to be rather minutely subdivided, whereas the *interior zone* spaces will commonly be divided into relatively large areas (such as stenographic rooms, lobbies, file rooms, etc.). All that has been previously said in this chapter applies to the peripheral zone areas; they will have rapidly changing cooling loads in summer, due to shifting sun and weather, and they will require heating in winter. During intermediate seasons one side of the building may require cooling while, at the same time, another requires heating. On the other hand, the interior zone spaces, whose thermal loads are derived almost entirely from lights, office equipment, and people, will require *cooling* at a *fairly uniform rate throughout* the year. Most often, conditioning of these interior spaces must be done by an independent system which is frequently of the *all-air* type. A considerable portion of the air extracted from these spaces must be reconditioned, mixed with a reasonable proportion of outdoor air at each circuit, and recirculated in order to achieve operating economy in summer and winter.

During intermediate seasons, when the outdoor temperatures approximate what the *delivery air* temperature should be for the zone, good results may often be obtained, without the use either of refrigeration or heat, by supplying a sufficient amount of outdoor air and little or no recirculation. Quite usually, the amount of true *exhaust* removed from office building floors will be relatively negligible, in comparison with the amounts of air to be supplied for conditioning but, in some manner, air must be removed at a rate comparable to rate of supply.

Office buildings will commonly be fully occupied during the hottest hours of the day (and little, or not at all, at night and on Sundays and holidays); therefore their *diversity-factor* will be *high* and their *annual load-factor* will be *low*.

2. *Hotel Rooms.* The typical hotel bedroom will be thermally similar to the peripheral zone rooms in office buildings except that, especially in tropical areas, they may be shaded frequently by outside balconies of some depth. Here the *similarity stops. Normally*, there will be an *interior* bathroom for each guest room and, in certain types of hotels, there may even be a small kitchenette. These will require exhaust ventilation that is quite often greater than the volume of outdoor air the bedroom itself would need for adequate ventilation. Since it is important to keep the bedroom slightly *pressurized* in order to avoid indrafts of possibly high-humidity air at windows, the bedroom air-conditioning system must bring in at least an amount of *conditioned* outdoor air equal to the amount of exhaust ventilation from bathrooms, etc. Also, since the door between public corridors and the bedroom should be tight-closing and, also, will be closed most of the time when the room is occupied, ventilation required for corridors, *serving pantries, or other such spaces* should be quite independent of the bedroom air-conditioning arrangement.

Guest rooms in hotels may be largely unoccupied during the hottest hours of the day (varying with locations and types of hotels), but will commonly be occupied at night and on holidays—thus giving a *lower* diversity-factor and a *higher* load-factor.

3. *Hospital Private and Semi-Private Patients' Rooms.* What has just been said of hotels applies in large measure to patients' rooms in hospitals but will be modified somewhat because one bathroom may serve several patients, and because doors between patients' rooms and corridors, etc., will be open more of the time than in a hotel.

Patients' rooms in hospitals will be occupied day and night for seven days of the week. This causes a still different relation between peak and average load conditions, all of which will affect both the required refrigerating capacity and its annual operating cost.

4. *Apartment Buildings.* These buildings differ from the previous three in a number of ways:

a. Typically, the individual rooms are larger.
b. Different rooms, even on opposite sides of the building in many cases, will often have archways or generally-open doors interconnecting them.
c. Kitchen exhaust will frequently be a factor that affects required air supply for the main rooms.
d. For reasons of esthetics and furniture layout, window areas may frequently be less in proportion to floor area than in the other three building types, especially if compared with office buildings.
e. There will be wide differences in electrical and human load, at different times. One apartment may be crowded with people, with all lights turned on, while another may be completely empty at the same time. The largest human and lighting loads will frequently occur after *sundown or late in the day. It is a real question* to what extent the air-conditioning should or can allow for the crowded conditions of a dinner party or cocktail party. This will to a large extent depend upon the type of house. What may be economically feasible in a luxury apartment may not be practicable for a low- or middle-income apartment. In many apartments, especially of the better grades, a *considerable* part of the population may be away (with all lights, etc., turned off) during some of the hottest periods of the year. Experience indicates that for all seasons the overall diversity factor for an apartment house will be very much lower than for other types of multiroom buildings.

These differences in buildings have been stressed to bring out the effect that they should have upon intelligent air-conditioning design. For the office building, the hotel, and probably the hospital, the air-conditioning will have a reasonably steady day-to-day use, so that investment and operating costs may be related to income earned. The apartment house, in most cases, must cope with the fact that some tenants will use the air conditioning much less than others, and some may object to paying a premium price for what they do not use or need. Systems entirely suitable for one type of multiroom building may not be the best for another type. For instance an apartment house owner may be more interested in low *initial* investment, whereas the hotel or office building may be more interested in low *annual* operating and maintenance costs.

## ZONING REQUIREMENTS

The first approach to a zoning problem is an examination of the building plans to determine the zoning requirements. *Any multistory building must be divided into four peripheral* zones (usually east, south, west and north), unless it is long and narrow with *blank* ends. The cooling load varies considerably as the sun progresses around the building. The presence or absence of this solar heat gain is one of the principal reasons for the zoning requirement. A fifth zone is created by any interior spaces with a load derived largely from people and lights.

