COMPARISONS OF HEAT STRESS INDEXES
(with applications to indoor room temperatures in winter)

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ABSTRACT

Four heat-related comfort indexes are compared. Temperature and relative humidity (RH) are the primary variables considered. The apparent temperature appears to be the most versatile measure. Inspection of apparent temperature in low ranges indicates that comfort can be increased in cool, heated rooms by increasing RH to moderate levels.

1. DISCUSSION

The heat wave of 1980 resulted in more than 1250 heat-related fatalities (1). In the 40 year period from 1936 to 1975, nearly 20,000 people were killed in the United States by the effects of excessive heat (2). The overall effect of excessive heat on the body is known as heat stress. Important factors contributing to heat stress are: 1. air temperature; 2. humidity; 3. air movements; 4. radiant heat from incoming solar radiation (insolation), bright lights, an oven, stove, or other source; 5. atmospheric pressure; 6. physiological factors which vary among people; 7. physical activity; and 8. clothing.

Of the above factors, temperature and humidity can be controlled by air conditioning. Air movement may be controlled by fans; even a slight breeze is usually effective in reducing heat stress (3). However, at very high temperatures (above about 100F), winds above 10 miles per hour can increase heat stress in a shaded area by adding more heat to the body. Nevertheless, when the body is exposed to direct sunlight the effect of wind is nearly always to reduce heat stress (exposure to full sunshine can increase apparent temperature by 13F). Radiant heating can be mitigated by shielding or by moving away from the source (for example, seeking shade). Atmospheric pressure is not usually a significant factor; however, at very high elevations, decreased pressure (and therefore decreased air supply) can contribute to heat exhaustion.

There are natural limits on how much physical conditioning can alter physiological heat responses. Two obvious physical necessities in reducing heat stress are: getting enough fluids to replace perspiration loss, and reducing physical activity during periods of extreme heat. The choice of clothing can be helpful since absorbent, light-colored materials provide more comfort under hot, humid conditions.

Under normal conditions, temperature and humidity are the most important elements influencing comfort. Research by R.G. Steadman (4) on sultriness assessment led to development of a special index based on human physiology and clothing science. This index is called apparent temperature and is a measure of what hot weather "feels like" to the average person for various temperatures and relative humidities. Fig. 1 gives apparent temperature versus actual air temperature and relative humidity.

As an example of how to read the graph in Fig. 1, an air temperature of 90F, combined with a 60 percent relative humidity, feels like 100F. The general assumptions are that the wind speed equals about 5 to 6 statute miles per hour, pressure is normal sea pressure (about 1013 mb), and there is no significant direct radiant heat source (e.g., the subject is in the shade and not next to a blast furnace). While interpretation of what a given apparent temperature feels like may vary from one person to another, the differences among various apparent temperatures are objective and based on physiological research. At low relative humidities, the apparent temperature will be lower than the ambient air temperature.

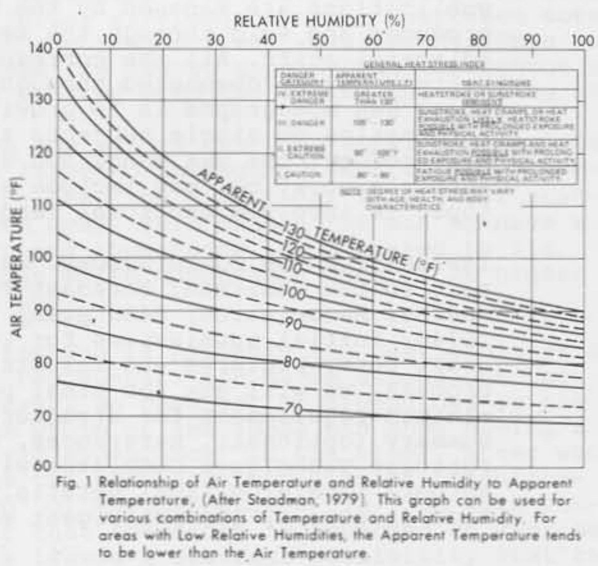

Fig. 1 Relationship of Air Temperature and Relative Humidity to Apparent Temperature, (After Steadman, 1979). This graph can be used for various combinations of Temperature and Relative Humidity. For areas with Low Relative Humidities, the Apparent Temperature tends to be lower than the Air Temperature.

