

THE HUMISERY AND OTHER MEASURES OF SUMMER DISCOMFORT

by

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1. INTRODUCTION

Westerner: "I've been in temperatures near 100 degrees many times back home, but I've never been hotter than I am visiting your 90 degree weather."

Easterner: "It's not the heat, it's the humidity."

The Easterner in this conversation is attempting to explain the Westerner's discomfort by telling why it feels so much hotter than it is. The Easterner's explanation is fairly reasonable as far as it goes, but of course, it does not provide a measurement. How does the Westerner feel

in the Easterner's weather? Suppose it is 90 degrees with a dew point of 77 degrees Fahrenheit (relative humidity, 66 percent)? Does it feel like 95°F, 100°F, 105°F?

A number of attempts have been made to provide such an estimate similar to the way the wind chill provides an estimate of winter discomfort (see Section 3 below). Unfortunately, although the wind chill is firmly established with the public, none of the summer measures have gained anything of the wind chill's general acceptance. It is appropriate to examine the reasons for this situation.

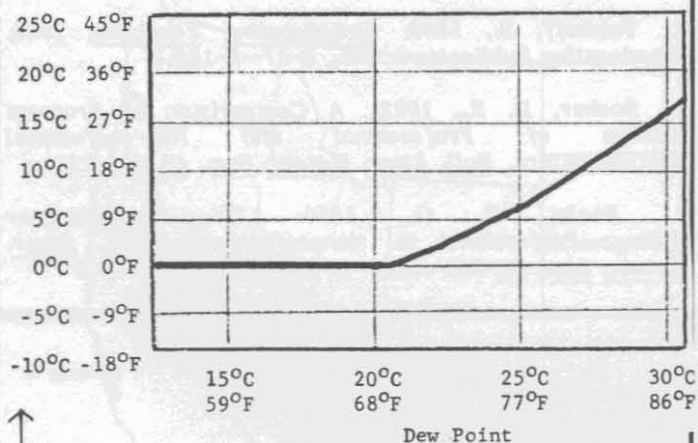
2. WHY THE WIND CHILL INDEX WORKS

Perhaps the strongest appeal of the wind chill index is its intuitive fit with experience. When the wind chill index is -50°F, people feel cold even with heavy clothing. Another characteristic of the wind chill is its simplicity to the public. It is a number that is always lower than the temperature and is identical with the temperature at low wind speeds. A final characteristic is its use of all the factors which both prevail over populated areas and which contribute to discomfort. In this case, there are two: temperature and wind. Perhaps if any of the summer discomfort measures had the same characteristics, they would be equally acceptable to the public.

3. THE SUMMER INDICES

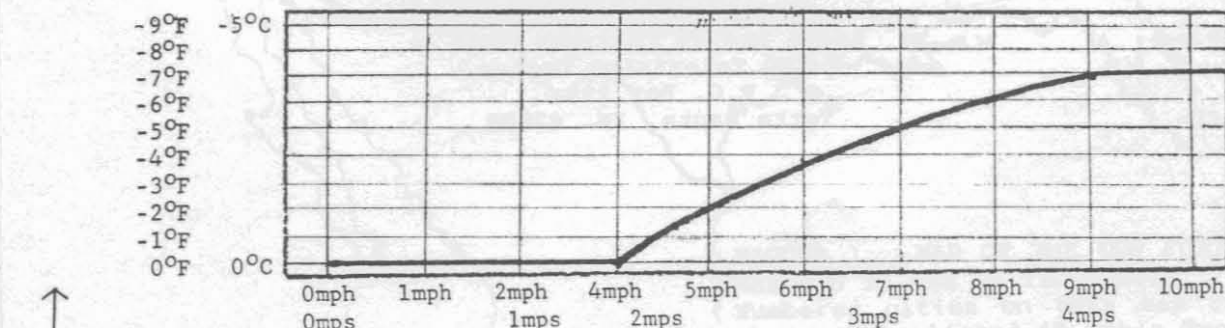
Various summer discomfort measures have been proposed since at least the 1920's.

