

where the period of occupancy is short, the contrast between outdoor and indoor air conditions becomes the deciding factor in regards to the temperature and humidity to be maintained. The object of cooling such places in the summer is to provide sufficient relief from the heat without causing sensations of chill or intense heat on entering and leaving the building.

The Comfort Chart has proved one of the most valuable tools of the heating and ventilating engineer. Research in other laboratories⁴³ has shown somewhat different quantitative relationships but these are easily accounted for by differences in metabolic activity and clothing. It appears from this other work that the Comfort Chart may perhaps exaggerate somewhat the influence of relative humidity at low temperatures and underestimate it at high temperatures; but the chart gives an essentially correct picture of those relations which exist where radiant influences and high air movement are not important factors.

PHYSIOLOGICAL OBJECTIVES OF HEATING AND VENTILATION

Aside from the removal of toxic fumes and dusts from heating appliances and industrial processes, the chief task of the heating and ventilating engineer is to keep his clients warm in winter and cool in summer.

For the normally vigorous person, normally clothed, and at rest, an air temperature of 65 F should be provided at knee-height, 18 in. in order to prevent chilling of the legs and feet. With some heating systems, this will correspond to 70 F at a 5 ft height. Air temperature may be increased or decreased in order to compensate for deviations of *mean radiant temperature* above or below air temperature.

In rooms occupied by persons of sub-normal vitality, knee-height temperatures must be higher than 65 F. Since dwellings are designed for occupancy by old people and children, the heating system should be able to provide a temperature of 70 F at knee-height under ordinary winter conditions.

The maintenance of such conditions as these in winter depends on three major factors, the heat produced in the occupied space, the heat absorbed from the sun and the heat loss through the walls, floor and ceiling of the structure to cold air and earth. Taking these up in the order in which they occur, in planning a new structure it is essential to remember the important effect of orientation and fenestration of the building with respect to the absorption of radiant heat from the sun. It has recently been shown that, in the vicinity of New York effective sun-heat on a wall facing south is almost five times as great in winter as in summer, but on a wall facing west-north-west it is six times as great in summer as in winter⁴⁴. The orientation of the same one-story house (in a laboratory model) was changed from a position in which its principal rooms faced northwest to a position in which these rooms (with rearranged and slightly increased fenestration) faced west of south. This change decreased average summer sun-heat to one-ninth and increased average winter sun-heat to fourfold of its value with the original orientation.

⁴³Loc. Cit. Note 9.

⁴⁴Solar Radiation as Related to Winter Heating in Residences, by H. N. Wright (Report of John B. Pierce Foundation, January 20, 1936).

The choice between the various methods of heating depends, of course, on many engineering and other factors. From the standpoint of human health and comfort, however, it is important to minimize floor-ceiling differentials as far as possible to avoid hot heads and cold feet. Furthermore, when the problem is a heating one, low air movement is desirable, since air temperature must be raised to balance the cooling effect of air motion.

Where occupants are closely aggregated, a new problem comes in, the removal of the excess heat produced by the human body itself. If the temperature of such a space be correctly adjusted when the occupants enter, it will steadily rise during the period of occupancy as a result of the heat produced by the occupants in the process of metabolism. Of the 400 Btu given off in metabolism 100 would perhaps be lost in evaporation, leaving 300 Btu per person per hour to warm the air. In a room containing many persons, the effects of this body heat can be neutralized by outside air without producing unpleasant and dangerous drafts on those near the windows or other inlets. The supply of air should be so tempered as to avoid drafts but in an amount and at a temperature which will remove the sensible heat produced by human metabolism. With no heat loss through walls (as in an interior auditorium) this will require 28 cfm of air per person with admitted air at 60 F and a maximum figure of 70 F, for air leaving the room. Under practical conditions, with one or more cold walls, and a room containing a moderate number of occupants and ample cubic space, window ventilation with deflectors and a gravity exhaust duct may suffice. With crowded rooms, and with any rooms containing 50 or more occupants, forced ventilation will be essential.

SUMMER COMFORT

The problem of keeping cool in summer is physiologically as important as keeping warm in winter. In summer the relative humidity of the atmosphere is of importance, along with air temperature, air movement, and wall temperature. There is no very practical method of cooling walls, but summer comfort can be promoted by modifying either one of the other three factors involved.

Increase of comfort by air movement can be effected in two ways. The first of these is promotion of natural circulation by cross or through ventilation; and here the architect is responsible for providing room planning and fenestration which will make such natural ventilation possible. In the lowest cost housing this should be considered as essential.

The direct control of air temperature and humidity is, of course, the ideal solution where the cost of a complete air conditioning equipment can be met. Where this objective is attained, there are two schools of thought concerning the relation between temperature and humidity to be maintained. For a given effective temperature some engineers favor comparatively low temperature with a high humidity as this results in a reduction of refrigeration requirements. Preliminary experiments at the A.S.H.V.E. Laboratory⁴⁵ would seem to indicate no appreciable impair-

⁴⁵A.S.H.V.E. RESEARCH REPORT No. 1035—Comfort Standards for Summer Air Conditioning, by F. C. Houghten and Carl Gutberlet (A.S.H.V.E. TRANSACTIONS, Vol. 42, 1936, p. 215). A.S.H.V.E. RESEARCH REPORT No. 1055—Cooling Requirements for Summer Air Conditioning, by F. C. Houghten, F. E. Giesecke, C. Tasker and Carl Gutberlet (A.S.H.V.E. TRANSACTIONS, Vol. 43, 1937, p. 145.)