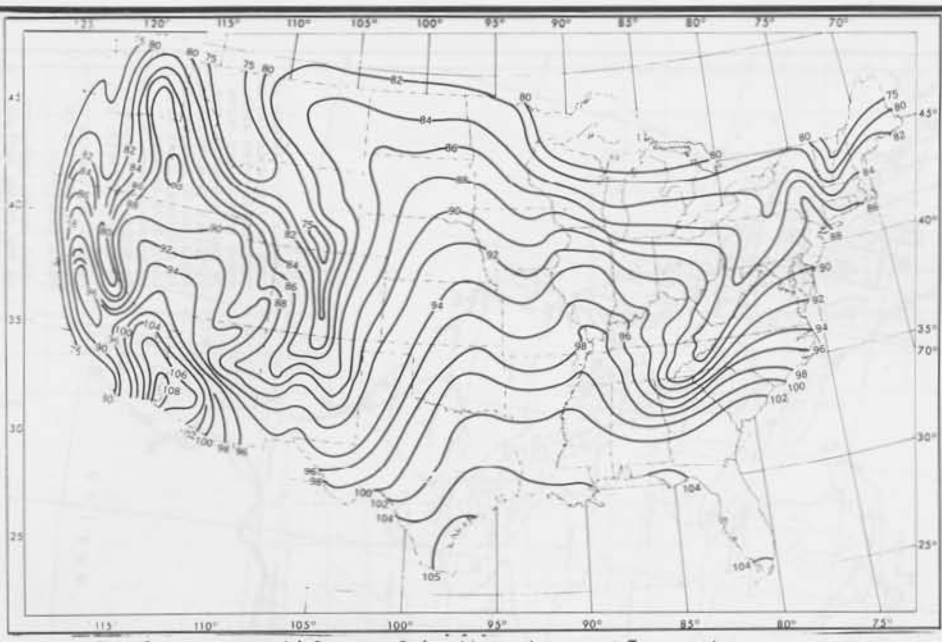

Fig. 2 Average Mid Summer Solar Noon Apparent Temperatures.
(adjusted for Relative Humidity, Wind, and Insolation;
After Steadman (1979) with supplemental data added by NCC).

Fig. 2 is a map of average midsummer (July) apparent temperatures for the contiguous U.S. Adjustment has been made for average wind speed and insolation in addition to relative humidity. Fig. 3 is a map of normal daily maximum temperatures for July without considering relative humidity, insolation or wind.

During periods of heat waves, apparent temperature may be about 15F to 20F higher and can be as much as 30F higher than ambient air temperatures in unventilated city areas, thus approaching or exceeding stroke danger categories, which are listed in Fig. 1.

Steadman's work is the most recent, and probably the most comprehensive, in the heat stress index field. Several earlier efforts contributed to the experience leading up to the development of apparent temperature. Humiture was originated in 1937 (5) with some revision in 1960 (6) and a later adaptation in 1979 (7). While based primarily on experience at Jacksonville, FL, the 1979 version was considered generally applicable to hot, humid weather. A graph of the 1979 version is shown in Fig. 4.

The most familiar heat stress index is probably the discomfort index (8), which came into use in the 1950's. It was renamed temperature-humidity index (THI) and used experimentally by the Weather Bureau in the late '50's (9). THI is not particularly sensitive to small but significant humidity changes (10). It is still sometimes used unofficially in the U.S., but since the discomfort range is so low (70 to 80 in terms of Fahrenheit index values), most of the public do not understand it, and use has been limited. A THI graph appears in Fig. 5. Yet another index, humidex, is shown in Fig. 6 (10). Like humiture, it attempts to employ easily understood values to which nonspecialists can relate. Humidex is very similar to the 1960 version of humiture (6), which is not shown in this report.

