BACKGROUND

The Bioclimatic Chart originally developed by Victor and Asilda Oyvay in the 1920’s has been revised as a result of additional research by: Edward Ansen, Associate Professor, Department of Architecture, University of California, Berkeley; Louis Zehr, Department of Architecture, Technical University of Scandinavia; Richard Glickman, Associate Professor, J. B. Pierce Foundation Laboratory and Associate Professor, School of Environmental, Yale University; Larry Berglund, Associate Professor, J. B. Pierce Foundation Laboratory and Lecturer, Department of Architecture, Yale University; and Preston McCall, Chief, Building Thermal and Services Systems Division, Center for Building Technology, National Engineering Laboratory, National Bureau of Standards, Washington, D.C. They were supported by the Department of Energy.

The chart was based on their paper, "A New Bioclimatic Chart: For Environmental Design," presented at the International Conference on Building Energy Management at the May 1984 meeting in Portugal. The paper will be available soon through the authors.

FACTORS

The chart is based on three conditions — (1) the weight of clothing worn, (2) the activity level of individuals and (3) the angle of the sun above a horizontal plane.

1. Clothing — The insulating value of clothing is expressed in Clo-values, 1.0 Clo, introduced by Gagge, is the insulating value of a man’s business attire in 1941. A clothing level of 0.8 Clo was chosen for this chart to represent typical clothing for both male and female in the cold part of the year. It also represents a compromise between expert and outdoor clothing. Further information on Clo values for common items of clothing can be found in "How To Do Clothing Analysis at 45° or 60°" by Zehr, a summary of research done in 1968 in 1974. Reference points include Precipitation at 0.5 Clo, open neck shirts, and shorts at 4 Clo. Combining clothes over 1.3 Clo tend to be too bulky for practical indoor wear.

2. Activity Level — 1.0 Met is the metabolic rate of the average resting adult. An activity level of 1.3 Met was chosen as representing typical levels of activity in homes, offices, and outdoor environments. The level of 1.3 Met corresponds to light household work, slow walking, and a common pattern of outdoor activities and outdoor activities and office work where the occupant is required to get up and move around occasionally.

3. Sun Angle — A sun angle or elevation of 45° was chosen as representing a typical value obtained at many times of year in large areas of the U.S. Other charts based on different values of clothing, activity, and sun angle are anticipated in the future for wider application.

HOW TO USE THIS CHART

Eighty percent of people wearing 0.8 Clo, having a metabolic rate of 1.3 Met (light exercise) will be comfortable in all air at combinations of temperature and relative humidity lying within boundaries of the comfort zone. In that zone Mean Radiant Temperature (MRT) of surrounding surfaces, is equal to the air temperature. Outside the comfort zone, the chart has contour lines, along which selected levels of radiation, air velocity, or evaporative cooling will result in a person’s thermal sensation in the nearest boundary of the comfort zone. The radiation values allow that are too low, and that the air velocity and evaporative cooling values are too high. Combinations of radiation and air velocity are not considered, in order to reduce the complexity of the chart. The levels of radiation and air movement represented on the chart extend to extreme values that are normally only encountered outdoors, and as a consequence the range of temperatures considered is wide.

A design procedure based on the superposition of outdoor climate and occupants comfort requirements requires a close coupling between outdoor and the location of the occupants. This coupling exists in outdoor spaces, and in "envelope-dominated" buildings like the residences whose climate elements are available indoors in the form of sunshine through windows, natural ventilation, and thermal transfer through walls and roofs. This design procedure is not appropriate for those large commercial buildings that create their own internal climate entirely by means of mechanical systems.

As a result of the rise in energy costs and energy availability problems, there is now trend toward designing large commercial buildings that are more "environmentally dominated," and toward passive solar design in commercial scale buildings as well. Envelope-dominated buildings have one or more of the following characteristics: more building perimeter to obtain daylighting, more natural ventilation through windows, higher ceiling height, direct solar gain into occupied spaces, high radiation temperature differences resulting from solar heated components, screens, or Trombe walls and high levels of localized radiant heating and cooling, and evaporative cooling.

EVAPORATIVE COOLING

High temperatures and low relative humidities can be made comfortable by evaporative cooling. Evaporative cooling is effective only in the shaded area to the left of the "evaporative cooling" line. For example, Point A, "91°F," and 20% RH, would be restored to the upper boundary of the comfort zone in "still air" by taking the air with an evaporative cooler adding, on the average, 21 grains of water per pound of dry air to the environment.

AIR VELOCITY

Temperatures in the upper eighteens and even in the thirties can be made comfortable by evaporative cooling. Air velocity affects the comfort at various humidities and air velocities. Example: Point B, "80°F," and 50% RH, is comfortable at an air velocity of 500 feet per minute, and at point C, "80°F," and 65% RH, air velocity of 1000 feet per minute.

SOLAR RADIATION

Temperatures as low as the middle thirties are uncomfortable under the full effect of a 45° sun. Above this temperature provide shading as required to avoid overheating.

Example: Point C, "80°F," and 60% RH, is comfortable with approximately a 55° sun.

SURFACE RADIATION

Surfaces that are warmer than the surrounding air temperature can have a heating effect similar to the sun. This difference between the Mean Radiant Temperature (MRT) and air temperature is shown on the chart as MRT-Ta.

Small differences in the range of 10° to 15° degrees, can be expected from previously occupied solar radiation. Differences of more than a few degrees can be achieved with special solar radiation absorbing devices or with conventional hot water, steam, or electric resistance heaters.

Example: Point D, "80°F," and 80% RH, is comfortable with radiation from hot surfaces whose mean radiant temperature (MRT) is 100° F above the air temperature of 75° F. A large surface as a "solarium" of 150 square feet would be required, since it would be impractical to heat all surfaces surrounding a portion to 90° F.

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