Figure 1. Humisery Index Adjustment Due to Humidity



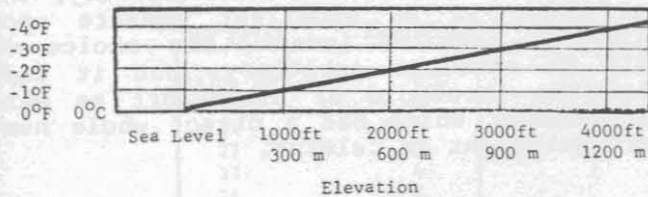
Contribution to Humisery Index

Figure 2. Humisery Index Adjustment Due to Wind



Contribution to Humisery Index

Figure 3. Humisery Index Adjustment Due to Elevation



Contribution to Humisery Index

Considering them one at a time, they are the "temperature-humidity index" (2), the "apparent temperature" (3), and the "Humiture" (4). Comparing them against the "wind chill" index standard will give some idea of their nature.

3.a The Temperature-Humidity Index

This index was the result of experiments which attempted to establish what combinations of heat and humidity gave equivalent feelings of discomfort. Perhaps the greatest barrier to acceptance is its lack of intuitive fit with experience. This index is set up such that at 70°F, few people are uncomfortable and at 80°F, nearly everybody is uncomfortable. The necessity of a double translation from index to percentage of people feeling uncomfortable to personal feeling of discomfort is a severe handicap. The index also does not consider wind or elevation. It continues to register, declining even at very low dew points, way outside the range of usefulness.

3.b The Apparent Temperature

The apparent temperature is the result of experiments and judgments about discomfort based on clothing and physiology. The index also predicts heat stress risk. The intuitive fit of this index is very good; however it does not have a base and thus the apparent temperature occasionally drops below the actual temperature.

A somewhat lesser problem is that apparent temperature is strongly based on relative humidity, a notoriously variable parameter. For example, in the case of the humid day previously noted (90°F temperature, 77°F dew point), a 1 degree decline in temperature will, at that dewpoint, cause more than a 1 percent increase in relative humidity. Because of its variability, relative humidity is considered a poor factor for use in calculating indices.

3.c The Humiture Index

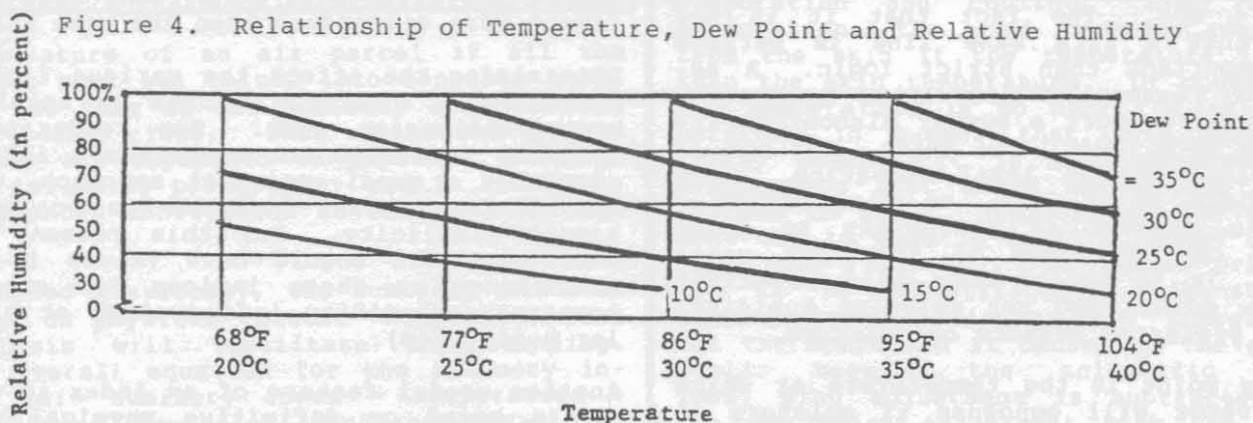
This index also provides a good intuitive fit with discomfort but suffers from the same lack of basis as does the apparent temperature. Its most striking feature is its computational simplicity. One equation of humiture is that it is equal to temperature plus dew point minus 65°F (or 18° Celsius). It frequently is less than temperature, however, and perhaps more seriously, it also continues to decline even at very low dew points. Wind and elevation are not considered in this index.

Notwithstanding these minor weaknesses, it must be admitted that each of these indices gives information about heat and humidity that is no less meaningful than the wind chill index. Indeed, it may be only a lack of a strong public education campaign that is keeping the indices out of general practice.

Nonetheless, considering in detail all the factors that make the wind chill acceptable, and applying them to the summer discomfort index, we should be able to produce a better notion of what an acceptable summer discomfort index should be like. I shall call this newly developed product the humisery index.