Humidex does not appear to be designed for low humidities and seems to be higher than apparent temperature for many ranges. Humiture, on the other hand, tends to read lower than apparent temperature in the lower humidity and temperature ranges. THI is always lower than temperature. Thus, apparent temperature seems to be a reasonable compromise. Indeed, a major virtue of apparent temperature appears to be its applicability over wide environmental range: Temperature from 60F to 122F, Dewpoint up to 88F.

Because of its versatility, apparent temperature can be adapted to wintertime room temperatures and heating requirements. It appears that increasing relative humditiy to moderate levels of about 50 to 60 percent (through use of a humidifier or other means) can increase the apparent temperature to near-ambient values in heated rooms in winter, even at fairly low temperatures such as 65F. This theoretically permits decreased thermostat settings resulting in heating energy savings. The concept is intuitively reasonable if one assumes that increased RH at room temperatures inhibits evaporative body cooling.

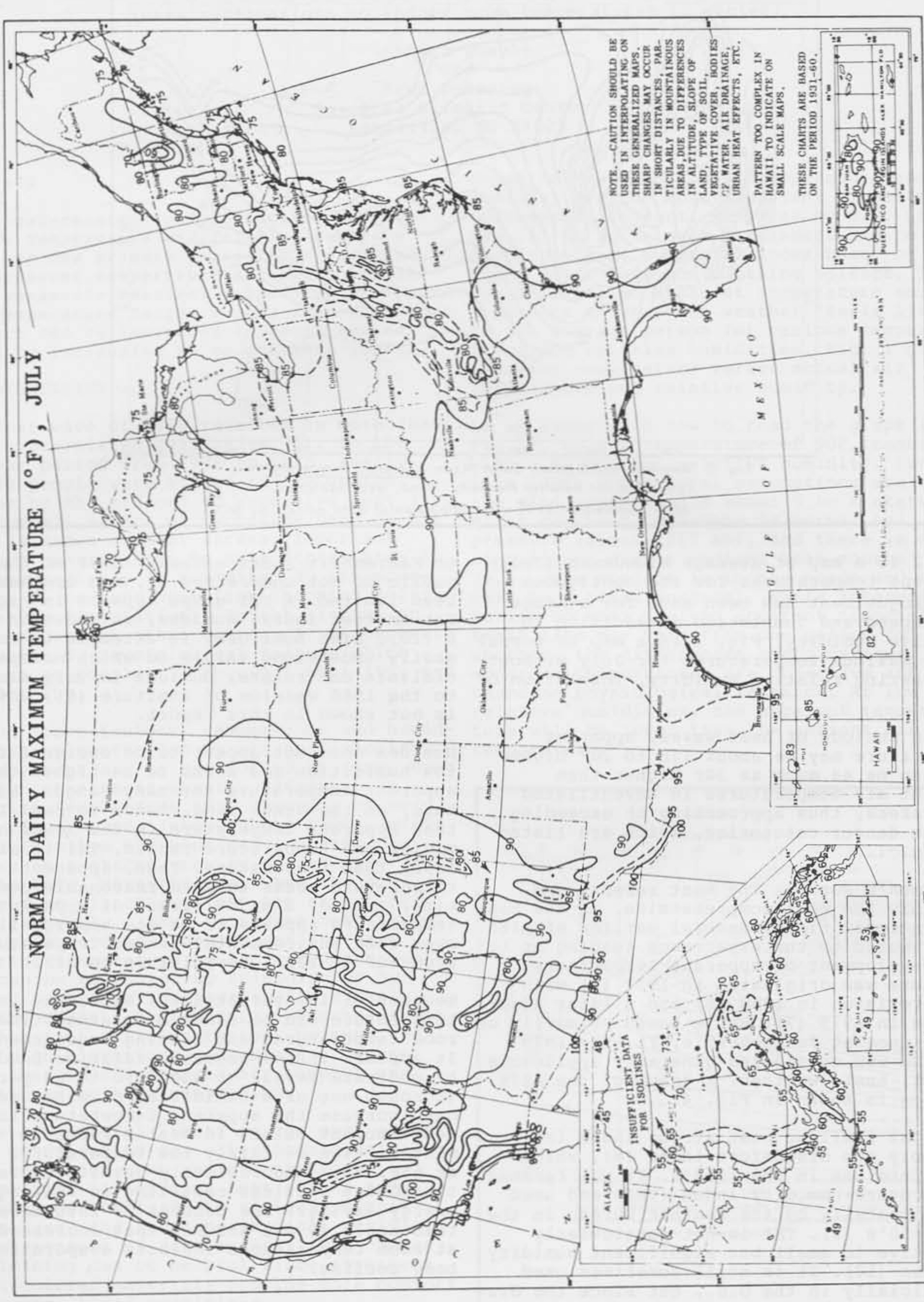
NORMAL DAILY MAXIMUM TEMPERATURE (°F), JULY
NOTE.—CAUTION SHOULD BE USED IN INTERPOLATING ON THESE GENERALIZED MAPS. SHARP CHANGES MAY OCCUR IN SHORT DISTANCES, PARTICULARLY IN MOUNTAINOUS AREAS, DUE TO DIFFERENCES IN ALTITUDE, SLOPE OF LAND, TYPE OF SOIL, VEGETATIVE COVER, BODIES OF WATER, AIR DRAINAGE, URBAN HEAT EFFECTS, ETC.
PATTERN TOO COMPLEX IN HAWAII TO INDICATE ON SMALL SCALE MAPS.
THESE CHARTS ARE BASED ON THE PERIOD 1931-60.
GULF OF MEXICO
INSUFFICIENT DATA FOR ISOLINES
ALASKA
HAWAII

