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 winter[44]. 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 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,

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

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. Laboratory[45] would seem to indicate no appreciable impairment of comfort with relative humidities as high as 80 per cent, provided the effective temperature is between 70 and 75 deg.

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 to reduce 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.

In connection with summer cooling mention should be made of the danger of over-doing it. Possible impairment to health may have resulted from the sharp contrast between air conditioned trains and the outside atmosphere in the early days of this practice. Current practice in theaters, restaurants, etc., follows a schedule similar to that shown in Table 5. This schedule should be used with considerable judgment, depending on the occupancy and local climatic conditions. There are some indications that a definite indoor effective temperature may be applicable throughout the cooling season, but other observations seem to show that changing indoor conditions are desirable with violently changing outdoor weather conditions. It is questionable whether entirely satisfactory air conditions could be adduced for practical use to meet the changing requirements of patrons from the time they enter to the time they leave a cooled space. Too many uncontrollable variables enter into the problem. Work now going on at the A.S.H.V.E. Research Laboratory and other institutions may throw considerable light on this complex problem.

For cooled banks and stores where the customers come and go, spending but a few minutes in the cooled space, observations indicate a schedule about 1 deg dry-bulb of effective temperature higher than that shown in Table 5. Laboratory experiments with exposures of 2 to 10 min indicate temperatures 2 to 10 F higher than those in Table 5, but with much lower relative humidities.

It should be kept in mind that southern people, with their more sluggish

[45]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.)