4. A NEW SUMMER INDEX - HUMISERY

Intuitively, a summer discomfort index should be in the 80s, 90s and 100s as people get more and more uncomfortable (when

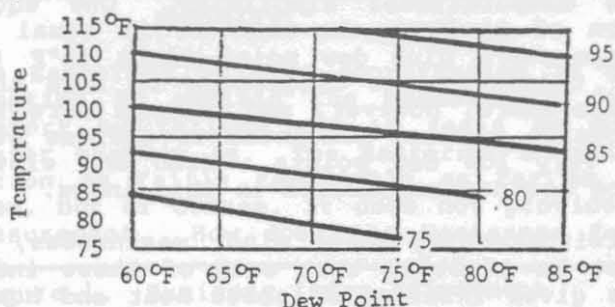


Note: Valid at 1000mb only, but relatively close at 950 mb.

working within the Fahrenheit scale). The index should also be higher as the air becomes more humid, stagnant or thicker (the last with lower elevation). Although shade conditions, clothing, pollution, physiology, and physical activity also influence discomfort, such factors vary so widely between individuals and within short distances that they cannot be used in an index.

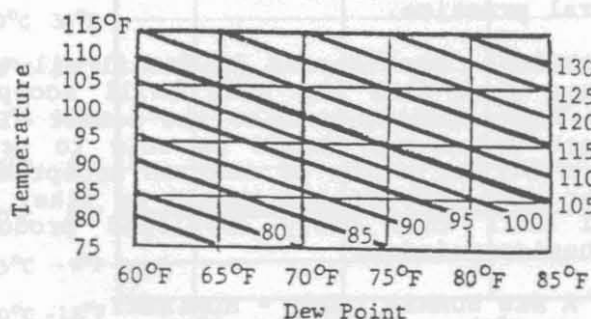
Determining a good base for a summer discomfort index must, of necessity be somewhat arbitrary or judgmental. The wind chill uses a 4 mph wind speed as its base, for example. Since 4 mph is a reasonable

Figure 5. Discomfort (Temperature-Humidity)



Note: Using dew point equation in Reference 2

Figure 6. Humiture



Note: From dew point equation in Reference 4.

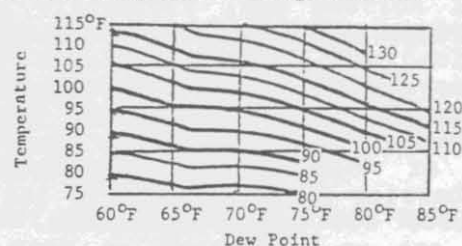
brisk walking speed, then logically the wind chill index should actually be warmer than the air temperature when the wind is under 4 mph. The fact that it is not shows that a firm base line is perhaps more important than strict logic. A series of reasonable base line parameters that would support a summer discomfort index are 68°F (20°C) dew point, a 4 mph (2 mps) wind and sea level elevation. Thus dew points below 68°F, or winds below 4 mph are treated as equivalent to these values, as explained in the next paragraph. It is useful once more to stress why dew point, and not relative humidity, is the preferred measure of moisture.

The dew point is the temperature at which water vapor will condense if moisture is neither added nor subtracted during cooling. Over the course of a summer day, the

dew point is unlikely to change much except in the unusual case of a swift frontal passage. Because of its stability, the dew point is an excellent measure upon which to base an index. The choice of 68°F is somewhat arbitrary, but it does seem the threshold of discomfort as well as a number which has a direct whole number equivalent in Celsius.

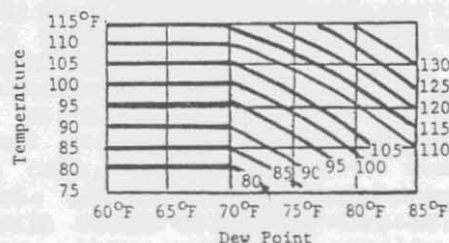
The 4 mph wind choice parallels the wind chill index wind speed base. The sea level elevation choice is defined on the basis that much of the population worldwide lives fairly close to that level.

Figure 7. Apparent Temperature



Base on Figure 1 of Reference 3 and interpolation and conversion to dew point valid at sea level and 5.6 mph wind.

Figure 8. Humisery



From Figure 1-3 of this paper, valid at sea level and 5.6 mph wind.

Now that the base line of the humisery index has been chosen, the next matter is to detail the effects of conditions that represent more discomfort than the base lines.