Figure 3.

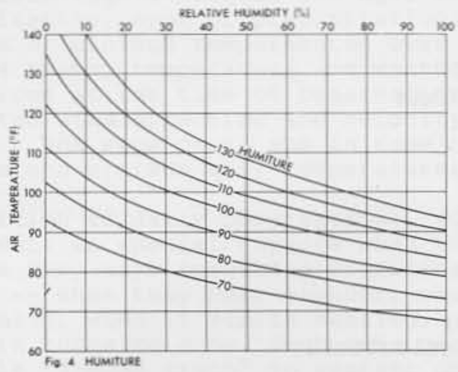

Fig. 4 HUMITURE

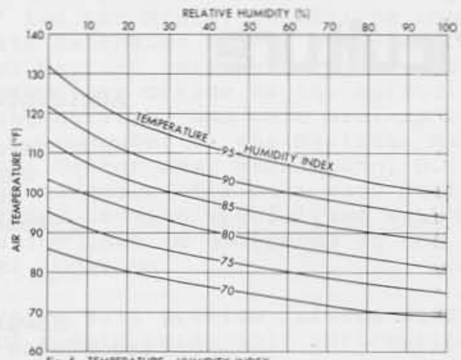

Fig. 5 TEMPERATURE - HUMIDITY INDEX

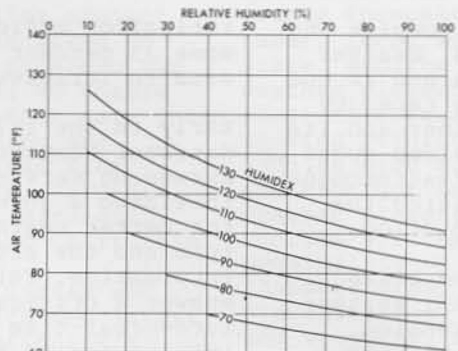

Fig. 6 HUMIDEX

2. SUMMARY, CONCLUSIONS AND ACKNOWLEDGEMENT

Comparisons of the four comfort indexes discussed here indicate that apparent temperature would probably be the best standard, if adoption of such a standard were deemed desirable at this time. It is further concluded that increasing indoor relative humidity to moderate levels for cool, heated rooms in winter is a wise, energy-conscious strategy.

We are indebted to Drs R.G. Steadman and W.J. Koss for their helpful suggestions. Much of the research for this paper was performed during preparation of the NCC Heat Stress brochure (11).

References and Footnotes

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