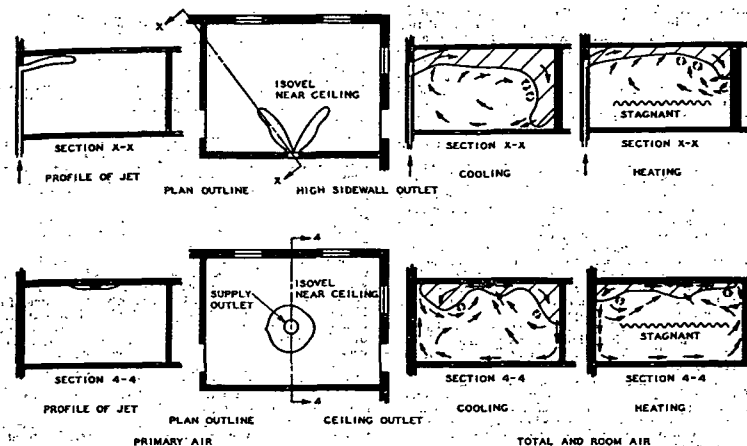
Fig. 1 . . . Percentage of Occupants Objecting to Drafts in Air-Conditioned Rooms

With a one degree temperature depression, a velocity of 15 fpm produces a feeling of warmth, whereas, velocities of 40 and 60 fpm would be acceptable to 90 and 80 percent of the occupants, respectively. Room air velocities from 20 to 50 fpm have been considered as a criterion for room air motion, however, Fig. 1 shows that even higher velocities may be acceptable to a large percentage of the occupants.

In the following section, it will be shown that, during heating, a temperature gradient exists in a stagnant zone with air velocities generally between 15-20 fpm. Since the stagnant zone occurs from the floor or ankle level up, Fig. 1 shows that 80-90 percent of the occupants will accept an ankle-to-sitting-level gradient of 3.5 to 4 F deg during heating. The following section also indicates possible regions of high room air velocities with various outlets and the later sections on jets give data to calculate the magnitude of the air velocities. With this information, Fig. 1 permits an evaluation of the acceptability of the air distribution.

Reference should be made to Chapter 7, Physiological Principles, for information on effective temperature and comfort lines, and to Chapter 14, Sound Control, for acceptable room noise levels and noise generated by air outlets. Material in Chapters 21 and 24 to 28 in the 1964 GUIDE AND DATA Book deals with the health, safety, and efficiency of workers, and with temperature and humidity requirements for products and manufacturing processes.

Space Air Distribution



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Fig. 2 . . . Air Motion Characteristics of Group A Outlets

PRINCIPLES OF AIR DISTRIBUTION

Conditioned air is supplied to air outlets at temperatures and velocities which differ greatly from those in the occupied zone of the room. Proper air distribution, therefore, calls for (1) entrainment of room air by the primary air stream outside of the zone of occupancy in order that air motion and temperature differences will be reduced to acceptable limits before the air enters the occupied zone, and (2) counteraction of the natural convection and radiation effects within the room.

The complexity of practical room air distribution problems is due to innumerable variations in building construction, system design, and operating requirements, and makes the exploration of the basic character of air distribution imperative. The theory of room air distribution is not complete but a considerable fund of knowledge supported by experimental guidance is available for the solution of many air distribution problems.

Many heating and cooling tests at the University of Illinois Engineering Experiment Station⁴ have resulted in the formulation of certain principles of outlet performance, which provide an important guide for solving air distribution problems involving (a) proper selection and application of supply and return intakes, (b) selection of pertinent indices of air distribution, (c) elimination of trouble spots in existing systems, (d) comparison of air distribution field studies, (e) evaluation of other factors which may affect air distribution, such as loading and blower operations, (f) evaluation of particular air distribution devices prior to installation, and (g) design of supply outlets.

Types of Air Outlets. Supply outlets may be classified as sidewall, ceiling, baseboard, or floor outlets, according to their location in the room. However, since there are numerous

outlet designs, outlets are often better described by their construction features. (See Chapter 30, Air Diffusing Equipment.)

Outlet Performance

In the outlet performance tests at the University of Illinois,⁴ the investigators used five groups of outlets:

1. Group A. Outlets mounted in or near the ceiling and discharging the air horizontally.
2. Group B. Outlets mounted in or near the floor and discharging the air vertically in a non-spreading jet.
3. Group C. Outlets mounted in or near the floor and discharging the air in a vertical spreading jet.
4. Group D. Outlets mounted in or near the floor and discharging the air horizontally.
5. Group E. Outlets mounted in or near the ceiling and projecting the primary air vertically. (This group was tested but not reported in Reference 4.)

Analysis of outlet performance was based on primary air pattern, total air pattern, stagnant air layer, natural convection currents, return air pattern, and room air motion.

Figs. 2 to 6 show the air motion characteristics of the five outlet groups. The general principles of air distribution emphasized by these tests which should be kept in mind while reviewing Figs. 2 to 6 are:

1. The primary air, shown by clear envelopes in Figs. 2 to 6, from the outlet down to a velocity of about 150 fpm can be treated analytically and shows the same characteristics for both heating and cooling.
2. The total air, shown by diagonally lined envelopes in Figs. 2 to 6, is still influenced by the primary air and is relatively high velocity air, but less than 150 fpm, with air temperatures generally within 1 F deg of the room temperature. The total air is influenced by the environment, and, thus, tends to drop during cooling and tends to rise during heating. The total air is not subject to precise analytical treatment.