Determining the effect the various factors have on the discomfort index is surely a most challenging task. The temperature-humidity and apparent temperature indices represent a quasi-empirical approach, with the humiture being modified for calculational simplicity. For this reason, the humisery index should have values in the same range as these indices (or similar temperature-humidity index values at similar humiseries).

Another useful feature of an index is that it is based on definitive physical values. A reasonable relation can be made to the rise in equivalent temperature (the

Table 1A. Moisture Adjustment (°C) to Humisery Based on Dew Point.

| Dew Point | Adjustment |
|------------|------------|
| Below 20°C | 0°C |
| 20 | 0 |
| 21 | 1 |
| 22 | 3 |
| 23 | 4 |
| 24 | 6 |
| 25 | 7 |

| Dew Point | Adjustment |
|-----------|------------|
| 26°C | 9°C |
| 27 | 11 |
| 28 | 13 |
| 29 | 14 |
| 30 | 16 |
| 31 | 18 |

| Dew Point | Adjustment |
|------------|------------|
| Below 68°F | 0°F |
| 68 | 0 |
| 69 | 1 |
| 70 | 3 |
| 71 | 4 |
| 72 | 6 |
| 73 | 7 |
| 74 | 9 |
| 75 | 11 |
| 76 | 12 |

| Dew Point | Adjustment |
|-----------|------------|
| 77°F | 14°F |
| 78 | 16 |
| 79 | 18 |
| 80 | 19 |
| 81 | 21 |
| 82 | 23 |
| 83 | 25 |
| 84 | 27 |
| 85 | 28 |
| 86 | 30 |

Table 1B. Moisture Adjustment (°F) to Humidity Based on Dew Point.

temperature of an air parcel if all the latent heat was turned into sensible heat) and the rise in the humisery index as the dew point rises. This relationship and others are explained in physical terms in the following paragraphs, and in the humisery index conversions in Tables 1 through 4.

As noted previously, the humisery index is based on physical values. Hopefully, such a basis will facilitate understanding. The overall equation for the humisery index is: Humisery index = temperature + adjustment (dew point, wind and elevation).

The adjustments are determined as follows:

At dew points above 68°F, (20°C), the dew point adjustment increases at 40 percent the rate that the equivalent temperature increases (see Figure 1). Obviously, one can call this a clumsy, reconciling assumption, even arbitrary. True, a judgment has been made. The alternative, however, is the huge expense of equipping laboratories, hiring experimental subjects, duplicating an enormous number of environmental conditions and normalizing extraneous factors. Frankly, it would stretch the bounds of credibility if one claimed success in this endeavor. Indeed, the apparent temperature and humiture index make no such claim, although vague reference to 'clothing science' etc., intrude there, too.

The clumsy compromise of 40 percent is based, however, on a number of physical arguments. The main argument has to do with evaporation. Evaporation of perspiration is believed to be the main mechanism by which the human body rids itself of heat during the summer. For example, high relative humidity is considered a primary inhibitor of evaporation. On the other hand, at lower temperatures, even very high relative humidities do not increase the feeling of heat very much. In fact, because water is such a good heat conductor, loss of heat at low temperatures becomes accelerated at high humidities. This is why hiking in the rain can produce hypothermia even at temperatures tens of degrees above freezing.

Obviously, the wind is an equally difficult factor to consider in the adjustment. The mechanism by which wind cools a body in summer is much different from the wind cooling mechanism in winter. The summer mechanism is the action of carrying away air molecules from the skin as they become saturated with water vapor due to body perspiration. The more wind, the more fresh unsaturated air is brought near the skin, thus increasing the rate of evaporation and cooling. Even without evaporation, the wind carries away heat from the skin if the temperature is less than the skin temperature. Of course, the air temperature is so near the skin temperature in summer that this effect is fairly small. It is the enhancement of evaporation that makes any breeze at all welcome on a hot, humid day. The adjustment due to wind is again a clumsy compromise (see Figure 2). As stated previously, it is scientifically reasonable to have a lower humisery than temperature, but the confusion it causes to the general public negates the scientific value. Thus, wind adjustment is subtracted from the dew point adjustment with the condition that remainders less than zero are set at zero.

