CHAPTER 3. HEAT STORAGE, DIVERSITY AND STRATIFICATION

The normal load estimating procedure has been to evaluate the instantaneous heat gain to a space and to assume that the equipment will remove the heat at this rate. Generally, it was found that the equipment selected on this basis was oversized and therefore capable of maintaining much lower room conditions than the original design. Extensive analysis, research and testing have shown that the reasons for this are:

1. Storage of heat in the building structure.
2. Non-simultaneous occurrence of the peak of the individual loads (diversity).
3. Stratification of heat, in some cases.

This chapter contains the data and procedures for determining the load the equipment is actually picking up at any one time (actual cooling load), taking into account the above factors. Application of these data to the appropriate individual heat gains results in the actual cooling load.

The actual cooling load is generally considerably below the peak total instantaneous heat gain, thus requiring smaller equipment to perform a specific job. In addition, the air quantities and/or water quantities are reduced, resulting in a smaller overall system. Also, as brought out in the tables, if the equipment is operated somewhat longer during the peak load periods, and/or the temperature in the space is allowed to rise a few degrees at the peak periods during cooling operation, a further reduction in required capacity results. The smaller system operating for longer periods at times of peak load will produce a lower first cost to the customer with commensurate lower demand charges and lower operating costs. It is a well-known fact that equipment sized to more nearly meet the requirements results in a more efficient, better operating system. Also, if a smaller system is selected, and is based on extended periods of operation at the peak load, it results in a more economical and efficient system at a partially loaded condition.

Since, in most cases, the equipment installed to perform a specific function is smaller, there is less margin for error. This requires more exacting engineering including air distribution design and system balancing.

With multi-story, multi-room application, it is usually desirable to provide some flexibility in the air side or room load to allow for individual room control, load pickup, etc. Generally, it is recommended that the full reduction from storage and diversity be taken on the overall refrigeration or building load, with some degree of conservatism on the air side or room loads. This degree should be determined by the engineer from project requirements and customer desires. A system so designed, full reduction on refrigeration load and less than full reduction on air side or room load, meets all of the flexibility requirements, except at time of peak load. In addition, such a system has a low owning and operating cost.

STORAGE OF HEAT IN BUILDING STRUCTURES

The instantaneous heat gain in a typical comfort application consists of sun, lights, people, transmission thru walls, roof and glass, infiltration and ventilation air and, in some cases, machinery, appliances, electric calculating machines, etc. A large portion of this instantaneous heat gain is radiant heat which does not become an instantaneous load on the equipment, because it must strike a solid surface and be absorbed by this surface before becoming a load on the equipment. The breakdown on the various instantaneous heat gains into radiant heat and convected heat is approximately as follows:

HEAT GAIN SOURCE	RADIANT HEAT	CONVECTIVE HEAT
Solar, without inside blinds	100%	—
Solar, with inside blinds	58%	42%
Fluorescent Lights	50%	50%
Incandescent Lights	80%	20%
People*	40%	20%
Transmission†	60%	40%
Infiltration and Ventilation	—	100%
Machinery or Appliances‡	20-80%	80-20%

*The remaining 40% is dissipated as latent load.

†Transmission load is considered to be 100% convective load. This load is normally a relatively small part of the total load, and for simplicity is considered to be the instantaneous load on the equipment.

‡The load from machinery or appliances varies, depending upon the temperature of the surface. The higher the surface temperature, the greater the radiant heat load.

CONSTANT SPACE TEMPERATURE AND EQUIPMENT OPERATING PERIODS

As the radiant heat from sources shown in the above table strikes a solid surface (walls, floor, ceiling, etc.), it is absorbed, raising the temperature at the surface of the material above that inside the material and the air adjacent to the surface. This temperature difference causes heat flow into the material by conduction and into the air by convection. The heat conducted away from the surface is stored, and the heat convected from the surface becomes an instantaneous cooling load. The portion of radiant heat being stored depends on the ratio of the resistance to heat flow into the material and the resistance to heat flow into the air film. With most construction materials, the resistance to heat flow into the material is much lower than the air resistance; therefore, most of the radiant heat will be stored. However, as this process of absorbing radiant heat continues, the material becomes warmer and less capable of storing more heat.

The highly varying and relatively sharp peak of the instantaneous solar heat gain results in a large part of it being stored at the time of peak solar heat gain, as illustrated in *Fig. 3*.

The upper curve in *Fig. 3* is typical of the *solar heat gain* for a west exposure, and the lower curve is the actual cooling load that results in an average construction application with the space temperature held constant. The reduction in the peak heat gain is approximately 40% and the peak load lags the peak heat gain by approximately 1 hour. The cross-hatched areas *(Fig. 3)* represent the Heat Stored and the Stored Heat Removed from the construction. Since all of the heat coming into a space must be removed, these two areas are equal.

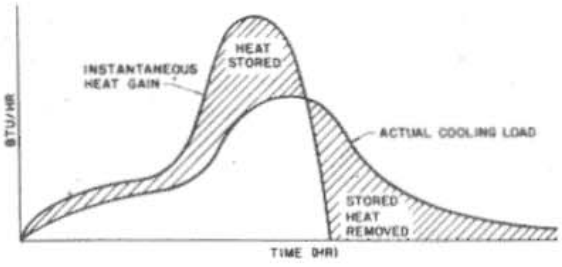


FIG. 3 — ACTUAL COOLING LOAD, SOLAR HEAT GAIN, WEST EXPOSURE, AVERAGE CONSTRUCTION

The relatively constant light load results in a large portion being stored just after the lights are turned on, with a decreasing amount being stored the longer the lights are on, as illustrated in *Fig. 4*.

The upper and lower curves represent the instantaneous heat gain and actual cooling load from *fluorescent lights* with a constant space temperature. The cross-hatched areas are the Heat Stored and the Stored Heat Removed from the construction. The dotted line indicates the actual cooling load for the first day if the lights are on longer than the period shown.

Figs. 3 and 4 illustrate the relationship between the instantaneous heat gain and the actual cooling load in average construction spaces. With light construction, less heat is stored at the peak (less storage capacity available), and with heavy construction, more heat is stored at the peak (more storage capacity available), as shown in *Fig. 5*. This aspect affects the extent of zoning required in the design of a system for a given building; the lighter the building construction, the more attention should be given to zoning.

The upper curve of *Fig. 5* is the instantaneous solar heat gain while the three lower curves are the actual cooling load for *light, medium and heavy construction* respectively, with a constant temperature in the space.

One more item that significantly affects the storage of heat is the operating period of the air conditioning equipment. All of the curves shown in

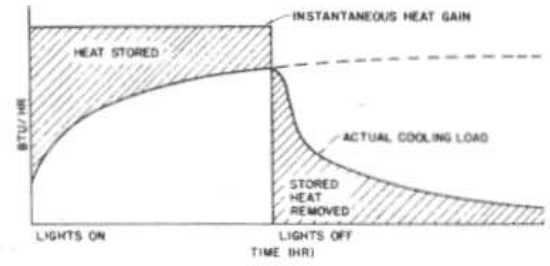


FIG. 4 — ACTUAL COOLING LOAD FROM FLUORESCENT LIGHTS, AVERAGE CONSTRUCTION

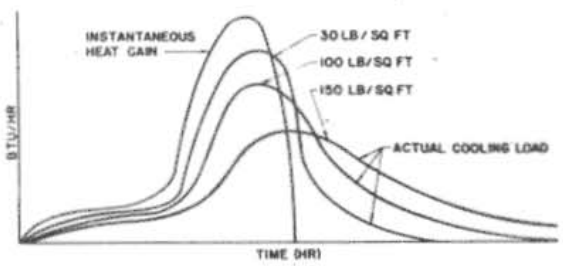


FIG. 5 — ACTUAL COOLING LOAD, SOLAR HEAT GAIN, LIGHT, MEDIUM AND HEAVY CONSTRUCTION

Figs. 3, 4, and 5 illustrate the actual cooling load for 24-hour operation. If the equipment is shut down after 16 hours of operation, some of the stored heat remains in the building construction. This heat must be removed (heat in must equal heat out) and will appear as a pulldown load when the equipment is turned on the next day, as illustrated in *Fig. 6*.

Adding the pulldown load to the cooling load for that day results in the actual cooling load for *16-hour operation,* as illustrated in *Fig. 7*.

The upper curve represents the instantaneous heat gain and the lower curve the *actual cooling load* for that day with a constant temperature maintained within the space during the operating period of the equipment. The dotted line represents the additional cooling load from the heat left in the building construction. The temperature in the space rises during the shutdown period from the nighttime transmission load and the stored heat, and is brought back to the control point during the pulldown period.

Shorter periods of operation increase the pulldown load because more stored heat is left in the building construction when the equipment is shut off. *Fig. 8* illustrates the *pulldown load for 12-hour operation*.

Adding this pulldown load to the cooling load for that day results in the actual cooling load for *12-hour operation,* as illustrated in *Fig. 9*.

The upper and lower solid curves are the instantaneous heat gain and the actual cooling load in average construction space with a constant temperature maintained during the operating period. The cross-hatched areas again represent the Heat Stored and the Stored Heat Removed from the construction.

The *light load (fluorescent)* is shown in *Fig. 10* for *12- and 16-hour operation* with a constant space temperature (assuming 10-hour operation of lights).

