Table 5 .... Comparison of Comfort Ranges With Zone of Thermal Neutrality

Investigators	Effective Temperature: Optimum Line	Effective Temperature: Range	Operative Temp Range	Remarks
Comfort Zone				
Houghten and Yaglou	66	63–71	...	Winter nonbasal; at rest, normally clothed. Men and women.
Yaglou and Drinker	71	66–75	...	Summer nonbasal; at rest and normally clothed. Men.
Yaglou	72.5	66–82	...	Entire year; nonbasal; at rest and stripped to waist. Men.
Keeton et al	75	74–76	...	Entire year; basal, nude. Steady state (9 hr exposure). Men and women.
Zone of Thermal Neutrality				
DuBois and Hardy	75	73.2–76.9	...	Basal; nude; men.
	71.8	64.8–76.0	...	Basal; clothed; men.
Winslow, Herrington, and Gagge	...	....	84.0–87.8	Nonbasal; at rest; nude; men.
	...	...	74 –84	Nonbasal; at rest; clothed; men.

It may be seen in Fig. 12 that line 3, slightly cool, is vertical, indicating that, at this temperature level, relative humidity has no effect on the feeling of warmth. Line 4, the comfortable level, is vertical below 70 percent relative humidity and shows only slight effect of humidity above 70 percent. Field tests[42] have also shown that, at comfortable temperatures, relative humidities below 70 percent have no influence on human comfort. Lines 5 and 6 indicate definite effects of humidity on the feeling of warmth, with the greatest effects occurring at the higher relative humidities. As conditions become warmer and the control of body temperature becomes increasingly dependent upon the evaporation of perspiration from the body surfaces, relative humidity would be expected to become an increasingly important factor in determining the feeling of warmth.

It is evident from Fig. 12 that the effective temperature lines predict a considerably greater effect of relative humidity on the feeling of warmth than do the newer lines. This does not mean that either set of lines is in error. Instead, it may be explained by the fact that they apply to different conditions. The effective temperature lines indicate a person's feeling of warmth *immediately* after entering the conditioned space, while the solid lines of Fig. 12 are for people who have been in the conditioned space for approximately three hours and are in equilibrium with the environmental conditions. It has been suggested that the overestimation of humidity effects can be explained largely by the phenomena of adsorption and desorption of moisture on the exposed skin and clothing, and by failure to take adaptation into account.[43]

As stated previously, the comfort chart indicates optimum effective temperatures for winter and summer of 68 and 71 F, respectively. The more recent studies[42] were carried on during both the winter and summer, with the subjects wearing the same weight clothing during both seasons. The solid lines given in Fig. 12 show averages of summer and winter data. Line 4 indicates the optimum condition at approximately 77.5 F. Separate analysis of the winter and summer data indicated a difference of about 1.2 F deg. Thus, the optimum winter and summer temperatures would be approximately 77 and 78 F, respectively. This summer temperature is in approximate agreement with the effective temperature chart, which would indicate about 77.5 F at 40 percent relative humidity, or 76.5 F at 50 percent. The agreement is not as good for winter. At 30 percent relative humidity, the effective temperature chart shows an optimum winter temperature of just under 75 F.

The desire for higher temperatures, particularly for the winter season, is probably a continuation of a long-established trend. Research prior to 1932[39] indicated that the optimum winter conditions would be found along the 66 ET line, and it was so noted on the early ET charts. Tests at the ASHRAE Laboratory in 1941[46] indicated a shift of the winter comfort line to 67.5 degrees, and still later studies[47] located the winter comfort line at 68 ET. This increase in optimum temperature is probably due primarily to the progressively lighter clothing being worn in winter.

Radiation from occupants to room surfaces, and between the occupants, has an important bearing on the feeling of warmth, and may alter to some measurable degree the optimum conditions for comfort previously indicated. Since the mean radiant temperature of a space is affected by cold walls and windows, as well as by the warm surfaces of heating units placed within the room or embedded in the walls, these factors must be compensated. Likewise, in densely occupied spaces, such as classrooms, theaters, and auditoriums, temperatures somewhat lower than those indicated by the comfort line may be desirable because of counter-radiation between the bodies of occupants in close proximity to each other. Such radiation will also elevate the mean radiant temperature of the room.