Table 2A

Moisture Adjustment ($^{\circ}\text{C}$) to Humisery Based on Relative Humidity

| Temperature (Centigrade) | 45°C | 0°C | 6°C | 9°C | 12°C | 15°C | 16°C | 17°C | 18°C | 19°C | 20°C | 21°C | 22°C | 23°C | 24°C | 25°C | 26°C | 27°C | 28°C | 29°C | 30°C | 31°C | 32°C | 33°C | 34°C | 35°C | 36°C | 37°C | 38°C | 39°C | 40°C | 41°C | 42°C | 43°C | 44°C | 45°C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 5 | 6 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0</ |

Table 2B

Moisture Adjustment ($^{\circ}\text{F}$) to Humisery Based on Relative Humidity

| Temperature ($^{\circ}\text{F}$) | 20 $^{\circ}\text{F}$ | 25 $^{\circ}\text{F}$ | 30 $^{\circ}\text{F}$ | 35 $^{\circ}\text{F}$ | 40 $^{\circ}\text{F}$ | 45 $^{\circ}\text{F}$ | 50 $^{\circ}\text{F}$ | 55 $^{\circ}\text{F}$ | 60 $^{\circ}\text{F}$ | 65 $^{\circ}\text{F}$ | 70 $^{\circ}\text{F}$ | 75 $^{\circ}\text{F}$ | 80 $^{\circ}\text{F}$ | 85 $^{\circ}\text{F}$ | 90 $^{\circ}\text{F}$ | 95 $^{\circ}\text{F}$ | 100 $^{\circ}\text{F}$ | 105 $^{\circ}\text{F}$ | 110 $^{\circ}\text{F}$ | 115 $^{\circ}\text{F}$ |
|------------------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|------------------------|------------------------|------------------------|------------------------|
| 25% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 35% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 40% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 45% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 55% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 60% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 65% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 75% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 80% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 85% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 95% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 100% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Elevation is the last factor to be considered in the adjustment. It is not nearly as important as the other factors since most people live fairly near sea level, but it does make a difference. At high elevation (and low pressure) there are fewer molecules near a water surface; thus, there is less chance of condensation

of vapor to replenish the water molecules lost to evaporation. In a near vacuum, vapor would rapidly disperse from around a water droplet and never condense back. It is partly this tendency to avoid the water stage that allows snow at high elevations to retain its powdery nature while snow at lower elevations gets packed more quickly (5).

Table 3A

Wind Adjustment to Humisery

| Wind Speed (metres/second) | Adjustment |
|-------------------------------|----------------------|
| 0 mps | 0 $^{\circ}\text{C}$ |
| 1 | 0 |
| 2 | 0 |
| 3 | -2 |
| 4 | -3 |
| 5 or greater | -4 |

Table 3B

Wind Adjustment to Humisery

| Wind Speed Miles/Hour | Adjustment |
|--------------------------|----------------------|
| Under 4 mph | 0 $^{\circ}\text{F}$ |
| 4 | 0 |
| 5 | -2 |
| 6 | -4 |
| 7 | -5 |
| 8 | -6 |
| 9 | -7 |
| 10 mph or more | -7 |

Table 4A

Elevation Adjustment to Humisery

| Elevation | Adjustment |
|-------------|----------------------|
| Sea Level | 0 $^{\circ}\text{C}$ |
| 300 metres | -1 |
| 600 metres | -1 |
| 900 metres | -2 |
| 1200 metres | -2 |
| 1500 metres | -3 |

Table 4B

Elevation Adjustment to Humisery

| Elevation | Adjustment |
|-----------|----------------------|
| Sea Level | 0 $^{\circ}\text{F}$ |
| 1000 feet | -1 |
| 2000 feet | -2 |
| 3000 feet | -3 |
| 4000 feet | -4 |
| 5000 feet | -5 |

Table 5

Comparison of Summer Discomfort Indices

| Narrative | Temp. °F | Dew Point °F | Relative Humidity | Temp. Humidity | Apparent Temp. | Humiture | Humisery |
|---------------------------|-------------|-----------------|----------------------|-------------------|-------------------|----------|----------|
| WARM | 80 | | | | | | |
| Very Dry | | 50°F | 35% | 72 | 79 | 65 | 80 |
| Dry | | 60 | 50 | 74 | 81 | 75 | 80 |
| Humid | | 70 | 70 | 76 | 85 | 85 | 85 |
| Very Humid | | 80 | 100 | 80 | 91 | 95 | 96 |
| HOT | 90 | | | | | | |
| Very Dry | | 50 | 26 | 77 | 88 | 75 | 90 |
| Dry | | 60 | 36 | 79 | 91 | 85 | 90 |
| Humid | | 70 | 50 | 81 | 96 | 95 | 95 |
| Very Humid | | 80 | 70 | 85 | 106 | 105 | 106 |
| VERY HOT | 100 | | | | | | |
| Very Dry | | 50 | 18 | 81 | 98 | 85 | 100 |
| Dry | | 60 | 26 | 83 | 102 | 95 | 100 |
| Humid | | 70 | 34 | 85 | 106 | 105 | 105 |
| Very Humid | | 80 | 52 | 89 | 115 | 115 | 116 |
| Westerner's Visit East | 90 | 77 | 66 | 84 | 103 | 102 | 101 |