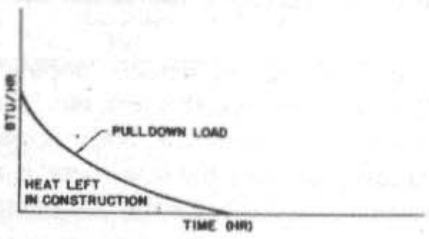


FIG. 6 — PULLDOWN LOAD, SOLAR HEAT GAIN, WEST EXPOSURE, 16-HOUR OPERATION

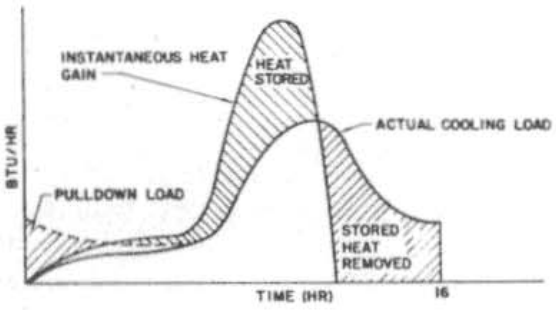


FIG. 7 — ACTUAL COOLING LOAD, SOLAR HEAT GAIN, WEST EXPOSURE, 16-HOUR OPERATION

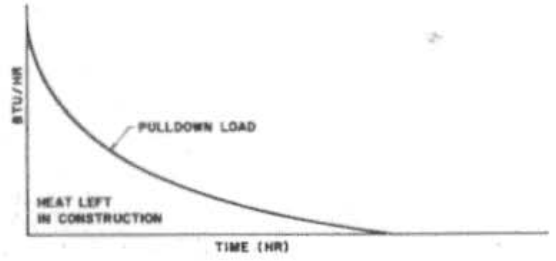


FIG. 8 — PULLDOWN LOAD, SOLAR HEAT GAIN, WEST EXPOSURE, 12-HOUR OPERATION

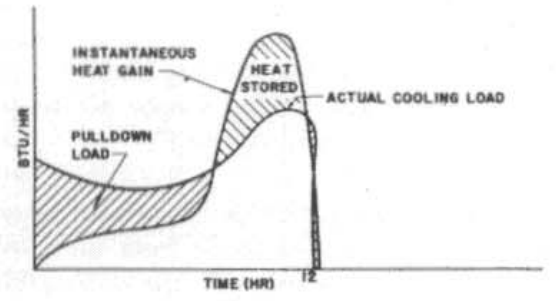


FIG. 9 — ACTUAL COOLING LOAD, SOLAR HEAT GAIN, WEST EXPOSURE, 12-HOUR OPERATION

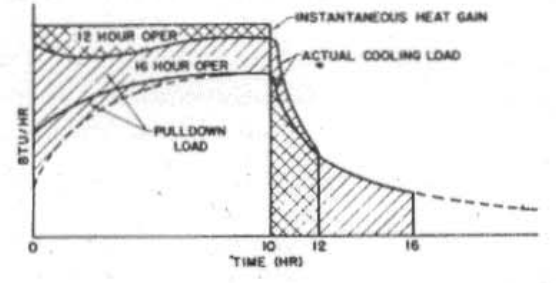


FIG. 10 — ACTUAL COOLING LOAD FROM FLUORESCENT LIGHTS, 12- AND 16-HOUR OPERATION

Basis of Tables 7 thru 12
Storage Load Factors, Solar and Light Heat Gain
12-, 16-, and 24-hour Operation, Constant Space Temperature

These tables are calculated, using a procedure developed from a series of tests in actual buildings. These tests were conducted in office buildings, supermarkets, and residences throughout this country.

The magnitude of the storage effect is determined largely by the thermal capacity or heat holding capacity of the materials surrounding the space. The thermal capacity of a material is the weight times the specific heat of the material. Since the specific heat of most construction material is approximately 0.20 Btu/(lb)(F), the thermal capacity is directly proportional to the weight of the material. Therefore, the data in the tables is based on weight of the materials surrounding the space, per square foot of floor area.

Use of Tables 7 thru 12
Storage Load Factors, Solar and Light Heat Gain
12-, 16-, and 24-hour Operation, Constant Space Temperature

Tables 7 thru 11 are used to determine the actual cooling load from the solar heat gain with a constant temperature maintained within the space for different types of construction and periods of operation. With both the 12- and 16-hour factors, the starting time is assumed to be 6 a.m. suntime (7 a.m. Daylight Saving Time). The weight per sq ft of types of construction are listed in *Tables 21 thru 33, pages 66-76.*

The actual cooling load is determined by multiplying the storage load factor from these tables for any or all times by the peak solar heat gain for the particular exposure, month and latitude desired. *Table 6* is a compilation of the peak solar heat gains for each exposure, month and latitude. These values are extracted from *Table 15, page 44.* The peak solar heat gain is also to be multiplied by either or both the applicable over-all factor for shading devices *(Table 16, page 52)* and the corrections listed under *Table 6.* Reduction in solar heat gain from the shading of the window by reveals and/or overhang should also be utilized.

Example 1 — Actual Cooling Load, Solar Heat Gain

Given:

A 20 ft × 20 ft × 8 ft outside office room with 6-inch sand aggregate concrete floor, with a floor tile finish, 2½-inch solid sand plaster partitions, no suspended ceiling, and a 12-inch common brick outside wall with ½-inch sand aggregate plaster finish on inside surface. A 16 ft × 5 ft steel sash window with a white venetian blind is in the outside wall and the wall faces west.

Find:

A. The actual cooling load from the solar heat gain in July at 4 p.m., 40° North latitude with the air conditioning equipment operating 24 hours during the peak load periods and a constant temperature maintained within the room:

B. The cooling load at 8 p.m. for the same conditions.

Solution:

The weight per sq ft of floor area of this room (values obtained from *Chapter 5*) is:

$$\text{Outside wall} = \frac{(20 \times 8) - (16 \times 5)}{20 \times 20} \times 126 \text{ lb/sq ft}$$

(Table 21, page 66)

$$= 25.2 \text{ lb/sq ft floor area}$$

$$\text{Partitions} = \tfrac{1}{2} \times \frac{20 \times 8 \times 3}{20 \times 20} \times 22 \text{ lb/sq ft}$$

(Table 26, page 70)

$$= 13.2 \text{ lb/sq ft floor area}$$

$$\text{Floor} = \tfrac{1}{2} \times \frac{20 \times 20}{20 \times 20} \times 59 \text{ lb/sq ft}$$

(Table 29, page 73)

$$= 29.5 \text{ lb/sq ft floor area}$$

$$\text{Ceiling} = \tfrac{1}{2} \times \frac{20 \times 20}{20 \times 20} \times 59 \text{ lb/sq ft}$$

(Table 29, page 73)

$$= 29.5 \text{ lb/sq ft floor area}$$

NOTE: One-half of the partition, floor and ceiling thickness is used, assuming that the spaces above and below are conditioned and are utilizing the other halves for storage of heat.

Total weight per sq ft of floor area
$= 25.2 + 13.2 + 29.5 + 29.5 = 97.4$ lb/sq ft.

The overall factor for the window with the white venetian blind is 0.56 *(Table 16, page 52)* and the correction for steel sash = 1/.85.

A. Storage factor, 4 p.m. = 0.66 *(Table 7)*

The peak solar heat gain for a west exposure in July at 40° North latitude = 164 Btu/(hr)(sq ft), *(Table 6).*

Actual cooling load

$$= \left(5 \times 16 \times 164 \times .56 \times \frac{1}{.85}\right) \times 0.66 = 5700 \text{ Btu/hr}$$

B. Storage factor, 8 p.m. = .20 *(Table 7)*

Actual cooling load

$$= \left(5 \times 16 \times 164 \times .56 \times \frac{1}{.85}\right) \times .20 = 1730 \text{ Btu/hr}$$

Table 12 is used to determine the actual cooling load from the heat gain from lights. These data may also be used to determine the actual cooling load from:

1. People — except in densely populated areas such as auditoriums, theaters, etc. The radiant heat exchange from the body is reduced in situations like this because there is relatively less surface available for the body to radiate to.
2. Some appliances and machines that operate periodically, with hot exterior surfaces such as ovens, dryers, hot tanks, etc.

NOTE: For Items 1 and 2 above, use values listed for fluorescent exposed lights.

Example 2 — Actual Cooling Load, Lights and People

Given:

The same room as in *Example 1* with a light heat gain of 3 watts per sq ft of floor area not including ballast, exposed fluorescent lights and 4 people. The room temperature to be maintained at 78 F db with 24-hour operation during the peak load periods.

Find:

The actual cooling load at 4 p.m. (with the lights turned on as the people arrive at 8 a.m.).

Solution:

The time elapsed after the lights are turned on is 8 hours (8 a.m. to 4 p.m.).

Storage load factor = .87 *(Table 12)*.

Sensible heat gain from people = 215 Btu/hr *(Table 48, page 100)*

Actual cooling load

$= [(3 \times 3.4 \times 1.25 \times 20 \times 20) + (4 \times 215)] \times .87$

$= 5190$ Btu/hr.

