in summer as in winter[46]. 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.

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 congregated, a new problem comes in, the removal of the excess heat and water vapor produced by the human body. If the temperature of such a space be correctly adjusted when the occupants enter, it will rise steadily during the period of occupancy as a result of the heat given off by the occupants. Of the 400 Btu per hour given off 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 admission of outside air without producing unpleasant and dangerous drafts on those near the windows or other inlets. The supply of air before it reaches the occupant should be so tempered as to avoid drafts but in an amount and at a temperature which will remove the sensible heat produced by metabolism. With no heat loss through walls (as in an interior auditorium) this will require 28 cfm of air per person when admitted at 60 F, and an average temperature 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 great 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 any one of the other three factors involved.

Increase of comfort by air movement may be had by the promotion of natural circulation by cross or through ventilation; and here the architect is responsible for providing fenestration which will make such natural ventilation possible. In the lowest cost housing this should be considered as essential.

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

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. Laboratory[47] would seem to indicate not much impairment of comfort with relative humidities of 70 per cent and somewhat higher, provided the effective temperature is between 70 and 73 deg. Until this subject is fully investigated it is desirable not to exceed 70 per cent and in general relative humidities of 60 per cent or less give more satisfactory results[48].

The second school favors a higher dry-bulb temperature, according to the prevailing outdoor dry-bulb, with a comparatively low humidity (well below 50 per cent), the main purpose being an assumed reduction in temperature contrasts upon entering and leaving the cooled space and to keep the clothing and skin dry. This second scheme requires more refrigeration with the present conventional type of apparatus.

INFLUENCE OF HUMIDITY

The limitation of the comfort zones in Fig. 6 with respect to humidity is not final but must be adhered to closely. Relative humidities below 30 per cent may prove satisfactory from the standpoint of comfort. In mild weather comparatively high relative humidities seem to be entirely feasible, but in cold weather they are objectionable on account of condensation and frosting on the windows. Information on this subject is given in Chapter 4.

As to the effects of dryness of the air, *per se*, and irrespective of thermal effects, there is a common belief that dry air in itself exerts a harmful effect upon the skin and mucous membranes; but there is no convincing evidence that the increase of atmospheric moisture which can practically be introduced by humidification into the air of cool occupied rooms has any effect upon health and comfort. All controlled experiments on this point have yielded negative results; and the respiratory membranes of industrial workers exposed to hot moist air are distinctly abnormal compared with those of workers exposed to hot dry air[49].

For the premature infant, a high relative humidity of about 65 per cent is demonstrably beneficial to health and growth[50] until the infants reach a weight of about 5 lb. No such clear-cut evidence exists in the case of adults. In the comfort zone experiments of the A.S.H.V.E. Research Laboratory, the relative humidity was varied between the limits of 30 and 70 per cent approximately, but the most comfortable range has not

[47]A.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).

[48]Loc. Cit. Note 35.

[49]Loc. Cit. Note 39.

[50]Loc. Cit. Note 42.