The peak load for each outside zone must be determined by a detailed cooling estimate, considering the hours of maximum solar heat gain. These estimates for each zone must be further *analyzed to determine the peak load for the building* as a whole. Assuming that the sun-exposed walls are of approximately the same area—and not shaded by other buildings—the building peak (at 40 deg north latitude) will normally occur at 4:00 p.m. on or about August 1 when the west sun is at a peak and transmission gains may likewise be at a maximum.



Table 1 .... Total Sensible Heat Gain Through Unshaded Single Plate Glass

*For 35 to 45 deg North Latitude for Aug. 1*

| T.D. Deg. | Sun Time | Btu per (Hour)(Square Foot) — True Orientation (or Solar Azimuth) — Degrees: 0 | 30 | 60 | 90 | 120 | 150 | 180 | 210 | 240 | 270 | 300 | 330 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | 0800 | 11 | 45 | 170 | 183 | 170 | 82 | 14 | 9 | 9 | 9 | 9 | 9 |
| 13 | 0900 | 11 | 31 | 141 | 167 | 162 | 120 | 38 | 12 | 10 | 10 | 10 | 10 |
| 15 | 1000 | 17 | 21 | 62 | 121 | 136 | 132 | 70 | 23 | 20 | 20 | 20 | 19 |
| 17 | 1100 | 24 | 26 | 30 | 66 | 108 | 111 | 95 | 46 | 26 | 26 | 26 | 24 |
| 18 | 1200 | 32 | 32 | 32 | 34 | 53 | 96 | 108 | 94 | 57 | 34 | 32 | 32 |
| 19 | 1300 | 35 | 35 | 35 | 35 | 35 | 53 | 104 | 127 | 120 | 73 | 40 | 35 |
| 20 | 1400 | 36 36 | 36 | 36 | 36 | 36 | 40 | 87 | 150 | 156 | 140 | 80 | 41 |
| 20 | 1500 | 35 | 35 | 35 | 35 | 35 | 35 | 61 | 156 | 185 | 190 | 162 | 55 |
| 20 | 1600 | 34 | 34 | 34 | 34 | 34 | 34 | 38 | 111 | 191 | 212 | 198 | 85 |
| 20 | 1700 | 34 | 34 | 29 | 29 | 29 | 29 | 30 | 63 | 181 | 202 | 189 | 100 |
| 19 | 1800 | 40 | 23 | 22 | 22 | 22 | 22 | 24 | 38 | 113 | 138 | 142 | 115 |
| | SUMMATION | 308 | 352 | 626 | 762 | 820 | 754 | 669 | 829 | 1072 | 994 | 908 | 525 |
| | AVERAGE | 28 | 32 | 57 | 69 | 75 | 69 | 61 | 75 | 97 | 90 | 84 | 48 |

Note: Underlined figure is peak value for that orientation.

The tendency, however, *to assume* that the peak load on all buildings will occur at 4:00 p.m., may frequently be in error. If the time of the peak load is not obvious, the designer should carefully check the load at, say, 2:00 p.m. when the sun may be shining simultaneously on both the south and west windows, or at 10:00 a.m. when the sun is on both east and south windows. Likewise, in the northern hemisphere the angle of incidence of the south sun is decreased during the late fall and early winter, which greatly increases the solar heat gain on a south exposure. While this condition may not increase the load for the building as a whole, it will represent a *demand* peak for the south zone. In any case, the proposed zoning should be carefully analyzed for several different hours and for different *seasons to insure* adequate capacity at any time during the year.

## SOLAR HEAT GAINS

Table 1 shows total sensible heat gains through *unshaded* single plate glass, *per net* square foot of glass, for various orientations, including both *direct radiant* energy and *transmission* due to temperature-difference.

Table 1 is based entirely on methods described earlier in the 1961 GUIDE AND DATA BOOK except that the differential between outdoor dry-bulb temperature and (an assumed) 75 F indoor dry-bulb has been assumed to vary (as shown in Table 1), increasing gradually from early morning until late afternoon. For this chapter, it will suffice to say that the use *either* of heat-absorbing glass or of *good* reflective inside Venetian blinds will reduce the total by 40 to 50 percent under maximum sunshine and temperature conditions. This percentage will vary somewhat with time of day, orientation, weather, etc. It may also be noted that in early October total heat gain will be *greater* than in July and August by about 50 percent for true south exposure. This percentage decreases systematically to about 9 percent at 60 deg (azimuth) either side of south.

## INTERNAL LOADS

Aside from the sun effect, there are other variable loads. The use of lights will vary from room to room according to the type of work being done and to personal preference. There may likewise be heat loads from business machines in certain areas.

### Lighting Loads

In accordance with the most recent practice *in office* buildings, fluorescent lighting will vary from 3 to 5 watts per sq ft of floor area and incandescent lighting from 4 to 7 watts per sq ft. In some instances where concealed lighting is used, the load may be as high as 10 watts per sq ft. At one time, it was considered that only half the lights in outside sun-exposed bays would be in use when the sun is shining and, therefore, only half the heat gain from these lights was included simultaneously with the maximum solar heat gain. However, experience has proved that the occupant uses all of the lights (including those nearest the windows), hence the total lighting load should be included.

In hotels, apartment buildings and hospitals, the average lighting load is frequently 2 to 3 watts per sq ft. Such lighting can, as a rule, be ignored in outside rooms, or rather considered non-concurrent with maximum sun load.