TABLE 6—PEAK SOLAR HEAT GAIN THRU ORDINARY GLASS*

Btu/(hr)(sq ft)

NORTH LAT.	MONTH	EXPOSURE NORTH LATITUDE N†	NE	E	SE	S	SW	W	NW	Horiz	MONTH	SOUTH LAT.
0°	June	59	156	147	42	14	42	147	156	226	Dec	0°
	July & May	48	153	152	52	14	52	152	153	233	Nov & Jan	
	Aug & April	25	141	163	79	14	79	163	141	245	Oct & Feb	
	Sept & March	10	118	167	118	14	118	167	118	250	Sept & March	
	Oct & Feb	10	79	163	141	34	141	163	79	245	Aug & April	
	Nov & Jan	10	52	152	153	67	153	152	52	233	July & May	
	Dec	10	42	147	156	82	156	147	42	226	June	
10°	June	40	153	155	55	14	55	155	153	243	Dec	10°
	July & May	30	148	158	66	14	66	158	148	247	Nov & Jan	
	Aug & April	13	130	163	94	14	94	163	130	250	Oct & Feb	
	Sept & March	10	103	164	127	28	127	164	103	247	Sept & March	
	Oct & Feb	10	66	155	149	73	149	155	66	230	Aug & April	
	Nov & Jan	9	37	143	161	106	101	143	37	210	July & May	
	Dec	9	28	137	163	120	163	137	28	202	June	
20°	June	26	154	160	73	14	73	160	154	250	Dec	20°
	July & May	19	138	163	85	14	85	163	138	251	Nov & Jan	
	Aug & April	11	118	165	113	26	113	165	118	247	Oct & Feb	
	Sept & March	10	87	163	140	65	140	163	87	233	Sept & March	
	Oct & Feb	9	52	147	160	111	160	147	52	208	Aug & April	
	Nov & Jan	8	26	128	164	141	164	128	26	180	July & May	
	Dec	8	18	121	167	149	167	121	18	170	June	
30°	June	20	139	161	90	21	90	161	139	250	Dec	30°
	July & May	16	131	164	100	30	100	164	131	246	Nov & Jan	
	Aug & April	11	108	165	129	63	129	165	108	235	Oct & Feb	
	Sept & March	9	90	158	152	105	152	158	90	212	Sept & March	
	Oct & Feb	8	39	135	163	145	163	135	39	179	Aug & April	
	Nov & Jan	7	16	116	162	159	162	116	16	145	July & May	
	Dec	6	12	105	162	163	162	105	12	131	June	
40°	June	17	133	162	111	54	111	162	133	237	Dec	40°
	July & May	15	127	164	125	69	125	164	127	233	Nov & Jan	
	Aug & April	11	102	162	146	102	146	162	102	214	Oct & Feb	
	Sept & March	9	58	149	162	140	162	149	58	183	Sept & March	
	Oct & Feb	7	35	122	163	162	163	122	35	129	Aug & April	
	Nov & Jan	5	12	100	156	166	156	100	12	103	July & May	
	Dec	5	10	86	148	165	148	86	10	85	June	
50°	June	16	126	164	135	93	135	164	126	220	Dec	50°
	July & May	14	117	163	143	106	143	163	117	211	Nov & Jan	
	Aug & April	11	94	158	157	138	157	158	94	185	Oct & Feb	
	Sept & March	8	58	138	163	158	163	138	58	148	Sept & March	
	Oct & Feb	5	29	105	157	167	157	105	29	94	Aug & April	
	Nov & Jan	4	9	64	127	153	127	64	9	53	July & May	
	Dec	3	7	47	116	141	116	47	7	40	June	
		S	SE	E	NE	N	NW	W	SW	Horiz		
		EXPOSURE SOUTH LATITUDE										

Solar Gain Correction	Steel Sash or No Sash	Haze	Altitude	Dewpoint Above 67 F	Dewpoint Below 67 F	South Lat Dec or Jan
	×1/.85 or 1.17	−15% (Max)	+0.7% per 1000 ft	−7% per 10 F	+7% per 10 F	+7%

*Abstracted from *Table 15, page 43.*

†Solar heat gain on North exposure (in North latitudes) or on South exposure (in South latitudes) consists primarily of diffuse radiation which is essentially constant throughout the day. The solar heat gain values for this exposure are the average for the 12 hr period (6 a.m. to 6 p.m.). The storage factors in *Tables 7 thru 11* assume that the solar heat gain on the North (or South) exposure is constant.

TABLE 7—STORAGE LOAD FACTORS, SOLAR HEAT GAIN THRU GLASS

WITH INTERNAL SHADE*

24 Hour Operation, Constant Space Temperature†

EXPOSURE (North Lat)	WEIGHT§ (lb per sq ft of floor area)	SUN TIME																							EXPOSURE (South Lat)
		AM							PM											AM					
		6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	
Northeast	150 & over	.47	.58	.54	.42	.27	.21	.20	.19	.18	.17	.16	.14	.12	.09	.08	.07	.06	.06	.05	.05	.04	.04	.04	.03	Southeast
	100	.48	.60	.57	.46	.30	.24	.20	.19	.17	.16	.15	.13	.11	.08	.07	.06	.05	.05	.04	.04	.03	.03	.02	.02	
	30	.55	.76	.73	.58	.36	.24	.19	.17	.15	.13	.12	.11	.07	.04	.02	.02	.01	.01	0	0	0	0	0	0	
East	150 & over	.39	.56	.62	.59	.49	.33	.23	.21	.20	.18	.17	.15	.12	.10	.09	.08	.08	.07	.06	.05	.05	.05	.04	.04	East
	100	.40	.58	.65	.63	.52	.35	.24	.22	.20	.18	.16	.14	.12	.09	.08	.07	.06	.05	.05	.04	.04	.03	.03	.02	
	30	.46	.70	.80	.79	.64	.42	.25	.19	.16	.14	.11	.09	.07	.04	.02	.02	.01	.01	0	0	0	0	0	0	
Southeast	150 & over	.04	.28	.47	.59	.64	.62	.53	.41	.27	.24	.21	.19	.16	.14	.12	.11	.10	.09	.08	.07	.06	.06	.05	.05	Northeast
	100	.03	.28	.47	.61	.67	.65	.57	.44	.29	.24	.21	.18	.15	.12	.10	.09	.08	.07	.06	.05	.05	.04	.04	.03	
	30	0	.30	.57	.75	.84	.81	.69	.50	.30	.20	.17	.13	.09	.05	.04	.03	.02	.01	0	0	0	0	0	0	
South	150 & over	.06	.06	.23	.38	.51	.60	.66	.67	.64	.59	.42	.24	.22	.19	.17	.15	.13	.12	.11	.10	.09	.08	.07	.07	North
	100	.04	.04	.22	.38	.52	.63	.70	.71	.69	.59	.45	.26	.22	.18	.16	.13	.12	.10	.09	.08	.07	.06	.06	.05	
	30	.10	.21	.43	.63	.77	.86	.88	.82	.56	.50	.24	.16	.11	.08	.05	.04	.02	.02	.01	.01	0	0	0	0	
Southwest	150 & over	.08	.08	.09	.10	.11	.24	.39	.53	.63	.66	.61	.47	.23	.19	.18	.16	.14	.13	.11	.10	.09	.08	.08	.07	Northwest
	100	.07	.08	.08	.08	.10	.24	.40	.55	.66	.70	.64	.50	.26	.20	.17	.15	.13	.11	.10	.09	.08	.07	.06	.05	
	30	.03	.04	.06	.07	.09	.23	.47	.67	.81	.86	.79	.60	.26	.17	.12	.08	.05	.04	.03	.02	.01	.01	0	0	
West	150 & over	.08	.09	.09	.10	.10	.10	.10	.18	.36	.52	.63	.65	.55	.22	.19	.17	.15	.14	.12	.11	.10	.09	.08	.07	West
	100	.07	.08	.08	.09	.09	.09	.09	.18	.36	.54	.66	.68	.60	.25	.20	.17	.15	.13	.11	.10	.08	.07	.06	.05	
	30	.03	.04	.06	.07	.08	.08	.08	.19	.42	.65	.81	.85	.74	.30	.19	.13	.09	.06	.05	.03	.02	.02	.01	0	
Northwest	150 & over	.08	.09	.10	.10	.10	.10	.10	.10	.16	.33	.49	.61	.60	.19	.17	.15	.13	.12	.10	.09	.08	.08	.07	.06	Southwest
	100	.07	.08	.09	.09	.10	.10	.10	.10	.16	.34	.52	.65	.64	.23	.18	.15	.12	.11	.09	.08	.07	.06	.06	.05	
	30	.03	.05	.07	.08	.09	.09	.10	.10	.17	.39	.63	.80	.79	.28	.18	.12	.09	.06	.04	.03	.02	.02	.01	0	
North and Shade	150 & over	.08	.37	.67	.71	.74	.76	.79	.81	.83	.84	.86	.87	.88	.29	.26	.23	.20	.19	.17	15	.14	.12	.11	.10	South and Shade
	100	.06	.31	.67	.72	.76	.79	.81	.83	.85	.87	.88	.90	.91	.30	.26	.22	.19	.16	.15	.13	.12	.10	.09	.08	
	30	0	.25	.74	.83	.88	.91	.94	.96	.96	.98	.98	.99	.99	.26	.17	.12	.08	.05	.04	.03	.02	.01	.01	.01	

Equation: Cooling Load, Btu/hr = [Peak solar heat gain, Btu/(hr) (sq ft), (*Table 6*)]
× [Window area, sq ft]
× [Shade factor, Haze factor, etc., (*Chapter 4*)]
× [Storage factor, (above Table at desired time)]

*Internal shading device is any type of shade located on the inside of the glass.

†These factors apply when maintaining a CONSTANT TEMPERATURE in the space during the operating period. Where the temperature is allowed to swing, additional storage will result during peak load periods. Refer to *Table 13* for applicable storage factors.

