Table 26 .... Rates of Heat Gain from Occupants of Conditioned Spaces[a]

Degree of Activity	Typical Application	Total Heat Adults, Male Btu/Hr	Total Heat Adjusted[b] Btu/Hr	Sensible Heat Btu/Hr	Latent Heat Btu/Hr
Seated at rest	Theater—Matinee Theater—Evening	390 390	330 350	180 195	150 155
Seated, very light work	Offices, hotels, apartments	450	400	195	205
Moderately active office work	Offices, hotels, apartments	475	450	200	250
Standing, light work; or walking slowly	Department store, retail store, dime store	550	450	200	250
Walking; seated Standing; walking slowly	Drugstore, Bank	550	500	200	300
Sedentary work	Restaurant[c]	490	550	220	330
Light bench work	Factory	800	750	220	530
Moderate dancing	Dance hall	900	850	245	605
Walking 3 mph; moderately heavy work	Factory	1000	1000	300	700
Bowling[d] Heavy work	Bowling alley Factory	1500	1450	465	985

[a] *Note:* Tabulated values are based on 80 F room dry-bulb temperature. For 78 F room dry-bulb, the total heat remains the same, but the sensible heat values should be increased by approximately 10 percent, and the latent heat values decreased accordingly.

[b] *Adjusted total heat gain* is based on normal percentage of men, women, and children for the application listed, with the postulate that the gain from an adult female is 85 percent of that for an adult male, and that the gain from a child is 75 percent of that for an adult male.

[c] Adjusted total heat value for *sedentary work, restaurant,* includes 60 Btu per hour for food per individual (30 Btu sensible and 30 Btu latent).

[d] For *bowling* figure one person per alley actually bowling, and all others as sitting (400 Btu per hour) or standing (550 Btu per hour).

One important purpose of the cooling-load estimate is to determine the conditions and quantity of air supplied to the space. All the various sensible and latent heat loads within the space must be included. Infiltration must be included in the space load since this air enters the doors and windows, and its heat and moisture load must be offset by the introduction of cooler, dryer air to the space. However, since outdoor air is taken through the conditioning equipment and cooled, this portion does not become a part of the space load, except a small portion which passes through the coil untreated. To determine the total load on the refrigeration machine, the remaining outdoor-air load must be included in the grand total load.

Example 9: For outdoor design conditions of 95 F dry-bulb and 75 F wet-bulb, and indoor design conditions of 80 F dry-bulb and 67 F wet-bulb and for the supply of outdoor air at the rate of 1000 cfm and the exhaust of room air at the corresponding rate, calculate the total, sensible, latent heat gains.

Solution: Substituting in Equation 6:

$$q_s = 1000 \times 1.08\ (95 - 80) = 16{,}200 \text{ Btu per hr.}$$

From psychrometric data $W_o = 0.01413$ $W_i = 0.01122$.
Substituting in Equations 7 and 8:

$$q_s = 100 \times 4840(0.01413 - 0.01122) = 14{,}100 \text{ Btu per hr.}$$

$$q_t = q_s + q_s = 30{,}300 \text{ Btu per hr.}$$

HEAT SOURCES WITHIN THE CONDITIONED SPACE

People. The rates at which heat and moisture are given off by human beings under different states of activity are given in Table 26. In many applications these sensible and latent heat gains become a large fraction of the total load. Appreciable variations in heat-emission rates must be recognized according to the age and sex of the individual, state of activity, environmental influences, and duration of occupancy (since for short occupancy the extra heat and moisture brought in by people may be a significant factor).

While Chapter 7 should be referred to for detailed information, Table 26, in this chapter summarizes practical data representing conditions commonly encountered.

Lighting. In general, the instantaneous rate of heat gain from electric lighting[43] may be calculated from the following relation:

$$q_{sl} = \left\{\frac{\text{total light}}{\text{wattage}}\right. \times \left\{\begin{matrix}\text{use}\\ \text{factor}\end{matrix}\right. \times \left\{\begin{matrix}\text{special allow-}\\ \text{ance factor}\end{matrix}\right. \times 3.41, \text{ Btuh} \quad (14)$$

The *total light wattage* is obtained from the ratings of all fixtures installed, both for general illumination and for display use.

The *use factor* is the ratio of the wattage in use, for the conditions under which the load estimate is being made, to the total installed wattage. For commercial applications such as stores, the use factor would be unity.

The *special allowance factor* is introduced to care for fluorescent fixtures, and for fixtures which are either ventilated or installed so that only part of their heat goes to the conditioned space. For *fluorescent fixtures,* the special allowance factor is recommended to be taken as 1.20 in order to allow for power consumed in the *ballast.* For *ventilated fixtures, recessed fixtures,* and the like, manufacturers' or other data[43] must be sought to establish the fraction of the total wattage which may be expected to enter the conditioned space.

Power. When equipment of any sort is operated within the conditioned space by electric motors, the heat equivalent of this operation must be considered in the cooling load. The general equation for calculating this load is:

$$q_{em} = \left(\frac{\text{Horsepower Rating}}{\text{Motor Efficiency}}\right) \times \left(\frac{\text{Load}}{\text{Factor}}\right) \times 2544, \text{ Btuh} \quad (15)$$

It is assumed that both the motor and the driven equipment are within the conditioned space. If the motor is outside the space, then *do not divide* by the motor efficiency in Equation 15. The *load factor* is merely the fraction of the rated load which is being delivered under the conditions of the cooling-load estimate. *Motor efficiencies* may be approximated as follows: about 50 to 60 percent at ¼ hp rating, increasing to 80 percent at 1 hp, and to 88 percent at 10 hp and above.