Notes: Temperature Humidity Index from relative humidity equation (See Reference 2).
 Apparent temperature from Figure 1 of Reference 3, assumes sea level and 5.6 mph.
 Humiture from dew point equation of Reference 11.
 Humisery from Tables 1-4B, sea level 5.6 mph.

The adjustment to elevation (Figure 3) is hence a very modest one. Once again, since the humisery is never lower than temperature, the elevation adjustment is subtracted from the dew point (or dew point minus wind) adjustment with the condition that remainders less than zero are set to zero.

For example, if the dew point adjustment were 10, the wind adjustment -5 and the elevation adjustment were -1, the total adjustment would be $10 - 6 = 4$. In the case of a dew point adjustment of 4 and the wind and elevation adjustments as before, the total adjustment would be $4 - 6 = -2$, set to 0.

Although the dew point is a better index of moisture than relative humidity because of smaller variability, it is not a value the public knows. See the chart in Figure 4 for conversion of temperature and relative humidity into dew point.

5. COMPARISON OF INDICES

To see how the various summer discomfort indices compare, a tabular comparison is useful. Table 5 shows how the different indices change on days ranging from warm to very hot and from very dry to very humid.

A number of notes on Table 5 are necessary. For one thing, it is given in the Fahrenheit scale (6). In addition, a wind speed (5.6 mph) and elevation (sea level) must be assumed to calculate the apparent temperature and humisery. The other two indices are, as explained before, not influenced by these factors. Table 5 does, however, illustrate the fact that the Humisery Index does not continue to decrease under very dry conditions (the others do) while it increases with very humid conditions at roughly the same rate as apparent temperature and humidity.

Table 6

Comparative Mean July - August Humiseries

| | July | August |
|---------------------------------------|------|--------|
| <u>SOUTHEAST</u> (most uncomfortable) | | |
| Port Arthur, TX | 91 | 94 |
| Corpus Christi, TX | 91 | 93 |
| Houston, TX | 87 | 94 |
| Victoria, TX | 89 | 91 |
| Lake Charles, LA | 90 | 90 |
| Apalachicola, FL | 87 | 90 |
| New Orleans, LA | 88 | 89 |
| Key West, FL | 88 | 89 |
| Shreveport, LA | 88 | 88 |
| Tallahassee, FL | 86 | 89 |
| <u>SOUTHEAST</u> (other large cities) | | |
| Atlanta, GA | 78 | 77 |
| Memphis, TN | 82 | 80 |
| Miami, FL | 84 | 87 |
| Dallas, TX | 85 | 86 |
| <u>WEST & SOUTHWEST</u> | | |
| Yuma, AZ | 94 | 93 |
| Las Vegas, NV | 89 | 87 |
| Bakersfield, CA | 84 | 82 |
| Honolulu, HI | 80 | 81 |
| <u>OTHERS</u> (East, Midwest, PR) | | |
| Kansas City, MO | 77 | 77 |
| St. Louis, MO | 79 | 77 |
| San Juan, PR | 81 | 81 |
| Newark, NJ | 76 | 75 |
| Washington (Natl) DC | 79 | 77 |

Generally speaking, the tendency of the humidity index to continue to decrease with lower and lower dew point is shown by Table 5. Also pronounced is the tendency of the 'apparent temperature' to exceed the other indices in very hot conditions while just barely continuing to decrease with low dew points. The most obvious point of Table 5 is that the humidity does not decrease with dew point reduction from 60°F to 50°F. For this reason, the humidity is only slightly lower in very hot and dry conditions (which might be thought of as the Westerner's native climate) than it is in the Eastern humidity. The other indices show greater differences between the Western and Eastern condition. This weakness of the humidity index is necessary in order to retain the "never lower than temperature" characteristic.