§Weight per sq ft of floor—

$$\text{Room on Bldg Exterior (One or more outside walls)} = \frac{\text{(Weight of Outside Walls, lb)} + \tfrac{1}{2}\text{ (Weight of Partitions, Floor and Ceiling, lb)}}{\text{Floor Area in Room, sq ft}}$$

$$\text{Room in Bldg Interior (No outside walls)} = \frac{\tfrac{1}{2}\text{ (Weight of Partitions, Floor and Ceiling, lb)}}{\text{Floor Area in Room, sq ft}}$$

$$\text{Basement Room (Floor on ground)} = \frac{\text{(Weight of Outside Walls, lb)} + \text{(Weight of Floor, lb)} + \tfrac{1}{2}\text{ (Weight of Partitions and Ceiling, lb)}}{\text{Floor Area in Room, sq ft}}$$

$$\text{Entire Building or Zone} = \frac{\text{(Weight of Outside Wall, Partitions, Floors, Ceilings, Structural Members and Supports, lb)}}{\text{Air Conditioned Floor Area, sq ft}}$$

With rug on floor—Weight of floor should be multiplied by 0.50 to compensate for insulating effect of rug.

Weights per sq ft of common types of construction are contained in *Tables 21 thru 33, pages 66 thru 76.*

TABLE 8—STORAGE LOAD FACTORS, SOLAR HEAT GAIN THRU GLASS

WITH BARE GLASS OR WITH EXTERNAL SHADE‡

24 Hour Operation, Constant Space Temperature†

EXPOSURE (North Lat)	WEIGHT§ (lb per sq ft of floor area)	SUN TIME AM 6	7	8	9	10	11	12	PM 1	2	3	4	5	6	7	8	9	10	11	12	AM 1	2	3	4	5	EXPOSURE (South Lat)
Northeast	150 & over	.17	.27	.33	.33	.31	.2	.27	.25	.23	.22	.20	.19	.17	.15	.14	.12	.11	.10	.09	.08	.07	.07	.06	.06	
	100	.19	.31	.38	.39	.36	.3	.27	.24	.22	.21	.19	.17	.16	.14	.12	.10	.07	.08	.07	.06	.05	.05	.04	.03	Southeast
	30	.31	.56	.65	.61	.46	.3	.26	.21	.18	.16	.14	.12	.09	.06	.04	.03	.02	.01	.01	.01	0	0	0	0	
East	150 & over	.16	.26	.34	.39	.40	.3	.34	.30	.28	.26	.23	.22	.20	.18	.16	.14	.13	.12	.10	.09	.08	.08	.07	.06	
	100	.16	.29	.40	.46	.46	.42	.36	.31	.28	.25	.23	.20	.18	.15	.14	.12	.11	.09	.08	.08	.06	.06	.05	.04	East
	30	.27	.50	.67	.73	.68	.53	.38	.27	.22	.18	.15	.12	.09	.06	.04	.03	.02	.01	.01	.01	.01	0	0	.01	
Southeast	150 & over	.08	.14	.22	.31	.38	.43	.44	.43	.39	.35	.32	.29	.26	.23	.21	.19	.16	.15	.13	.12	.11	.10	.09	.08	
	100	.05	.12	.23	.35	.44	.49	.51	.47	.41	.36	.31	.27	.24	.21	.18	.16	.14	.12	.10	.09	.08	.08	.06	.06	Northeast
	30	0	.18	.40	.59	.72	.77	.72	.60	.44	.32	.23	.18	.14	.09	.07	.05	.03	.02	.01	.01	.01	0	0	0	
South	150 & over	.10	.10	.13	.20	.28	.35	.42	.48	.51	.51	.48	.42	.37	.33	.29	.26	.23	.21	.19	.17	.15	.14	.13	.12	
	100	.07	.06	.12	.20	.30	.39	.48	.54	.58	.57	.53	.45	.37	.31	.27	.23	.20	.18	.16	.14	.12	.11	.10	.08	North
	30	0	0	.12	.29	.48	.64	.75	.82	.81	.75	.61	.42	.28	.19	.13	.09	.06	.04	.03	.02	.01	.01	0	0	
Southwest	150 & over	.11	.10	.10	.10	.10	.14	.21	.29	.36	.43	.47	.46	.40	.34	.30	.27	.24	.22	.20	.18	.16	.14	.13	.12	
	100	.09	.09	.08	.09	.09	.14	.22	.31	.42	.50	.53	.51	.44	.35	.29	.26	.22	.19	.17	.15	.13	.12	.11	.09	Northwest
	30	.02	.03	.05	.06	.08	.12	.34	.53	.68	.78	.78	.68	.46	.29	.20	.14	.09	.07	.05	.03	.02	.02	.01	.01	
West	150 & over	.12	.11	.11	.10	.10	.10	.10	.13	.19	.27	.36	.42	.44	.38	.33	.29	.26	.23	.21	.18	.16	.15	.13	.12	
	100	.09	.09	.09	.09	.09	.09	.10	.12	.19	.30	.40	.48	.51	.42	.35	.30	.25	.22	.19	.16	.14	.13	.11	.09	West
	30	.02	.03	.05	.06	.07	.07	.08	.14	.29	.49	.67	.76	.75	.53	.33	.22	.15	.11	.08	.05	.04	.03	.02	.01	
Northwest	150 & over	.10	.10	.10	.10	.10	.10	.10	.10	.12	.17	.25	.34	.39	.34	.29	.26	.23	.20	.18	.16	.14	.13	.12	.10	
	100	.08	.09	.09	.09	.09	.09	.09	.09	.11	.19	.29	.40	.46	.40	.32	.26	.22	.19	.16	.14	.13	.11	.10	.08	Southwest
	30	.02	.04	.05	.07	.08	.09	.10	.10	.13	.27	.48	.65	.73	.49	.31	.21	.16	.10	.07	.05	.04	.03	.02	.01	
North and Shade	150 & over	.16	.23	.33	.41	.47	.52	.57	.61	.66	.69	.72	.74	.59	.52	.46	.42	.37	.34	.31	.27	.25	.23	.21	.17	
	100	.11	.33	.44	.51	.57	.62	.66	.70	.74	.76	.79	.80	.60	.51	.44	.37	.32	.29	.27	.23	.21	.18	.16	.13	South and Shade
	30	0	.48	.66	.76	.82	.87	.91	.93	.95	.97	.98	.98	.52	.34	.24	.16	.11	.07	.05	.04	.02	.02	.01	.01	

Equation: Cooling Load, Btu/hr = [Peak solar heat gain, Btu/(hr) (sq ft), (*Table 6*)]
× [Window area, sq ft]
× [Shade factor, Haze factor, etc., (*Chapter 4*)]
× [Storage factor, (above Table at desired time)]

‡Bare glass — Any window with no inside shading device. Windows with shading devices on the outside or shaded by external projections are considered bare glass.

†These factors apply when maintaining a CONSTANT TEMPERATURE in the space during the operating period. Where the temperature is allowed to swing, additional storage will result during peak load periods. Refer to *Table 13* for applicable storage factors.

§Weight per sq ft of floor—

$$\text{Room on Bldg Exterior (One or more outside walls)} = \frac{\text{(Weight of Outside Walls, lb)} + \tfrac{1}{2}\text{ (Weight of Partitions, Floor and Ceiling, lb)}}{\text{Floor Area in Room, sq ft}}$$

$$\text{Room in Bldg Interior (No outside walls)} = \frac{\tfrac{1}{2}\text{ (Weight of Partitions, Floor and Ceiling, lb)}}{\text{Floor Area in Room, sq ft}}$$

$$\text{Basement Room (Floor on ground)} = \frac{\text{(Weight of Outside Walls, lb)} + \text{(Weight of Floor, lb)} + \tfrac{1}{2}\text{ (Weight of Partitions and Ceiling, lb)}}{\text{Floor Area in Room, sq ft}}$$

$$\text{Entire Building or Zone} = \frac{\text{(Weight of Outside Wall, Partitions, Floors, Ceilings, Structural Members and Supports, lb)}}{\text{Air Conditioned Floor Area, sq ft}}$$

With rug on floor—Weight of floor should be multiplied by 0.50 to compensate for insulating effect of rug.
Weights per sq ft of common types of construction are contained in *Tables 21 thru 33, pages 66 thru 76.*