Appliances. Care must be taken in a cooling-load estimate to take into account the heat gain from all appliances, electrical, gas, or steam.

The most common types of heat producing appliances found in the conditioned area are those used for food preparation in commercial and industrial food service establishments such as restaurants, institutions, hospitals, schools, clubs, hotels and in-plant cafeterias. Counter and back-bar appliances are frequently located in the dining or serving area while heavy duty equipment is usually confined to the kitchen and installed under an exhaust hood. However, since the trend is to air condition the kitchen as well as the dining area, a method to estimate the cooling load due to both types of appliances is needed.

Laboratory tests[42] show that appliance surfaces contribute most of the heat to commercial kitchens and that when installed under an effective hood the cooling load is independent of the fuel or energy employed for similar equipment doing the same cooking operations. The tests also indicated that the heat is primarily radiant energy from the appliance surfaces and cooking utensils and that convected heat and latent heat is negligible.

A conservative estimate as to the maximum heat released into the kitchen due to radiation is 32 percent of the maximum hourly Btu input to hooded appliances. The magnitude of this maximum hourly input can be safely estimated as 50 percent of the total nameplate or catalog input ratings because of diversity of appliance use and the effect of thermostatic controls. Numerous demand studies by utility companies confirm this *usage factor* of 0.50 for commercial cooking equipment. Therefore the maximum hourly heat gain for electric and steam appliances installed under a hood can be estimated from the following equation:

$$q_a = q_i \times F_U \times F_R \quad (16)$$

or

$$q_a = 0.16\, q_i \quad (17)$$

Direct fuel-fired cooking appliances require more heat input than electric or steam equipment of the same type and size. In the case of gas fuel, field studies[40,41] have established an overall figure of approximately 60 percent more. The laboratory tests[42] already referred to confirm that where the appliances are installed under an effective hood only radiant heat adds to the cooling load and that convected and latent heat from the cooking process and combustion products are exhausted and do not enter the kitchen. It is therefore necessary to correct Equation 16 for fuel-fired appliances to compensate for the 60 percent higher input ratings since the appliance surface temperatures are the same and the extra heat input is completely exhausted to outdoors along with the combustion products. This correction is made by the introduction of a *flue loss factor* as follows:

$$q_a = \frac{q_i \times F_U \times F_R}{F_{FL}} \quad (18)$$

or

$$q_a = 0.10 q_i \quad (19)$$

The simplified Equations 17 and 19 provide an easy and quick solution to the problem of estimating the cooling load chargeable to electric, steam and fuel-fired cooking appliances located under an effective exhaust hood.

For all cooking appliances not installed under an exhaust hood or directly vent connected and located in the conditioned area the heat gain may be estimated as 50 percent (usage factor = 0.50) of the rated hourly input regardless of the type energy or fuel used. On the average, 34 percent of the heat may be assumed to be latent and the remaining 66 percent sensible heat.

Table 27 presents recommended data[42] for estimating the rate of heat gain from commercial cooking appliances. The data in the last column assumes installation under a properly designed exhaust hood connected to a mechanical fan-exhaust system. For poorly designed or undersized exhaust systems the heat gains listed should be doubled, and half of the increase assumed as latent heat.

Laboratory tests[42] have shown that radiant heat temperature rises can be substantially reduced by shielding the fronts of cooking appliances. These reductions amounted to 59 percent with asbestos paper, 61 percent with glass panels and 78 percent using polished aluminum shielding. A floor-slot air curtain in front of the appliances reduced the radiant temperature rise by 15 percent.

For each meal served the heat transferred to the dining space is approximately 50 Btu per hr, of which 75 percent is sensible and 25 percent latent.

Heat gains from cooking appliances, motors, lights, and people are not considered in cooling load calculations if the appliances are located in a separate kitchen that is not part of the conditioned area.

Table 28 lists suggested[42] rates of heat gain for miscellaneous electric and gas appliances.

LOAD FROM MOISTURE TRANSFER THROUGH PERMEABLE BUILDING MATERIALS

The diffusion of moisture through all common building materials is a natural phenomenon which is always present to a greater or lesser degree.

The permeability and permeance values for various building materials are given in Table 2 of Chapter 23, together with an explanation of moisture transmission through these materials.

In the usual comfort air-conditioning application, it is common practice to neglect moisture transfer through walls, because the actual rate is quite small and the corresponding latent-heat load is hardly significant. *Vapor barriers* are frequently employed in modern construction for the purpose of keeping moisture transfer to a minimum, and reducing the deteriorating and insulation-destroying effects of moisture.

Industrial jobs, on the other hand, frequently call for a low moisture content to be maintained in a conditioned space. Here the matter of moisture transfer cannot be neglected; indeed, it is quite possible to have the latent-heat load accompanying this transfer be of greater magnitude than any other latent-heat load. The equation for computing this load is:

$$\left(\frac{q_m}{A}\right) = \frac{M}{7000} \times \left(\begin{matrix}\text{Vapor-Pressure}\\ \text{Difference, In. Hg}\end{matrix}\right) \times 1076, \text{ Btuh/sq ft} \quad (20)$$

where

M = permeance of the specimen in perms, or grains per (square foot) (hour) (inch of mercury vapor-pressure difference).

7000 = grains per pound.

The factor 1076 is defined in list of symbols at Equation 8. (Sensible cooling of the water vapor is included in the factor 1076.)

The only means of preventing moisture transfer is to use a vapor proof wall, or to apply a special lining, which is vapor proof. All openings in moisture proof construction must be equipped with special gaskets to prevent entrance of moisture.

When moisture transfer contributes an appreciable part of the latent-heat load, it is recommended that estimates