Table 1 . . . . Design Room Conditions Usually Specified for Summer Average Peak Load in Comfort Air Conditioning[a]

Type of Installation	Dry-Bulb Temp	Wet-Bulb Temp[b]	Relative Humidity Percent	Grains Per Lb[b]	Effective Temp[c]
1. Ample capacity........	78	65	50	72.7	72.2
2. Practical application..	80	67	51	78.5	74.0
3. Occupancy—15 to 40 min................	82	68	49	80.0	75.3

[a] Values in Table 1 are for *peak load* conditions. It is general practice to operate a system at approximately 75 F and 50 percent relative humidity at other than peak load.

[b] Psychrometric data for standard barometric pressure.

[c] Fig. 10, Chapter 6, air movement 15 to 25 fpm.

perature of 90 F or less; and the *15 to 40 min* occupancy values, or even somewhat higher dry-bulb temperatures, would indicate acceptable conditions for very hot localities. Table 1 *is to be used with good judgment*, for there is no universal rule that may be applied to indoor design conditions.

Guarantees of conditions to be maintained for summer operation are based upon a definite set of load conditions. At other than the guarantee load, the conditions produced by a system are determined by the balance of imposed load and equipment capacity, and by the method adopted for regulating the system operation. Complete specifications of indoor design conditions would include part-load and overload operation, particularly from the viewpoint of economy.

In the field of *industrial air conditioning*, indoor design conditions are established by the requirements of goods and processes, in addition to the comfort and efficiency of the workers. Many typical indoor design conditions for products in industrial air conditioning are given in Chapter 50.

The load calculations for either comfort or industrial air conditioning are usually made in accordance with a guarantee. In comfort applications, for example, this is frequently 80 F and 51 percent relative humidity or 78 F and 50 percent relative humidity. The system is *normally operated* at 75 or 76 F and approximately 50 percent relative humidity at all times as long as the equipment has capacity to maintain these conditions. During very hot weather, the room temperature will rise above the control point and the equipment will operate continuously. Normally, industrial jobs are operated at design conditions at all times if the optimum conditions are selected for the benefit of the product.

The indoor design conditions suggested have had reference to conditions to be maintained at the level of occupancy. For extremely high ceilings in public or industrial buildings, only the zone from 10 to 15 ft above the floor may be cooled to the full extent. The air temperature at the ceiling would be much higher, and this should be kept in mind when calculating the convective portion of the roof heat gain. A reduction of outdoor-to-indoor air temperature differential may be assumed in such instances but radiation from the inner roof surface is not diminished.

Outdoor Conditions

Summer climatic conditions and suggested design wet-bulb and dry-bulb temperatures are given in Table 2 for various locations in the United States. The highest temperature ever recorded is for the period of record shown. In some cases it should be noted that this period of record is comparatively short, and higher temperatures may be expected. In making comparisons for localities other than those shown in Table 2, due consideration must be given to elevation.

Column 6 of Table 2 indicates the design dry-bulb temperature suggested by the ASHAE Technical Advisory Committee on Weather Design Conditions. This temperature is the maximum hourly outdoor temperature which has been equalled or exceeded 2½ percent of the total hours of June, July, August, and September for the period of record, in this case the 5-year period 1935–1939, and should not be confused with the period of record given in Column 4 which applies only to highest temperature ever recorded. Since all of these data (Column 4) are based on airport records, they are not necessarily applicable to cities.

The data given in Columns 7 and 8 were obtained from local ASHAE Chapter Secretaries, and represent the design temperatures in local use. Where such information was not available, it was taken from a publication of the ARI[1] and from various other sources.

The Technical Advisory Committee on Weather Design Conditions has suggested that wet-bulb design temperature be taken as that wet-bulb temperature which has been equalled or exceeded in 5 percent of the hours during months of the period of record. While not available for this edition of THE GUIDE, due to the tremendous task of compiling these data, it is hoped that they will be available for some stations for future editions.

The wind velocity to be used in design should be that wind velocity which accompanies the design temperatures in each instance, but since these data are not available, the average summer wind velocities for the period of record were taken from U. S. Weather Bureau records revised to 1948. It is pointed out that this is not necessarily the velocity which coincides with the design temperatures, but it may serve as a guide to the designer.

Other weather data, such as *daily range of temperature*, are useful particularly when making cooling load calculations for an early morning peak on an east exposure. Daily range of temperature is the difference between the average of the daily maximum dry-bulb temperatures and the average of the daily minimum temperatures. This range is highest in semi-arid or desert regions and at high elevations, and lowest near the oceans or very large lakes. The daily range of temperature (Fahrenheit degrees) in July for the principal areas of the United States can be approximated from the following tabulation:

East Sea Shore..................................	12 to 18
East of Mississippi River..........................	19 to 24
Gulf Sea Shore..................................	12 to 18
Great Lakes Shore...............................	18 to 21
Mississippi River to Rocky Mountains............	24 to 33
Rocky Mountain Area.............................	33 to 42
West Coastal States..............................	20 to 36
West Sea Shore..................................	15 to 20

Ventilation Rate

The introduction of outdoor air is necessary for the ventilation of conditioned spaces. Chapter 6 suggests *minimum* outdoor air requirements for representative applications; but it is to be emphasized that minimum requirements are not necessarily *adequate* requirements for all psychological attitudes and physiological responses. Where maximum economy in space and load are essential, as in submarines or other restricted spaces, as little as 1 cfm of outdoor air per person has been found to be sufficient provided that satisfactory ventilation is simultaneously obtained by an adequate decontamination of recirculated air.[2]

Local codes and ordinances frequently specify ventilation requirements for public places and for industrial installations. For operating rooms, minimum requirements for safe practice are given in a National Board of Fire Underwriters' pamphlet.[3] This pamphlet does not require 100 percent outdoor air in operating rooms, although 100 percent outdoor air is normally used and recommended.