TABLE 9—STORAGE LOAD FACTORS, SOLAR HEAT GAIN THRU GLASS

WITH INTERNAL SHADING DEVICE*

16 Hour Operation, Constant Space Temperature†

EXPOSURE (North Lat)	WEIGHT§ (lb per sq ft of floor area)	SUN TIME AM 6	7	8	9	10	11	12	PM 1	2	3	4	5	6	7	8	9	EXPOSURE (South Lat)
Northeast	150 & over	.53	.64	.59	.47	.31	.25	.24	.22	.18	.17	.16	.14	.12	.09	.08	.07	Southeast
	100	.53	.65	.61	.50	.33	.27	.22	.21	.17	.16	.15	.13	.11	.08	.07	.06	
	30	.56	.77	.73	.58	.36	.24	.19	.17	.15	.13	.12	.11	.07	.04	.02	.02	
East	150 & over	.47	.63	.68	.64	.54	.38	.27	.25	.20	.18	.17	.15	.12	.10	.09	.08	East
	100	.46	.63	.70	.67	.56	.38	.27	.24	.20	.18	.16	.14	.12	.09	.08	.07	
	30	.47	.71	.80	.79	.64	.42	.25	.19	.16	.14	.11	.09	.07	.04	.02	.02	
Southeast	150 & over	.14	.37	.55	.66	.70	.68	.58	.46	.27	.24	.21	.19	.16	.14	.12	.11	Northeast
	100	.11	.35	.53	.66	.72	.69	.61	.47	.29	.24	.21	.18	.15	.12	.10	.09	
	30	.02	.31	.57	.75	.84	.81	.69	.50	.30	.20	.17	.13	.09	.05	.04	.03	
South	150 & over	.19	.18	.34	.48	.60	.68	.73	.74	.64	.59	.42	.24	.22	.19	.17	.15	North
	100	.16	.14	.31	.46	.59	.69	.76	.70	.69	.59	.45	.26	.22	.18	.16	.13	
	30	.12	.23	.44	.64	.77	.86	.88	.82	.56	.50	.24	.16	.11	.08	.05	.04	
Southwest	150 & over	.22	.21	.20	.20	.20	.32	.47	.60	.63	.66	.61	.47	.23	.19	.18	.16	Northwest
	100	.20	.19	.18	.17	.18	.31	.46	.60	.66	.70	.64	.50	.26	.20	.17	.15	
	30	.08	.08	.09	.09	.10	.24	.47	.67	.81	.86	.79	.60	.26	.17	.12	.08	
West	150 & over	.23	.23	.21	.21	.20	.19	.18	.25	.36	.52	.63	.65	.55	.22	.19	.17	West
	100	.22	.21	.19	.19	.17	.16	.15	.23	.36	.54	.66	.68	.60	.25	.20	.17	
	30	.12	.10	.10	.10	.10	.10	.09	.19	.42	.65	.81	.85	.74	.30	.19	.13	
Northwest	150 & over	.21	.21	.20	.19	.18	.18	.17	.16	.16	.33	.49	.61	.60	.19	.17	.15	Southwest
	100	.19	.19	.18	.17	.17	.16	.16	.15	.16	.34	.52	.65	.23	.18	.15	.12	
	30	.12	.11	.11	.11	.13	.11	.11	.10	.17	.39	.63	.80	.79	.28	.18	.12	
North and Shade	150 & over	.23	.58	.75	.79	.80	.80	.81	.82	.83	.84	.86	.87	.88	.39	.35	.31	South and Shade
	100	.25	.46	.73	.78	.82	.82	.83	.84	.85	.87	.88	.89	.90	.40	.34	.29	
	30	.07	.22	.69	.80	.86	.93	.94	.95	.97	.98	.98	.99	.99	.35	.23	.16	

Equation: Cooling Load, Btu/hr = [Peak solar heat gain, Btu/(hr) (sq ft), (*Table 6*)]
× [Window area, sq ft]
× [Shade factor, Haze factor, etc., (*Chapter 4*)]
× [Storage factor, (above Table at desired time)]

*Internal shading' device is any type of shade located on the inside of the glass.

†These factors apply when maintaining a CONSTANT TEMPERATURE in the space during the operating period. Where the temperature is allowed to swing, additional storage will result during peak load periods. Refer to *Table 13* for applicable storage factors.

§Weight per sq ft of floor—

$$\text{Room on Bldg Exterior (One or more outside walls)} = \frac{\text{(Weight of Outside Walls, lb)} + \frac{1}{2}\text{ (Weight of Partitions, Floor and Ceiling, lb)}}{\text{Floor Area in Room, sq ft}}$$

$$\text{Room in Bldg Interior (No outside walls)} = \frac{\frac{1}{2}\text{ (Weight of Partitions, Floor and Ceiling, lb)}}{\text{Floor Area in Room, sq ft}}$$

$$\text{Basement Room (Floor on ground)} = \frac{\text{(Weight of Outside Walls, lb)} + \text{(Weight of Floor, lb)} + \frac{1}{2}\text{ (Weight of Partitions and Ceiling, lb)}}{\text{Floor Area in Room, sq ft}}$$

$$\text{Entire Building or Zone} = \frac{\text{(Weight of Outside Wall, Partitions, Floors, Ceilings, Structural Members and Supports, lb)}}{\text{Air Conditioned Floor Area, sq ft}}$$

With rug on floor—Weight of floor should be multiplied by 0.50 to compensate for insulating effect of rug.
Weights per sq ft of common types of construction are contained in *Tables 21 thru 33, pages 66 thru 76.*

TABLE 10—STORAGE LOAD FACTORS, SOLAR HEAT GAIN THRU GLASS

WITH BARE GLASS OR WITH EXTERNAL SHADE‡

16 Hour Operation, Constant Space Temperature†

EXPOSURE (North Lat)	WEIGHT§ (lb per sq ft of floor area)	SUN TIME AM 6	7	8	9	10	11	12	PM 1	2	3	4	5	6	7	8	9	EXPOSURE (South Lat)
Northeast	150 & over	.28	.37	.42	.41	.38	.36	.33	.31	.23	.22	.20	.19	.17	.15	.14	.12	Southeast
	100	.28	.39	.45	.45	.41	.39	.31	.27	.22	.21	.19	.17	.16	.14	.12	.10	
	30	.33	.57	.66	.62	.46	.33	.26	.21	.18	.16	.14	.12	.09	.06	.04	.03	
East	150 & over	.29	.38	.44	.48	.48	.46	.41	.36	.28	.26	.23	.22	.20	.18	.16	.14	East
	100	.27	.38	.48	.54	.52	.48	.41	.35	.28	.25	.23	.20	.18	.15	.14	.12	
	30	.29	.51	.68	.74	.69	.53	.38	.27	.22	.18	.15	.12	.09	.06	.04	.03	
Southeast	150 & over	.24	.29	.35	.43	.49	.53	.53	.51	.39	.35	.32	.29	.26	.23	.21	.19	Northeast
	100	.19	.24	.33	.44	.52	.57	.57	.53	.41	.36	.31	.27	.24	.21	.18	.16	
	30	.03	.20	.41	.60	.73	.77	.72	.60	.44	.32	.23	.18	.14	.09	.07	.05	
South	150 & over	.33	.31	.32	.37	.43	.49	.55	.60	.57	.51	.48	.42	.37	.33	.29	.26	North
	100	.27	.24	.28	.34	.42	.50	.58	.60	.60	.57	.53	.45	.37	.31	.27	.23	
	30	.06	.04	.15	.31	.49	.65	.75	.82	.81	.75	.61	.42	.28	.19	.13	.09	
Southwest	150 & over	.35	.32	.30	.28	.26	.28	.30	.37	.43	.47	.46	.40	.34	.30	.27	.24	Northwest
	100	.31	.28	.25	.24	.22	.26	.33	.40	.46	.50	.53	.51	.44	.35	.29	.26	
	30	.11	.10	.10	.09	.10	.14	.35	.54	.68	.78	.78	.68	.46	.29	.20	.14	
West	150 & over	.38	.34	.32	.28	.26	.25	.23	.25	.26	.27	.36	.42	.44	.38	.33	.29	West
	100	.34	.31	.28	.25	.23	.22	.21	.21	.23	.30	.40	.48	.51	.43	.35	.30	
	30	.17	.14	.13	.11	.11	.10	.10	.15	.29	.49	.67	.76	.75	.53	.33	.22	
Northwest	150 & over	.33	.30	.28	.26	.24	.23	.22	.20	.18	.17	.25	.34	.39	.34	.29	.26	Southwest
	100	.30	.28	.25	.23	.22	.20	.19	.17	.17	.19	.29	.40	.46	.40	.32	.26	
	30	.18	.14	.12	.12	.12	.12	.12	.11	.13	.27	.48	.65	.73	.49	.31	.21	
North and Shade	150 & over	.31	.57	.64	.68	.72	.73	.73	.74	.74	.75	.76	.78	.78	.59	.52	.46	South and Shade
	100	.30	.47	.60	.67	.72	.74	.77	.78	.79	.80	.81	.82	.83	.60	.51	.44	
	30	.04	.07	.53	.70	.78	.84	.88	.91	.93	.95	.97	.98	.99	.62	.34	.24	

Equation: Cooling Load, Btu/hr = [Peak solar heat gain, Btu/(hr) (sq ft), (*Table 6*)]
× [Window area, sq ft]
× [Shade factor, Haze factor, etc., (*Chapter 4*)]
× [Storage factor, (above Table at desired time)]

‡Bare glass — Any window with no inside shading device. Windows with shading devices on the outside or shaded by external projections are considered bare glass.

†These factors apply when maintaining a CONSTANT TEMPERATURE in the space during the operating period. Where the temperature is allowed to swing, additional storage will result during peak load periods. Refer to *Table 13* for applicable storage factors.

§Weight per sq ft of floor—

$$\text{Room on Bldg Exterior (One or more outside walls)} = \frac{\text{(Weight of Outside Walls, lb)} + \tfrac{1}{2}\text{ (Weight of Partitions, Floor and Ceiling, lb)}}{\text{Floor Area in Room, sq ft}}$$

$$\text{Room in Bldg Interior (No outside walls)} = \frac{\tfrac{1}{2}\text{ (Weight of Partitions, Floor and Ceiling, lb)}}{\text{Floor Area in Room, sq ft}}$$

$$\text{Basement Room (Floor on ground)} = \frac{\text{(Weight of Outside Walls, lb)} + \text{(Weight of Floor, lb)} + \tfrac{1}{2}\text{ (Weight of Partitions and Ceiling, lb)}}{\text{Floor Area in Room, sq ft}}$$

$$\text{Entire Building or Zone} = \frac{\text{(Weight of Outside Wall, Partitions, Floors, Ceilings, Structural Members and Supports, lb)}}{\text{Air Conditioned Floor Area, sq ft}}$$

With rug on floor—Weight of floor should be multiplied by 0.50 to compensate for insulating effect of rug.

