arrives. In industrial plants, quite a different condition exists, and heat sources, if they are always available during the period of human occupancy, may be substituted for a portion of the heating installation. In no case should the actual heating installation (exclusive of heat sources) be reduced below that required to maintain at least 40 F in the building.

Electric Motors and Machinery

Motors and the machinery which they drive, if both are located in the room, convert all of the electrical energy supplied into heat, which is retained in the room if the product being manufactured is not removed until its temperature is the same as the room temperature.

If power is transmitted to the machinery from the outside, then only the heat equivalent of the brake horsepower supplied is used. In the first case the Btu supplied per hour $= \dfrac{\text{Motor horsepower}}{\text{Efficiency of motor}} \times 2546$, and in the second case Btu per hour $=$ bhp $\times$ 2546, in which 2546 is the Btu equivalent of 1 hp-hr. In some mills this is the chief source of heating and it is frequently sufficient to overheat the building even in zero weather, thus requiring cooling by ventilation the year round.

The heat (in Btu per hour) from electric lamps is obtained by multiplying the watts per lamp by the number of lamps and by 3.413. One cubic foot of producer gas gives off about 150 Btu per hour; one cubic foot of manufactured gas about 535 Btu per hour; and one cubic foot of natural gas about 1000 Btu per hour. A Welsbach burner averages 3 cu ft of gas per hour and a fish-tail burner, 5 cu ft per hour. For information concerning the heat supplied by persons, refer to data given in Chapter 2.

INTERMITTENTLY HEATED BUILDINGS

In the case of intermittently heated buildings additional heat is required for raising the temperature of the air, the building materials and the material contents of the building to the specified inside temperature. The rate at which this additional heat must be supplied depends upon the heat capacity of the structure and its material contents and upon the time in which these are to be heated[6].

This additional heat may be figured and allowed for as conditions require, but inasmuch as the heating system proportioned for taking care of the heat losses will usually have a capacity about 100 per cent greater than that required for average winter weather, and inasmuch as most buildings may either be continuously heated or have more time allowed for heating-up during the few minimum temperature days, no allowance is usually made except in the size of boilers or furnaces. For churches, auditoriums and other intermittently heated buildings, additional capacity should be provided.

RESIDENCE HEAT LOSS PROBLEMS

Example 5. Calculate the heat loss of residence shown in Fig. 2 located in the vicinity of Chicago. Assume inside and outside design temperatures to be 70 F and −10 F respectively. The attic is unheated. Assume ground temperature to be 50 F under basement and garage floors and 32 F adjoining basement walls. Estimate infiltration by crack method, assuming average wind velocity to be 12.5 mph during December, January and February. No wall, ceiling or roof insulation is to be figured in this problem, but all first and second floor windows are to have storm sash. The building is constructed as follows (transmission coefficients (U) in parentheses):

Walls: Brick veneer, building paper, wood sheathing, studding, metal lath and plaster (0.28). Walls of dormer over garage, same except wood siding in place of brick veneer (0.26).

Attic Walls: Brick veneer, building paper, wood sheathing on studding (0.42).

Basement Walls: 10 in. concrete (0.10).

Roof: Asphalt shingles on wood sheathing on rafters (0.53).

Ceiling (Second floor): Metal lath and plaster (0.69).

Windows: Double-hung wood windows with storm sash (0.45). Steel casement sash in basement (1.13).

Floor (Bedroom D): Maple finish flooring on yellow pine sub-flooring; metal lath and plaster ceiling below (0.25).

Floor (Basement and Garage): 4 in. stone concrete on 3 in. cinder concrete (0.10).

Solution: The calculations for this problem are given in Table 4, and a summary of the results in Table 5. The values in column F of Table 4 were obtained by multiplying together the figures in columns C, D and E. The heat losses are calculated to the nearest 10 Btu. See reference notes for Table 4 for further explanation of data.

Attention is called to the summary of heat losses (Table 5) of the uninsulated residence (Fig. 2). As storm windows are used in this instance the *glass* and *door* transmission heat losses of 20.9 per cent are relatively small. The infiltration losses (12.8 per cent) are also comparatively small in this case because the storm windows serve substantially the same purpose as weatherstripping. In this problem, the wall, ceiling and floor transmission losses comprise 66.3 per cent of the total. If the building is insulated, the relative heat loss percentages will materially change. (See Example 6 and Table 6.)

Example 6. Calculate the heat loss of residence shown in Fig. 2 based on the same conditions as in Example 5 but insulated throughout as shown on the following page (coefficients in parentheses).

Walls: Brick veneer, $2\frac{5}{32}$ in. insulation board sheathing, studding, 1 in. insulation board lath and plaster (0.13). Walls of dormer over garage same except wood siding in place of brick veneer (0.12).

Attic Walls: Brick veneer, $2\frac{5}{32}$ in. insulation board sheathing on studding (0.28).

---

[6]Heat Requirement Tables for Intermittently Heated Buildings, (*Engineering Experiment Station Bulletin*, No. 60, A. and M. College of Texas, College Station, Texas), contains a set of tables applicable to either intermittent heating or cooling. Further information may be found in a paper, A Method of Compiling Tables for Intermittent Heating, by Elmer G. Smith (A.S.H.V.E. JOURNAL SECTION, *Heating, Piping and Air Conditioning*, June, 1942, p. 386).

TABLE 5. SUMMARY OF HEAT LOSSES OF UNINSULATED RESIDENCE

Heat losses given in Btu per hour

Room or Space	Walls	Ceiling and Roof	Floor	Glass and Door	Infiltration	Totals
Bedroom A	5330	6660	....	1440	1010	14,440
Bedroom B	3490	4400	....	1440	1010	10,340
Bedroom C	2560	3300	....	970	500	7,330
Bedroom D	2650	3300	960	720	500	8,130
Bathroom 1	670	1510	....	500	500	3,180
Bathroom 2	1770	960	310	320	420	3,780
Living Room	7260	....	....	1800	1120	10,180
Dining Room	3720	....	....	3880	870	8,470
Kitchen	2850	....	....	950	760	4,560
Lavette	3000	....	....	1100	530	4,630
Entrance Hall	870	2490	....	640	560	4,560
Garage	−1030[a]	....	−1550[b]	3410	2700	3,530
Recreation	840	....	570	720	490	2,620
Totals	33,980	22,620	290	17,890	10,970	85,750
Percentages	39.6	26.4	0.3	20.9	12.8	100.0

[a]Wall heat loss of 2110 Btu minus wall heat gain of 3140 Btu.
[b]Heat gains; 960, 310 and 280 Btu.