The graphic differences between the indices are shown in Figures 5 through 8. Each figure shows how the index varies with temperature and dew point. An inspection shows that the temperature-humidity and humidity index bears a distinctly linear relationship to dew point. The apparent temperature relationship to dew point is nonlinear. It is also irregular in that its slope increases and decreases

with increasing dew points. This observation is caused by the fact that the index itself is based on relative humidity. On a similar chart, with a horizontal axis of relative humidity, the relationship would be nonlinear but regular. The humidity index is also nonlinear in its relationship to dew point and temperature (above 68°F dew point) but is regular with the slope changing in a smooth manner. The effect of the baseline dew point on humidity is also obvious in the graph.

One additional observation is that the two more empirical indices (temperature-humidity and apparent temperature) seem to differ from each other as much as the indices based on physical reasoning (humidity and humidity).

6. CLIMATIC FACTORS

A climatology based on humidity rather than temperature provides some interesting insights into the interaction of temperature and other variables as they account for summer discomfort. The July mean temperature and humidity and August mean temperature and humidity are shown in Figures 9 and 10, respectively (7). These figures show only the Southeast since elsewhere

the two indices are identical.

Indeed, from the figures, it is apparent that even in the Southeast, the mean humidity and temperature are identical almost everywhere north of Mississippi, Alabama, Georgia and South Carolina. Another interesting feature is that whereas the July isotherms are farther north than those of August, that is not true of humidity isolines. In fact, the southern sections of the Gulf States are as much as 2°F higher in humidity in August than in July. It is reasonable to relate the cooler August in Arkansas, Tennessee, and North Carolina to decreasing daylight hours and to penetration of the polar jet stream in late August. This, of course, brings with it somewhat cooler air masses. The higher

August humidity farther south should be related to the northward movement of Gulf air, which continues as the Gulf waters warm throughout the entire summer.

A comparison of humidity in the Southeast, Southwest and some large Eastern cities noted for their uncomfortable summers is given in Table 6.

Only the Southeastern cities (and not all of these) actually have a mean humidity different from temperature. It should, however, be obvious that even though the inhabitants of these large Eastern cities may consider their summers humid, the average values in Table 6 do not indicate that their discomfort is anywhere near as great as those of the Gulf Coast cities.

Figure 9a. July Mean Temperature in Degrees Fahrenheit



9b. July Mean Humidity in Degrees Fahrenheit

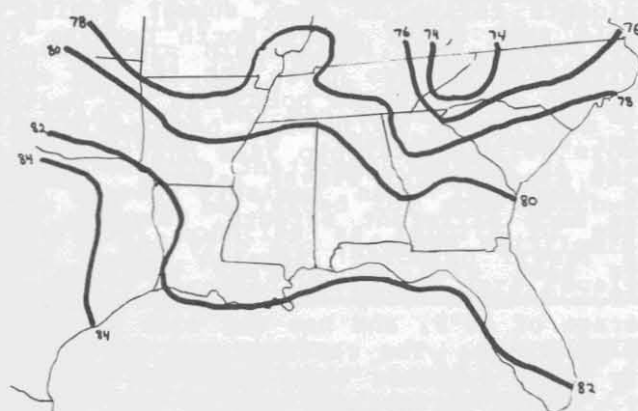
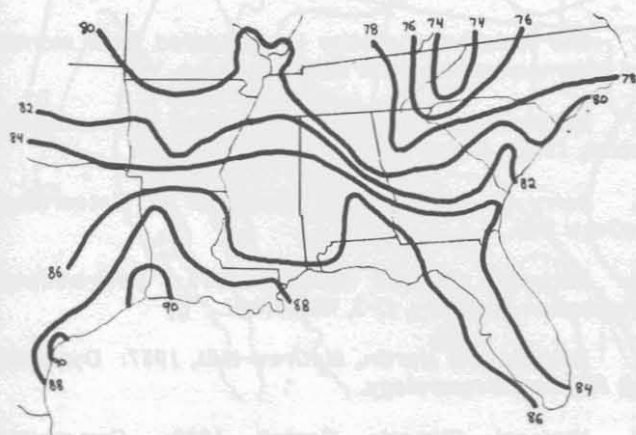