Weights per sq ft of common types of construction are contained in *Tables 21 thru 33, pages 66 thru 76.*

TABLE 11—STORAGE LOAD FACTORS, SOLAR HEAT GAIN THRU GLASS

12 Hour Operation, Constant Space Temperature†

EXPOSURE (North Lat)	WEIGHT§ (lb per sq ft of floor area)	INTERNAL SHADE*												BARE GLASS OR EXTERNAL SHADE‡												EXPOSURE (South Lat)
		SUN TIME																								
		AM							PM					AM							PM					
		6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	
Northeast	150 & over	.59	.67	.62	.49	.33	.27	.25	.24	.22	.21	.20	.17	.34	.42	.47	.45	.42	.39	.36	.33	.30	.29	.26	.25	Southeast
	100	.59	.68	.64	.52	.35	.29	.24	.23	.20	.19	.17	.15	.35	.45	.50	.49	.45	.42	.34	.30	.27	.26	.23	.20	
	30	.62	.80	.75	.60	.37	.25	.19	.17	.15	.13	.12	.11	.40	.62	.69	.64	.48	.34	.27	.22	.18	.16	.14	.12	
East	150 & over	.51	.66	.71	.67	.57	.40	.29	.26	.25	.23	.21	.19	.36	.44	.50	.53	.53	.50	.44	.39	.36	.34	.30	.28	East
	100	.52	.67	.73	.70	.58	.40	.29	.26	.24	.21	.19	.16	.34	.44	.54	.58	.57	.51	.44	.39	.34	.31	.28	.24	
	30	.53	.74	.82	.81	.65	.43	.25	.19	.16	.14	.11	.09	.36	.56	.71	.76	.70	.54	.39	.28	.23	.18	.15	.12	
Southeast	150 & over	.20	.42	.59	.70	.74	.71	.61	.48	.33	.30	.26	.24	.34	.37	.43	.50	.54	.58	.57	.55	.50	.45	.41	.37	Northeast
	100	.18	.40	.57	.70	.75	.72	.63	.49	.34	.28	.25	.21	.29	.33	.41	.51	.58	.61	.61	.56	.49	.44	.37	.33	
	30	.09	.35	.61	.78	.86	.82	.69	.50	.30	.20	.17	.13	.14	.27	.47	.64	.75	.79	.73	.61	.45	.32	.23	.18	
South	150 & over	.28	.25	.40	.53	.64	.72	.77	.77	.73	.67	.49	.31	.47	.43	.42	.46	.51	.56	.61	.65	.66	.65	.61	.54	North
	100	.26	.22	.38	.51	.64	.73	.79	.79	.77	.65	.51	.31	.44	.37	.39	.43	.50	.57	.64	.68	.70	.68	.63	.53	
	30	.21	.29	.48	.67	.79	.88	.89	.83	.56	.50	.24	.16	.28	.19	.25	.38	.54	.68	.78	.84	.82	.76	.61	.42	
Southwest	150 & over	.31	.27	.27	.26	.25	.27	.50	.63	.72	.74	.69	.54	.51	.44	.40	.37	.34	.36	.41	.47	.54	.57	.60	.58	Northwest
	100	.33	.28	.25	.23	.23	.35	.50	.64	.74	.77	.70	.55	.53	.44	.37	.35	.31	.33	.39	.46	.55	.62	.64	.60	
	30	.29	.21	.18	.15	.14	.27	.50	.69	.82	.87	.79	.60	.48	.32	.25	.20	.17	.19	.39	.56	.70	.80	.79	.69	
West	150 & over	.63	.31	.28	.27	.25	.24	.22	.29	.46	.61	.71	.72	.56	.49	.44	.39	.36	.33	.31	.31	.35	.42	.49	.54	West
	100	.67	.33	.28	.26	.24	.22	.20	.28	.44	.61	.72	.73	.60	.52	.44	.39	.34	.31	.29	.28	.33	.43	.51	.57	
	30	.77	.34	.25	.20	.17	.14	.13	.22	.44	.67	.82	.85	.77	.56	.38	.28	.22	.18	.16	.19	.33	.52	.69	.77	
Northwest	150 & over	.68	.28	.27	.25	.23	.22	.20	.19	.24	.41	.56	.67	.49	.44	.39	.36	.33	.30	.28	.26	.26	.30	.37	.44	Southwest
	100	.71	.31	.27	.24	.22	.21	.19	.18	.23	.40	.58	.70	.54	.49	.41	.35	.31	.28	.25	.23	.24	.30	.39	.48	
	30	.82	.33	.25	.20	.18	.15	.14	.13	.19	.41	.64	.80	.75	.53	.36	.28	.24	.19	.17	.15	.17	.30	.50	.66	
North and Shade	150 & over	.96	.96	.96	.96	.96	.96	.96	.96	.96	.96	.96	.96	.75	.75	.79	.83	.84	.86	.88	.88	.91	.92	.93	.93	South and Shade
	100	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.81	.84	.86	.89	.91	.93	.93	.94	.94	.95	.95	.95	
	30	← 1.00 →												← 1.00 →												

Equation: Cooling Load, Btu/hr = [Peak solar heat gain, Btu/(hr) (sq ft), (*Table 6*)]
× [Window area, sq ft]
× [Shade factor, Haze factor, etc., (*Chapter 4*)]
× [Storage factor, (above Table at desired time)]

*Internal shading device is any type of shade located on the inside of the glass.

‡Bare glass — Any window with no inside shading device. Windows with shading devices on the outside or shaded by external projections are considered bare glass.

†These factors apply when maintaining a CONSTANT TEMPERATURE in the space during the operating period. Where the temperature is allowed to swing, additional storage will result during peak load periods. Refer to *Table 13* for applicable storage factors.

§Weight per sq ft of floor—

$$\text{Room on Bldg Exterior (One or more outside walls)} = \frac{\text{(Weight of Outside Walls, lb)} + \frac{1}{2}\text{ (Weight of Partitions, Floor and Ceiling, lb)}}{\text{Floor Area in Room, sq ft}}$$

$$\text{Room in Bldg Interior (No outside walls)} = \frac{\frac{1}{2}\text{ (Weight of Partitions, Floor and Ceiling, lb)}}{\text{Floor Area in Room, sq ft}}$$

$$\text{Basement Room (Floor on ground)} = \frac{\text{(Weight of Outside Walls, lb)} + \text{(Weight of Floor, lb)} + \frac{1}{2}\text{ (Weight of Partitions and Ceiling, lb)}}{\text{Floor Area in Room, sq ft}}$$

$$\text{Entire Building or Zone} = \frac{\text{(Weight of Outside Wall, Partitions, Floors, Ceilings, Structural Members and Supports, lb)}}{\text{Air Conditioned Floor Area, sq ft}}$$

With rug on floor—Weight of floor should be multiplied by 0.50 to compensate for insulating effect of rug
Weights per sq ft of common types of construction are contained in *Tables 21 thru 33, pages 66 thru 76.*

TABLE 12—STORAGE LOAD FACTORS, HEAT GAIN—LIGHTS*

Lights On 10 Hours† with Equipment Operating 12, 16 and 24 Hours, Constant Space Temperature

	EQUIP. OPER-ATION Hours	WEIGHT§ (lb per sq ft of floor area)	NUMBER OF HOURS AFTER LIGHTS ARE TURNED ON																							
			0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Fluorescent Lights Exposed	24	150 & over	.37	.67	.71	.74	.76	.79	.81	.83	.84	.86	.87	.29	.26	.23	.20	.19	.17	.15	.14	.12	.11	.10	.09	.08
		100	.31	.67	.72	.76	.79	.81	.83	.85	.87	.88	.90	.30	.26	.22	.19	.16	.15	.13	.12	.10	.09	.08	.07	.06
		30	.25	.74	.83	.88	.91	.94	.96	.96	.98	.98	.99	.26	.17	.12	.08	.05	.04	.03	.02	.01	.01	.01	0	0
	16	150 & over	.60	.82	.83	.84	.84	.84	.85	.85	.86	.88	.90	.32	.28	.25	.23	.19								
		100	.46	.79	.84	.86	.87	.88	.88	.89	.89	.90	.90	.30	.26	.22	.19	.16								
		30	.29	.77	.85	.89	.92	.95	.96	.96	.98	.98	.99	.26	.17	.12	.08	.05								
	12	150 & over	.63	.90	.91	.93	.93	.94	.95	.95	.95	.96	.96	.37												
		100	.57	.89	.91	.92	.94	.94	.95	.95	.96	.96	.97	.36												
		30	.42	.86	.91	.93	.95	.97	.98	.98	.99	.99	.99	.26												
Fluorescent Lights Recessed in Susp. Ceiling or Exposed Incandescent Lights.	24	150 & over	.34	.55	.61	.65	.68	.71	.74	.77	.79	.81	.83	.39	.35	.31	.28	.25	.23	.20	.18	.16	.15	.14	.12	.11
		100	.24	.56	.63	.68	.72	.75	.78	.80	.82	.84	.86	.40	.34	.29	.25	.20	.18	.17	.15	.14	.12	.10	.09	.08
		30	.17	.65	.77	.84	.88	.92	.94	.95	.97	.98	.98	.35	.23	.16	.11	.07	.05	.04	.03	.02	.01	.01	0	0
	16	150 & over	.58	.75	.79	.80	.80	.81	.82	.83	.84	.86	.87	.39	.35	.31	.28	.25								
		100	.46	.73	.78	.82	.82	.82	.83	.84	.85	.87	.88	.40	.34	.29	.25	.20								
		30	.22	.69	.80	.86	.89	.93	.94	.95	.97	.98	.98	.35	.23	.16	.11	.07								
	12	150 & over	.69	.86	.89	.90	.91	.91	.92	.93	.94	.95	.95	.50												
		100	.58	.85	.88	.88	.90	.92	.93	.94	.94	.94	.95	.48												
		30	.40	.81	.88	.91	.93	.96	.97	.97	.98	.99	.99	.35												
Fluorescent or Incandescent Lights Recessed in Susp. Ceiling and Ceiling Plenum Return System.	24	150 & over	.23	.33	.41	.47	.52	.57	.61	.66	.69	.72	.74	.59	.52	.46	.42	.37	.34	.31	.27	.25	.23	.21	.18	.16
		100	.17	.33	.44	.52	.56	.61	.66	.69	.74	.77	.79	.60	.51	.44	.37	.32	.30	.27	.23	.20	.18	.16	.14	.12
		30	0	.48	.66	.76	.82	.87	.91	.93	.95	.97	.98	.52	.34	.24	.16	.11	.07	.05	.04	.02	.02	.01	0	0
	16	150 & over	.57	.64	.68	.72	.73	.73	.74	.74	.75	.76	.78	.59	.52	.46	.42	.37								
		100	.47	.60	.67	.72	.74	.77	.78	.79	.80	.81	.82	.60	.51	.44	.37	.32								
		30	.07	.53	.70	.78	.84	.88	.91	.93	.95	.97	.98	.52	.34	.24	.16	.11								
	12	150 & over	.75	.79	.83	.84	.86	.88	.89	.91	.91	.93	.93	.75												
		100	.68	.77	.81	.84	.86	.88	.89	.89	.92	.93	.93	.72												
		30	.34	.72	.82	.87	.89	.92	.95	.95	.97	.98	.98	.52												

*These factors apply when maintaining a CONSTANT TEMPERATURE in the space during the operating period. Where the temperature is allowed to swing, additional storage will result during peak load periods. Refer to *Table 13* for applicable storage factors.

