above which no heat is required by the structure) from Fig. 12 at the intersection of the day heat loss line and the zero load line.

3. *Determine the Balance Point Temperatures* for the calculated day and night heat losses and the system capacity. These temperatures are obtained from Fig. 12 at the intersection of the heat loss and system capacity lines.

4. Obtain the average outdoor temperature and hours of occurrence *below the changeover temperature* by tabulating the weather data in the form given by Table 1. The day and night structure heat loss, as well as the system heating capacity at this average outdoor temperature, can then be obtained from Fig. 12. Also, it will be necessary to obtain, from manufacturer's data, the kilowatt demand of the compressor and the heat-source, heat-sink auxiliary equipment, such as outdoor coil fans or deep well pumps, at the average outdoor temperature.

The kilowatt-hours of the compressor-outdoor fan combination below the changeover temperature is, therefore, the product of (structure heat loss times the hours of occurrence divided by the system heating capacity) and (the kilowatt demand of compressor-outdoor fan combination) at the average outdoor temperature below the changeover temperature.

5. Obtain the average outdoor temperature and hours of occurrence *below the balance point* by tabulating the weather data in the form given by Table 1. The day and night structure heat losses, as well as the system heating capacity at the average temperature below the balance point, can then be obtained from Fig. 12.

The amount of supplemental or booster heat required (indicated by the crosshatch lines on Fig. 12) is then the product of (the difference between the structure heat loss and the system heating capacity) and (the hours of occurrence) at the average outdoor temperature below the balance point.

6. The heating kilowatt-hours for the day and night periods are the sum of the compressor-outdoor fan kilowatt-hours from step 4 and the booster heat kilowatt-hours from step 5.

7. The total heating kilowatt-hours is the sum of the day and night kilowatt-hours in step 6.

An example of this procedure is given in Table 3, with calculations of the energy requirements for heating in the month of January. Calculations should be made for all other months and the data recorded in the form of Table 2.

Cooling

8. Calculate the day and night heat gain in the form given by Fig. 13. These heat gains include the transmission, solar, internal ventilation or infiltration air, as discussed in the section Heating and Cooling Load Estimates. The system cooling capacities, at various outdoor temperatures, are obtained from the manufacturer's published data.

9. Determine the outdoor temperature range corresponding to each of the four steps of compressor capacity, from curves such as Fig. 13, for the day and night cycle. The approximate range for *the day cycle* is:

54 F or below, use outdoor air
55–59 F, use ¼ capacity
60–74 F, use ½ capacity
75–84 F, use ¾ capacity
85 F and above, use full capacity

The approximate range for *the night cycle* is:

75–84 F, use ¼ capacity
85–95 F, use ½ capacity

10. Obtain the number of hours at the four ranges of outdoor temperature (corresponding to the four steps of capacity modulation) given by step 9. These operating hours can be compiled from weather bureau data for each of the cooling months, as illustrated by Table 1 for the month of July.

11. The cooling requirement, in ton-hours, for each of the four steps of capacity, is the product of the (hours of occurrence, from step 10) and (system capacity, in tons).

12. The kilowatt-hours for each of the four steps of capacity are products of the (ton-hours, from step 11) and (the kilowatts per ton-hour, from manufacturer's data).

13. The total cooling kilowatt-hours for the day and night periods are the sum of the kilowatt-hours for the four capacity steps of step 12.

14. The grand total cooling kilowatt-hours for the month is the sum of the day and night kilowatt-hours from step 13.

Table 3 .... Example of Procedure for Calculating Energy Requirements of Compressor-Outdoor Coil Combination for Commercial Installation

Heating—Month of January

Step	Description	Units	Day	Night
1.	Net Total Calculated Heat Loss at Design Temp, Fig. 12	Btuh	1,510,000	2,130,000
2.	Changeover Temperature, Fig. 12	F	41	65
3.	Balance Point, Fig. 12	F	12	21
4.	Below Changeover Temp (given in Line 2)			
	a. Average Outdoor Temp, Table 1	F	33	37
	b. Hours, Table 1	Hr	196	371
	c. Structure Heat Loss, Fig. 12	Btuh	400,000	1,080,000
	d. Heat Pump Capacity, Fig. 12	Btuh	2,060,000	1,275,000
	e. Kw-Compressor and Fan (from manufacturer's data)	Kw	235	240
	f. Kwh-Compressor and Fan: Lines $\frac{4c \times 4b}{4d} \times 4e$	Kwh	8950	44,300
5.	Below Balance Point (given in Line 3)			
	a. Average Outdoor Temp, Table 1	F	12	17
	b. Hours, Table 1	Hr	...	20
	c. Structure Heat Loss, Fig. 12	Btuh	1,425,000	1,850,000
	d. Heat Pump Capacity, Fig. 12	Btuh	1,425,000	1,570,000
	e. Booster Heat: Lines $\frac{(5c-5d)\times 5b}{3413}$	Kwh	...	1640
6.	Total Kwh for Month: Lines 5e+4f	Kwh	8950	45,940
7.	Grand Total: Day and Night	Kwh	54,890	

BIBLIOGRAPHY

S. M. Minor, Cal Kleinschmidt, and Richard Borcherding: Air-source heat pump finds its place in northern climates (*Actual Specifying Engineer*, January 1959 and February 1959).