Many field studies[47] have been made to determine the optimum indoor effective temperature for both winter and summer in several metropolitan districts of the United States and Canada, in cooperation with the managements of offices employing large numbers of workers. Some of the results of these studies for the summer season are shown in Fig. 13. On the whole, women of all age group studies prefer an effective temperature for comfort 1.0 degree higher than men. All men and women over 40 years of age prefer a temperature 1 deg ET higher than that desired by persons below this age. The persons serving in all of these studies were representative of office workers dressed for air-conditioned spaces in the summer season, and engaged in the customary office activity.

The curves of Fig. 13 indicate that in the warmer areas of the country the optimum effective temperature for summer cooling is approximately 3 degrees higher than in the northern cities. Variations in sensation of comfort among individuals may be greater for any given location than variations due to a difference in geographical location. Available information indicates that changes in weather conditions over a period of a few days do not alter optimum indoor temperature.

Laboratory studies of Keeton and others,[48] and years of practical field experience, show that the adjustments in the temperature regulatory mechanisms of healthy people on entering and leaving air-conditioned spaces are prompt, easy, and safe. The sudden sensation of coolness on entering a cooled room from the hot street is associated with sweat on the skin and in the clothing. Several minutes are required for the skin temperature to fall and the free moisture to disappear. Even ambulatory heart patients endure such changes with ease. The use of the word *shock* to describe any part of these adjustments is unwarranted.

Upon leaving an air-cooled space and re-entering a hot atmosphere, sudden warming occurs. Experiments at the ASHRAE Research Laboratory[49] and elsewhere[48] indicated no demonstrable harm to a healthy individual. Adaptation occurs as soon as normal perspiration is established. Mild exercise shortens the adaptation time.

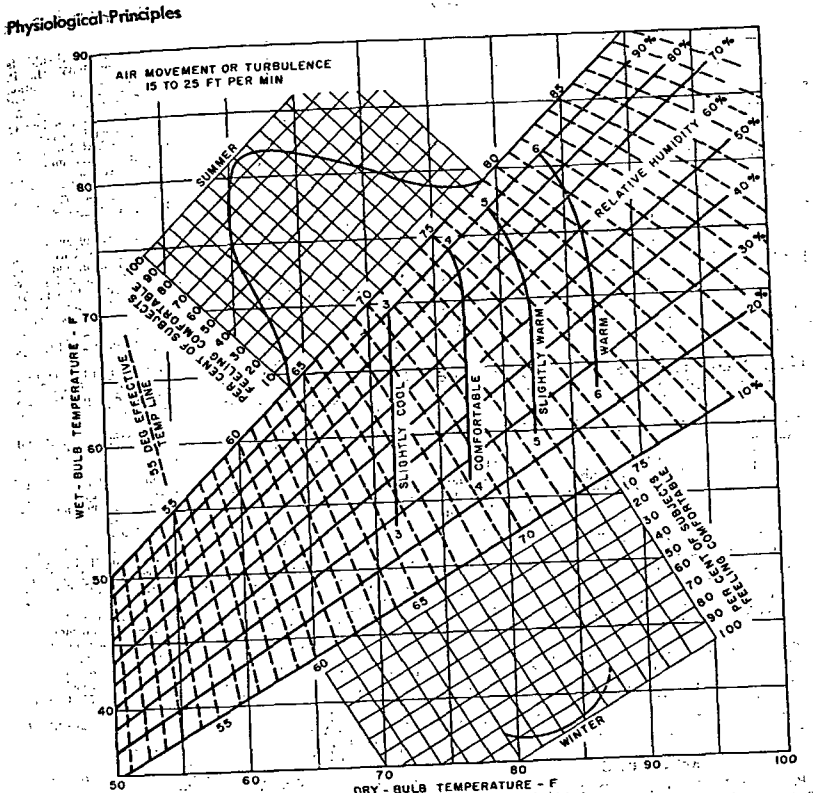

Fig. 12 .... Revised ASHRAE Comfort Chart

Satisfactory comfort conditions for persons at work vary, depending upon the rate of work and the amount of clothing worn. In general, the greater the degree of activity, the lower the temperature necessary for comfort. All of the above discussion regarding effective temperatures and comfort conditions is applicable to persons seated and at rest. However, the results of tests[46] made at the ASHRAE Laboratory in very hot conditions, with subjects doing light work, were in close agreement with the effective temperature chart shown in Fig. 12. Studies were also made at the Society Laboratory with lightly clothed[51] and normally clothed[52] subjects doing heavier work, and effective temperature charts for these conditions are presented in the reference papers. With the higher work rates, the effective temperature lines were found to become more nearly horizontal. Other studies,[53] made with