With lights operating the same number of hours as the time of equipment operation, use a load factor of 1.00.

†Lights On for Shorter or Longer Period than 10 Hours

Occasionally adjustments may be required to take account of lights operating less or more than the 10 hours on which the table is based. The following is the procedure to adjust the load factors:

A–WITH LIGHTS IN OPERATION FOR SHORTER PERIOD THAN 10 HOURS and the equipment operating 12, 16 or 24 hours at the time of the overall peak load, extrapolate load factors as follows:

1. Equipment operating for 24 hours:
   a. Use the storage load factors as listed up to the time the lights are turned off.
   b. Shift the load factors beyond the 10th hour (on the right of heavy line) to the left to the hour the lights are turned off. This leaves last few hours of equipment operation without designated load factors.
   c. Extrapolate the last few hours at the same rate of reduction as the end hours in the table.
2. Equipment operating for 16 hours:
   a. Follow the procedure in Step 1, using the storage load factor values in 24-hour equipment operation table.
   b. Now construct a new set of load factors by adding the new values for the 16th hour to that denoted 0, 17th hour to the 1st hour, etc.
   c. The load factors for the hours succeeding the switching-off the lights are as in Steps 1b and 1c.
3. Equipment operating for 12 hours:

   Follow procedure in Step 2, except in Step 2b add values of 12th hour to that designated 0, 13th hour to the 1st hour, etc.

B–WITH LIGHTS IN OPERATION FOR LONGER PERIOD THAN 10 HOURS and the equipment operating 12, 16 or 24 hours at the time of the overall peak load, extrapolate load factors as follows:

1. Equipment operating for 24 hours:
   a. Use the load factors as listed through 10th hour and extrapolate beyond the 10th hour at the rate of the last 4 hours.
   b. Follow the same procedure as in Step 1b of "A" except shift load factors beyond 10th hour now to the right, dropping off the last few hours.
2. Equipment operating for 16 hours or 12 hours:
   a. Use the load factors in 24-hour equipment operation table as listed through 10th hour and extrapolate beyond the 10th hour at the rate of the last 4 hours.
   b. Follow the procedure in Step 1b of "A" except shift the load factors beyond 10th hour now to the right.
   c. For 16-hour equipment operation, follow the procedure in Steps 2b and 2c of "A".
   d. For 12-hour equipment operation, follow the procedure in Step 3 of "A".

Example

Adjust values for 24-hour equipment operation and derive new values for 16-hour equipment operation for fluorescent lights in operation 8 and 13 hours, and an enclosure of 150 lb/sq ft of floor.

EQUIP OPERATION Hours	WEIGHT§ (lb per sq ft of floor area)	NUMBER OF HOURS AFTER LIGHTS ARE TURNED ON																							LIGHTS ON Hours
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
24	150	.37	.67	.71	.74	.76	.79	.81	.83	.84	.86	.87	.89	.90	.92	.29	.26	.23	.20	.19	.17	.15	.14	.12	.11	13
		.37	.67	.71	.74	.76	.79	.81	.83	.84	.29	.26	.23	.20	.19	.17	.15	.14	.12	.11	.10	.09	.08	.07	.06	8
		.37	.67	.71	.74	.76	.79	.81	.83	.84	.86	.87	.29	.26	.23	.20	.19	.17	.15	.14	.12	.11	.10	.09	.08	10
16	150	.60	.87	.90	.91	.91	.93	.93	.94	.94	.95	.95	.96	.96	.97	.29	.26									13
		.51	.79	.82	.84	.85	.87	.88	.89	.90	.29	.26	.23	.20	.19	.17	.15									8
		.60	.82	.83	.84	.84	.84	.85	.85	.86	.88	.90	.32	.28	.25	.23	.19									10

§Weight per sq ft of floor—

$$\text{Room on Bldg Exterior (One or more outside walls)} = \frac{\text{(Weight of Outside Walls, lb)} + \frac{1}{2}\text{(Weight of Partitions, Floor and Ceiling, lb)}}{\text{Floor Area in Room, sq ft}}$$

$$\text{Room in Bldg Interior (No outside walls)} = \frac{\frac{1}{2}\text{(Weight of Partitions, Floor and Ceiling, lb)}}{\text{Floor Area in Room, sq ft}}$$

$$\text{Basement Room (Floor on ground)} = \frac{\text{(Weight of Outside Walls, lb)} + \text{(Weight of Floor, lb)} + \frac{1}{2}\text{(Weight of Partitions and Ceiling, lb)}}{\text{Floor Area in Room, sq ft}}$$

$$\text{Entire Building or Zone} = \frac{\text{(Weight of Outside Wall, Partitions, Floors, Ceilings, Structural Members and Supports, lb)}}{\text{Air Conditioned Floor Area, sq ft}}$$

With rug on floor—Weight of floor should be multiplied by 0.50 to compensate for insulating effect of rug.
Weights per sq ft of common types of construction are contained in *Tables 21 thru 33, pages 66 thru 76.*

SPACE TEMPERATURE SWING

In addition to the storage of radiant heat with a constant room temperature, heat is stored in the building structure when the space temperature is forced to swing. If the cooling capacity supplied to the space matches the cooling load, the temperature in the space remains constant throughout the operating period. On the other hand, if the cooling capacity supplied to the space is lower than the actual cooling load at any point, the temperature in the space will rise. As the space temperature increases, less heat is convected from the surface and more radiant heat is stored in the structure. This process of storing additional heat is illustrated in *Fig. 11.*

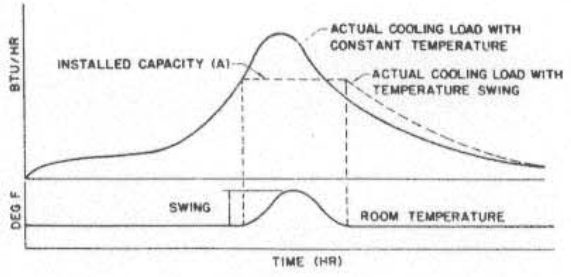


FIG. 11 — ACTUAL COOLING LOAD WITH VARYING ROOM TEMPERATURE

The solid curve is the actual cooling load from the solar heat gain on a west exposure with a constant space temperature, 24-hour operation. Assume that the maximum cooling capacity available is represented by *A*, and that the capacity is controlled to maintain a constant temperature at partial load. When the actual cooling load exceeds the available cooling capacity, the temperature will swing as shown in the lower curve. The actual cooling load with temperature swing is shown by the dotted line. This operates in a similar manner with different periods of operation and with different types of construction.

NOTE: When a system is designed for a temperature swing, the maximum swing occurs only at the peak on design days, which are defined as those days when all loads simultaneously peak. Under normal operating conditions, the temperature remains constant or close to constant.

Basis of Table 13 — Storage Factors, Space Temperature Swing

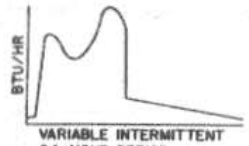
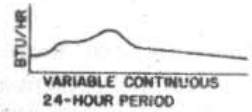
The storage factors in *Table 13* were computed using essentially the same procedure as *Tables 7 thru 12* with the exception that the equipment capacity available was limited and the swing in room temperature computed.

The magnitude of the storage effect is determined largely by the thermal capacity or heat holding

TABLE 13—STORAGE FACTORS, SPACE TEMPERATURE SWING

Btu/(hr) (deg F swing) (sq ft of floor area)

NOTE: This reduction is to be taken at the time of peak load only.