Figure 10a. August Mean Temperature in Degrees Fahrenheit

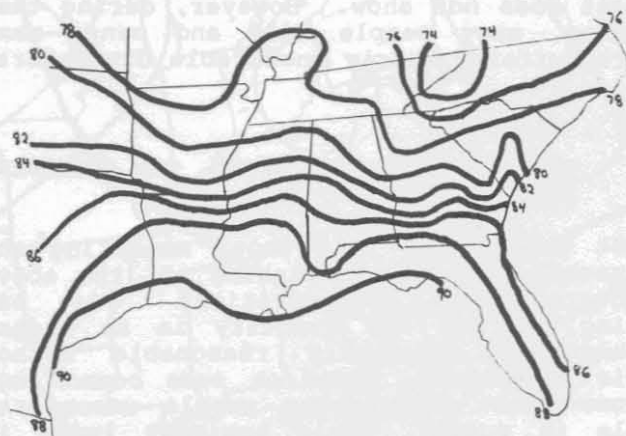


Figure 10b. August Mean Humidity in Degrees Fahrenheit

Further consideration indicates there might be some good reason (aside from ego) that people in Eastern cities complain about their summers. Indeed, there is such a reason and it has to do with adaptability and variability.

The subject can be approached by using a winter wind chill example. When the wind chill is 30°F in North Dakota in January, the North Dakotans feel warm but the same wind chill on the Gulf Coast is considered Arctic. What is wrong with our index? The answer is that nothing is wrong but that the index does not consider seasonal adaptability. It has to do with acclimations; the natives of North Dakota actually get used to, and feel fairly comfortable in, the kind of winter that would make a Gulf Coast resident miserable. So it is not surprising that the Gulf Coast residents thrive in mean summer humisery levels that would put a North Dakotan in severe discomfort. The fact is that the humisery does not and cannot adjust for this factor (neither can the wind chill or other summer indices). With adaptability, there is another important consideration; two identical mean humisery levels can have much different effects. Suppose, as a simplified example, one city had 31 July days each with an average humisery of 81°F. Another city had 30 days with an average of 80°F, and one day with an average of 111°F. The residents of the second city would remember that month for the one day. Such variability as in the second city is virtually impossible, but over a summer, and especially over many summers, a lesser variability is likely. For example, during the summer of 1980, much of Missouri had a temperature of 15°F (and humiseries of 25°F) above normal. Obviously, over a 30 year average, such an event does not show. However, during that summer, many people died and many, many more suffered nearly unbearable discomfort.

7. THE BENEFITS OF USING THE HUMISERY INDEX

What can now be said about measuring the discomfort of summer, taking all the above factors into consideration? For one thing, we can now quantify in an understandable, physically reasonable method this discomfort, based on some common notions about what makes people uncomfortable in summer. This humisery index is easily derived from tables and figures and is based on parameters that are readily accessible from the common weather measurements taken hourly by the U. S. National Weather Service, namely temperature, moisture, (dew point or relative humidity), wind and elevation. The index is constructed to be as close as possible to a summer analogue of the wind chill index

and to give values in accordance with intuition.

The humisery index does not take into consideration, physiological factors - sunlight exposure, etc. It does not measure summer discomfort perfectly, or even significantly better than do some other indices (although it will be more understandable to the public). What it does (to use the initial dialogue) is to allow the Easterner to tell the visiting Westerner that the reason the latter feels as if it is about 100°F is because that is what the humisery index is. Perhaps, more importantly, the Easterner can also understand why he himself is more uncomfortable on some hot days than on others and can prepare the home or office appropriately, based on an easily calculated index.

REFERENCES AND FOOTNOTES

1. Mr. Weiss did undergraduate work in Meteorology at the University of Wisconsin and graduate work in Hydrology at the University of Nevada. He has written extensively on air quality physics for the U.S. Dept. of Transportation where he has worked for the last few years.
2. U.S. Weather Bureau 1959: Letter Series 5922, Notes on Temperature Humidity Index.
3. National Climatic Center, 1980: Environmental Information Summary C-19, Heat Stress.
4. George Winterling, WJXT - Jacksonville, Florida, 1979: Informational Memorandum.
5. As an aside, it should be noted that the chance of heat exhaustion may actually increase at high altitudes since, when body moisture is low, the perspiration cooling mechanism is suppressed. Nevertheless, given a person whose body does have normal moisture, and other things being equal, higher elevations will feel cooler.
6. For equations to produce the temperature - Humidity Index in Celsius, see "Climate and Man's Environment," by John E. Oliver, John Wiley & Sons, Inc., 1973.
7. The Relative Humidity is calculated from morning and afternoon readings for each month.
8. Meteorology Tables, Smithsonian Miscellaneous Tables, 1958: Meteorological Tables, vol. 114.
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10. National Climatic Center, 1975: Environmental Information Summary, C-3, Wind Chill.
11. Haltiner and Martin, McGraw-Hill, 1957: Dynamical and Physical Meteorology.
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