Neil Hill: Heat pump reclaim system proves new design approach (*Heating, Piping and Air Conditioning*, September 1960).

Gershon Meckler: Heat pump redistribution systems (*Progressive Architecture*, December 1959).

R. C. Burkhardt and R. G. Werden: Water source heat pump (*Actual Specifying Engineer*, July 1961).

Heat Pump Performance (*Symposium Bulletin*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, 1959).

Philip Sporn and E. R. Ambrose: Design and application for electric heat (*Air Conditioning, Heating and Ventilating*, July 1960).

J. R. Harnish: Achieving economy in the design and use of heat pumps (*Air Conditioning, Heating and Ventilating*, August 1959).

L. N. Brown: Heat pumps—basis of operation (*All Electric Heat Pump Symposium*, Houston Lighting and Power Co., Houston, Texas, April 1959).

G. L. Biehn: Multiple heat pump installations (*Air Conditioning, Heating and Ventilating*, February 1956).

CHAPTER 5

WARM AIR HEATING SYSTEMS

Forced Warm Air Systems; Air Distribution; Supply Outlets and Return Grilles; Duct Construction; Simplified Methods of Design for Perimeter Systems of Loop, Radial, and Extended-Plenum Types; Return Duct System for Perimeter Installations; Inside Wall Delivery Systems; Design of Large Systems; Automatic Controls; Adjustment of System; Worm Air Ceiling Panel Systems; Summer Operation; Gravity Warm Air Systems

WARM air heating systems may be conveniently divided into two classifications depending upon the manner in which the motive power for circulating the warm air is supplied. In *gravity* systems, the motive head is due to the difference in weight between the heated air leaving the top of the furnace casing and the cooler return air entering the bottom of the casing. In a *forced* warm air heating system, all or part of the motive head is supplied by a fan. Although a great many gravity warm air heating systems are in use, only a limited number of new gravity installations are now being made. Emphasis will therefore be placed upon the design and installation of forced warm air heating systems.

FORCED WARM AIR SYSTEMS

In forced warm air heating systems, the air circulation is effected by motor-driven centrifugal fans, commonly referred to as blowers. The advantages of forced air systems are:

1. The furnace may be placed in any part of the structure.
2. Distribution ducts can be made small enough to be inconspicuous and out of the way, or be completely concealed from view where desired.
3. Circulation of air is positive, and in a properly designed system, can be controlled in such a way as to give a comfortably uniform temperature distribution.
4. Humidity control is readily attained.
5. The air may be cleaned by filters or other means.
6. If properly designed or suitably adapted, the same air distribution system can be used for summer cooling as for winter heating.
7. The use of the fan permits flexibility in the location of supply and return grilles as required to obtain proper distribution of air for comfort.
8. Controlled quantities of ventilation air may be drawn into the system and conditioned before it is introduced into occupied portions of the structure. Recirculated air can be treated as necessary to obtain the desired quality.

Warm air heating systems are equally adaptable for use in residential and non-residential structures. Although most commonly found in one and two family residences, recent developments in equipment and system design have contributed to the increased use of warm air heating systems in school buildings, apartment houses, and commercial and industrial structures. Other factors which have contributed to this trend include the desire to use one distribution system for both winter and summer air conditioning, and the desire of owners to turn over to the tenant responsibility for all utilities in apartments and commercial buildings.

The construction features of forced warm air furnace units and the function and selection of the various parts of a system are discussed in Chapter 43 of the 1961 Guide and Data Book and other publications.[1]

AIR DISTRIBUTION

The conditions of comfort obtained in a room are influenced greatly by the type of supply outlet used, and the locations of the supply outlets and return grilles. In general it has been found that changes in the type, air velocity, and location of the supply outlet affect the room conditions much more than the changes in the location of the return grilles. Although the principles of air distribution which are discussed in Chapter 11 of the 1961 Guide And Data Book apply in the design of warm air heating systems, simplified methods of selecting outlet size and location are usually used. Three methods of locating outlets and grilles are in common use. *One method* is to locate all supply outlets in or near the outside wall, usually beneath windows, and to use outlet grilles or diffusers which deliver the air upward in a fan-shaped pattern to blanket the cold area. This arrangement causes mixing of the warm supply air with the cool air from the high-heat-loss area and with the cold air from infiltration, to prevent drafts. This method of introducing warm air into a structure is called *perimeter heating*. A *second method* is to locate the supply openings on the inside wall, near the floor or near the ceiling, and locating the return openings near the greatest outside exposure. A *third method* is to locate the supply outlets in the ceiling, and the return openings near the greatest outside exposure. Any of these methods of introducing the supply air can be used for summer air conditioning.

In any case, the warm air registers should be so located and so designed that the air stream never discharges directly against people at rest. Tests[2] in Warm Air Research Residences No. 1 and No. 2 at the University of Illinois, have indicated that nearly continuous blower operation gave better results than intermittent operation. This type of operation is more commonly achieved by suitable adjustments of air quantity and fan switch settings than by continuous operation of the blower.[2]

Supply Outlets and Return Grilles

The type of supply outlet that should be used depends upon the type of distribution system to which it is applied. With perimeter duct systems, the supply outlets are usually located in the floor, in the baseboard, or low in the side-wall and underneath a window. In order to be most effective, perimeter diffusers must deliver the air upward and in a fan-shaped pattern so as to blanket the window or cold wall with warm air, thus mixing with and tempering the