TYPE APPLICATION		WEIGHT (lb/sq ft floor area)	GLASS RATIO‡ (%)	HOURS OF OPERATION								
				24			16			12		
Load Pattern	Bldg Type			Temperature Swing (F)								
				1-2	3-4	5-6	1-2	3-4	5-6	1-2	3-4	5-6
	Office Bldg Periphery, Except North Side	150 and Over	75	1.90	1.80	1.65	1.80	1.70	1.55	1.60	1.50	1.40
			50	1.70	1.60	1.45	1.60	1.50	1.35	1.50	1.35	1.25
			25	1.50	1.40	—	1.40	1.30	—	1.30	1.20	—
		100	75	1.70	1.60	1.45	1.50	1.45	1.35	1.40	1.35	1.30
			50	1.50	1.40	1.30	1.35	1.30	1.20	1.30	1.25	1.10
			25	1.35	1.25	1.20	1.25	1.00	.90	1.20	.95	.70
		30	75	1.40	1.25	1.00	1.20	1.10	.95	1.00	.95	.88
			50	1.20	.95	.80	1.10	.90	.80	.90	.85	.80
			25	.90	.80	.70	.85	.75	.60	.80	.70	.55
	Interior Zones† Department Stores, Factories	150 and Over	—	1.60	1.55	1.50	1.50	1.45	—	1.35	—	—
		100	—	1.40	1.38	1.36	1.30	1.28	1.25	1.25	1.20	—
		30	—	.95	.92	.90	.90	.88	.85	.85	.80	—
	Apartment Houses, Hotels, Hospitals Residences	150 and Over	75	1.85	1.75	1.40	—	—	—	—	—	—
			50	1.65	1.50	—	—	—	—	—	—	—
			25	1.45	—	—	—	—	—	—	—	—
		100	75	1.55	1.45	1.40	—	—	—	—	—	—
			50	1.40	1.35	—	—	—	—	—	—	—
			25	1.30	—	—	—	—	—	—	—	—
		30	75	1.20	1.10	.95	—	—	—	—	—	—
			50	1.10	.90	.80	—	—	—	—	—	—
			25	.85	.70	—	—	—	—	—	—	—

Equation: Reduction in Peak Cooling Load, Btu/hr = (Floor Area, sq ft) × (Desired Temp Swing, *Table 4, page 20*) × (Storage Factor, above table)

*Weight per sq ft of floor may be obtained from equation on page 30.

†For 12-hour operation, use a 2 degree max temp swing.

‡Glass ratio is the percent of glass area to the total wall area.

capacity of the materials surrounding the space. It is limited by the amount of heat available for storage. Load patterns for different applications vary approximately as shown in the first column of *Table 13*. For instance, an office building has a rather large varying load with a high peak that occurs intermittently. An interior zone has an intermittent peak but the load pattern is relatively constant. A hospital, on the other hand, has a constant base load which is present for 24 hours with an additional intermittent load occurring during daylight hours. The thermal capacity of a material is the weight times the specific heat of the material. Since the specific heat of most construction material is approximately 0.20 Btu/(lb)(F), the thermal capacity is directly proportional to the weight of the material. Therefore, the data in the tables is based on weight of the materials surrounding the space, per square foot of floor area.

Use of Table 13 — Storage Factors, Space Temperature Swing

Table 13 is used to determine the reduction in cooling load when the space temperature is foiced to swing by reducing the equipment capacity below that required to maintain the temperature constant. This reduction is to be subtracted from the room sensible heat.

NOTE: This reduction is only taken at the time of *peak cooling load.*

Example 3 — Space Temperature Swing

Given:

The same room as in *Example 1, page 28.*

Find:

The actual cooling load at 4 p.m. from sun, lights, and people with 3 F temperature swing in the space.

Solution:

The peak sensible cooling load in this room from the sun, lights, and people (neglecting transmission infiltration, ventilation and other internal fleat gain) is

5700 + 5190 = 10,890 Btu/hr. *(Examples 1 and 2.)*

NOTE: The peak cooling load in this room occurs at approximately 4 p.m. The solar and light loads are almost at their peak at 4 p.m. Although the transmission across the large glass window peaks at about 3 p.m., the peak infiltration and ventilation load also occurs at 3 p.m. and the relatively small transmission load across the wall peaks much later at about 12 midnight. The sum of these loads re-

sults in the peak cooling load occurring at about 4 p.m. in the spaces with this exposure.

The weight of the materials surrounding the room in *Example 1* is 97.4 lb/sq ft of floor area.

Reduction in cooling load for a 3 F swing *(Table 13)*
$= 20 \times 20 \times 1.4 \times 3 = 1680$ Btu/hr.
Cooling load = 10,890 − 1680 = 9210 Btu/hr.

(For comparison purposes, the instantaneous heat gain from sun, lights, and people in this particular room is 14,610 Btu/hr.)

Since the normal thermostat setting is about 75 F or 76 F db, the design temperature (78 F = 75 F thermostat setting + 3 F swing) occurs only on design peak days at the time of peak load. Under partial load operation, the room temperature is between 75 F db and 78 F db, or at the thermostat setting (75 F), depending on the load.

PRECOOLING AS A MEANS OF INCREASING STORAGE

Precooling a space below the temperature normally desired *increases the storage of heat* at the time of peak load, only when the precooling temperature is maintained as the control point. This is because the potential temperature swing is increased, thus adding to the amount of heat stored at the time of peak load. Where the space is precooled to a lower temperature and the control point is reset upward to a comfortable condition when the occupants arrive, no additional storage occurs. In this situation, the cooling unit shuts off and there is no cooling during the period of warming up. When the cooling unit begins to supply cooling again, the cooling load is approximately up to the point it would have been without any precooling.

Precooling is very useful in reducing the cooling load in applications such as churches, supermarkets, theaters, etc., where the precooled temperature can be maintained as the control point and the temperature swing increased to 8 F or 10 F.

DIVERSITY OF COOLING LOADS

Diversity of cooling load results from the probable non-occurrence of part of the cooling load on a design day. Diversity factors are applied to the refrigeration capacity in large air conditioning systems. These factors vary with location, type and size of the application, and are based entirely on the judgment of the engineer.

Generally, diversity factors can be applied to people and light loads in large multi-story office, hotel or apartment buildings. The possibility of having all of the people present in the building and all of the lights operating at the time of peak load are slight. Normally, in large office buildings, some people will be away from the office on other business. Also, the lighting arrangement will frequently be such that the lights in the vacant offices will not be on. In addition to lights being off because the people are not present, the normal maintenance procedure in large office buildings usually results in some lights being inoperative. Therefore, a diversity factor on the people and light loads should be applied for selecting the proper size refrigeration equipment.

The size of the diversity factor depends on the size of the building and the engineer's judgment of the circumstances involved. For example, the diversity factor on a single small office with 1 or 2 people is 1.0 or no reduction. Expanding this to one floor of a building with 50 to 100 people, 5% to 10% may be absent at the time of peak load, and expanding to a 20, 30 or 40-story building, 10% to 20% may be absent during the peak. A building with predominantly sales offices would have many people out in the normal course of business.

This same concept applies to apartments and hotels. Normally, very few people are present at the time the solar and transmission loads are peaking, and the lights are normally turned on only after sundown. Therefore, in apartments and hotels, the diversity factor can be much greater than with office buildings.

These reductions in cooling load are real and should be made where applicable. *Table 14* lists some typical diversity factors, based on judgment and experience.

TABLE 14—TYPICAL DIVERSITY FACTORS FOR LARGE BUILDINGS

(Apply to Refrigeration Capacity)

TYPE OF APPLICATION	DIVERSITY FACTOR	
	People	Lights
Office	.75 to .90	.70 to .85
Apartment, Hotel	.40 to .60	.30 to .50
Department Store	.80 to .90	.90 to 1.0
Industrial*	.85 to .95	.80 to .90

Equation:
Cooling Load (for people and lights), Btu/hr
= (Heat Gain, Btu/hr, *Chapter 7*)
× (Storage Factor, *Table 12*) × (Diversity Factor, above table)

*A diversity factor should also be applied to the machinery load. Refer to *Chapter 7*.

Use of Table 14 — Typical Diversity Factors for Large Buildings

The diversity factors listed in *Table 14* are to be used as a guide in determining a diversity factor for any particular application. The final factor must

necessarily be based on judgment of the effect of the many variables involved.

STRATIFICATION OF HEAT

There are generally two situations where heat is stratified and will reduce the cooling load on the air conditioning equipment:

1. Heat may be stratified in rooms with high ceilings where air is exhausted through the roof or ceiling.
2. Heat may be contained above suspended ceilings with recessed lighting and/or ceiling plenum return systems.

The first situation generally applies to industrial applications, churches, auditoriums, and the like. The second situation applies to applications such as office buildings, hotels, and apartments. With both cases, the basic fact that hot air tends to rise makes it possible to stratify loads such as convection from the roof, convection from lights, and convection from the upper part of the walls. The convective portion of the roof load is about 25% (the rest is radiation); the light load is about 50% with fluorescent (20% with incandescent), and the wall transmission load about 40%.

In any room with a high ceiling, a large part of the convection load being released above the supply air stream will stratify at the ceiling or roof level. Some will be induced into the supply air stream. Normally, about 80% is stratified and 20% induced in the supply air. If air is exhausted through the ceiling or roof, this convection load released above the supply air may be subtracted from the air conditioning load. This results in a large reduction in load if the air is to be exhausted. It is not normally practical to exhaust more air than necessary, as it must be made up by bringing outdoor air through the apparatus. This usually results in a larger increase in load than the reduction realized by exhausting air.

Nominally, about a 10 F to 20 F rise in exhaust air temperature may be figured as load reduction if there is enough heat released by convection above the supply air stream.

Hot air stratifies at the ceiling even with no exhaust but rapidly builds up in temperature, and no reduction in load should be taken where air is not exhausted through the ceiling or roof.

With suspended ceilings, some of the convective heat from recessed lights flows into the plenum space. Also, the radiant heat within the room (sun, lights, people, etc.) striking the ceiling warms it up and causes heat to flow into the plenum space. These sources of heat increase the temperature of air in the plenum space which causes heat to flow into the underside of the floor structure above. When the ceiling plenum is used as a return air system, some of the return air flows through and over the light fixture, carrying more of the convective heat into the plenum space.

Containing heat within the ceiling plenum space tends to "flatten" both the room and equipment load. The storage factors for estimating the load with the above conditions are contained in *Table 12.*