Recommended and minimum ventilation rates for the most common applications are summarized in Table 3. For further general applications, a basis of estimating the cfm per person may be taken as:

1. People not smoking.... 7½ *Recommended* 5 *Minimum*
2. People smoking........ 40 *Recommended* 25 *Minimum*

The cooling load due to the introduction of outdoor air for ventilation is determined once the indoor and outdoor design conditions are fixed. Calculations will be discussed subsequently.

INSTANTANEOUS HEAT LOAD

The total cooling load is frequently divided for convenience into two components, *sensible heat* and *latent heat*. While this subdivision is not imperative, past practice has found it convenient.

A gain of *sensible heat* is considered to occur when there is a direct addition of heat to the enclosure by any one or all of the mechanisms of conduction, convection, and radiation. A gain of *latent heat* is considered to occur when there is an addition of water vapor to the air of the enclosure. For example, when the humidity in an enclosure is increased by water vapor emitted by human occupants, or by water vapor resulting from a process such as cooking, the heat required to vaporize the water does *not* come from the air. Maintenance of a constant humidity ratio in a sealed enclosure requires the condensation of water vapor in the cooling apparatus at a rate equal to its rate of addition within the enclosure. The rate of heat removal from this condensing vapor would be substantially equal to the product of the rate of condensation and the latent heat of condensation; this product, expressed in Btu per hour, would be called a *latent heat* load.

As a further example, the infiltration of outdoor air with a high dry-bulb temperature and a high humidity ratio, and the corresponding escape of room air at a lower dry-bulb temperature and a lower humidity ratio, would increase both the *sensible heat* load and the *latent heat* load.

SOLAR RADIATION

Magnitude of Solar Radiation

If a plane surface were set perpendicular to the sun's rays (i.e., for *normal incidence*) outside the earth's atmosphere, it would receive solar radiation of about 420 Btu per (hr) (sq ft). A similarly oriented surface, at the surface of the earth, would receive considerably less solar energy because a large part of the radiation is scattered in passing through the air; moisture, smoke, and dust which comprise the earth's atmosphere, and also, because some of the atmospheric constituents, notably water vapor, ozone, and carbon dioxide, absorb solar radiation. The intensity of solar radiation varies with wavelength, reaching a peak at about 0.5 microns (a micron equals 1/1000 of a millimeter) and, for practical purposes, is confined to the radiation spectrum between 0.3 and 2.3 microns. The effects of scattering and absorption vary with the wavelength, but to make an exact analysis of these phenomena is impracticable in air-conditioning estimates. The important principle to remember is that the total radiation I_t, received by a surface at the earth, is the sum of I_D and I_d, where

I_D = KI_{Dn} = the *direct* or *beamed* solar radiation, Btu per (hour) (square foot of receiving surface).

I_{Dn} = the direct solar radiation on a plane normal to the sun's rays, Btu per (hour) (square foot of receiving surface).

I_d = the *sky* or *diffuse* solar radiation, Btu per (hour) (square foot of receiving surface). This comes principally from the atmosphere itself as a consequence of scattering. Vertical surfaces also receive solar radiation by reflection of direct and diffuse radiation from the ground and other objects. Such radiation is usually diffuse. The diffuse radiation strikes at *all* angles.

I_t = total incident solar radiation, Btu per (hour) (square foot of receiving surface).

K = cosine of the angle of incidence, θ. For a vertical surface, θ is defined in Fig. 1.

Standardized, practical-purpose values of the *direct* solar radiation I_{Dn} incident upon a plane *perpendicular* to the sun's rays at the earth's surface, have been proposed by Moon.[4] Table 4 gives these values. They are representative of a *clear* summer day at sea level elevation, and are nearly identical with values derived from suggested design sol-air temperatures for Lincoln, Nebraska.[5] Values typical of a humid industrial area derived from sol-air data for New York City[6] are also given in Table 4. Day-to-day changes in the amount of dust and water vapor in the atmosphere cause large differences in solar intensity values observed on cloudless days at a given locality. For example, it has been observed in Cleveland that values of the order of those given for industrial atmospheres are usually associated with dry-bulb and wet-bulb temperatures near the design values of 95 F and 75 F (67 F dew point). On the other hand, values approaching or exceeding those for a clear atmosphere are often encountered during Cleveland summers, but with dew-point and maximum dry-bulb temperatures 10 to 15 deg lower. Considerable judgment, therefore, is required in selecting solar intensity values for design purposes.

Data regarding the irradiation of vertical and horizontal surfaces by diffuse or sky radiation are few. Suggested design values for a 40-deg latitude on August 1 (18-deg declination,

(*Continued on p. 176*)

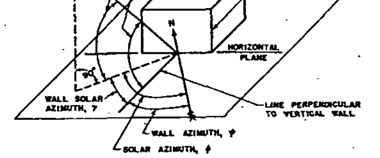

Fig. 1 . . . . Definition of Solar Angles