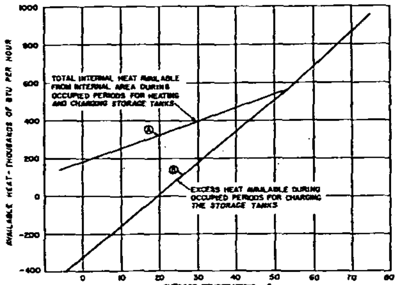


** 20 percent has been added to the available internal gain to account for the heat of compression added with the air-conditioning compressor.*

Fig. 11 .... Quantity of Internal Heat Available to External Areas and Storage Tank at Various Outdoor Temperatures During Occupied Periods*

exterior and interior zones. Figure 11 shows the result of transferring this internal excessive heat gain to the exterior zone by means of a heat pump. Curve A of Fig. 11 is the total internal heat available and curve B is excess heat (above that needed by the exterior zone) which can be kept in a storage tank (using a cycle similar to that shown by Fig. 4) for future use at night, weekends, or other unoccupied periods. For this particular installation, during the occupied periods no outside heat source or supplemental heat is needed at outdoor temperatures of minus 5 F or above.

## OPERATING COST

It is preferable to compute the electric consumption of the refrigerating compressors and outdoor fans separately from that of the auxiliary equipment which is used more or less constantly, such as conditioner fans and water circulating pumps. This auxiliary equipment can then be included as part of the basic load of the structure. This is particularly true with air source-sink systems where the kilowatt inputs to the compressor and the heat source-sink fans vary with the outdoor temperature and, consequently, must be related to the expected hours of operation at the various outdoor temperatures.

In computing operating cost of air-source heat pumps, it has been found from a study of actual installations that the kilowatt-hours consumed during the defrosting cycle are approximately 2-3 percent of the total heat pump electrical consumption during the two or three coldest months and, therefore, can be neglected in the calculations without causing an appreciable error.

The first step in operating cost analysis is to plot the day and night heat loss and the system heating capacity at various outdoor temperatures, as illustrated by Fig. 12, in order to obtain the day and night balance points, which are the points at which the heating capacity satisfies the structure heat loss for the period. If these balance points are above the outdoor design temperature, the portions represented by the shaded area must be furnished by supplemental heat. The actual required supplemental heat is represented by the difference between the quantity needed to heat the structure below the balance point and the quantity supplied by the heat pump system.

It can be noted from Fig. 12 that no heat is required during

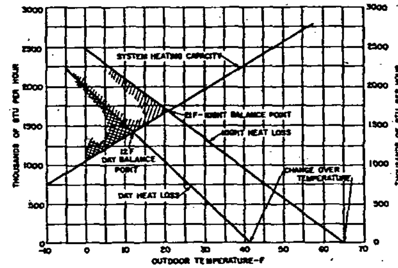


Fig. 12 .... Typical Plot of Structure Heat Loss and System Capacity for Various Outdoor Temperatures

the day at outdoor temperatures above 41 F. This temperature, at which the system changes from heating to cooling cycle, is referred to as the *changeover temperature*. The hourly occurrence of the various outdoor temperatures, needed to properly evaluate the operating cost for a particular area, can be compiled, for convenience, in the form of Table 1. This type of weather data, for the period of 1935-1939, can be obtained from the United States Department of Commerce, Weather Bureau, Asheville, North Carolina. Also, a number

Table 1 .... Average Hourly Occurrence of Outdoor Temperatures[a]

*For the 5-year period 1934-39 for Roanoke, Virginia*

| | Temp Range F | JANUARY Accumulative Hours Day[b] | Night[b] | Total | Weighted Average Operating Temp[c] Day[b] | Night[b] | Total |
|---|---|---|---|---|---|---|---|
| Heating | 0-4 | — | — | — | — | — | — |
| | 5-9 | — | — | — | — | — | — |
| | 10-14 | 2 | 4 | 6 | 12 | 12 | 12 |
| | 15-19 | 7 | 13 | 20 | 15 | 15 | 15 |
| | 20-24 | 18 | 31 | 49 | 19 | 19 | 19 |
| | 25-29 | 39 | 68 | 107 | 23 | 23 | 23 |
| | 30-34 | 101 | 141 | 242 | 28 | 28 | 28 |
| | 35-39 | 171 | 227 | 398 | 32 | 31 | 31 |
| | 40-44 | 234 | 290 | 524 | 35 | 34 | 34 |
| | 45-49 | 286 | 333 | 619 | 37 | 35 | 36 |
| | 50-54 | 319 | 354 | 673 | 38 | 36 | 37 |
| | 55-59 | 344 | 367 | 711 | 39 | 37 | 38 |
| | 60-64 | 362 | 371 | 733 | 41 | 37 | 39 |
| | | JULY | | | | | |
| Cooling | 55-59 | — | 9 | — | | | |
| | 60-64 | 12 | 50 | 62 | | | |
| | 65-69 | 35 | 167 | 202 | | | |
| | 70-74 | 102 | 292 | 394 | | | |
| | 75-79 | 175 | 347 | 522 | | | |
| | 80-84 | 264 | 367 | 631 | | | |
| | 85-89 | 335 | 371 | 706 | | | |
| | 90-94 | 362 | 372 | 734 | | | |
| | 95-99 | 370 | 373 | 743 | | | |
| | 100-104 | 372 | — | — | | | |

[a] The average hourly occurrence of the outdoor temperature over the 5-year period was obtained from the United States Department of Commerce, Weather Bureau, Asheville, North Carolina.
[b] The day hours, columns 2, 3 and 4, were assumed for the period 8 a.m.-8 p.m. and the night hours from 8 p.m.-8 a.m.
[c] The weighted average temperatures, columns 5, 6 and 7, are equal to the sum of (the product of the individual temperatures and the hours of occurrence) divided by the (summation of the hours of occurrence).



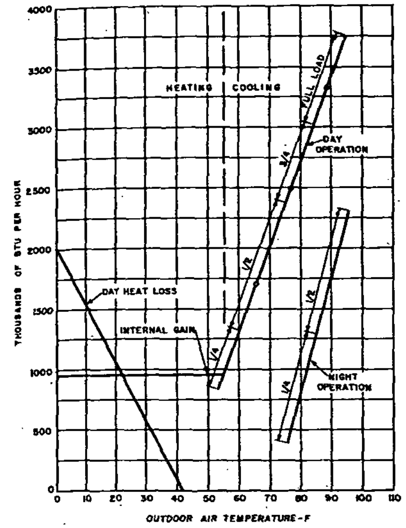


Fig. 13 .... Calculated Heat Loss and Gain at Various Outdoor Temperatures

of manufacturer's product and application manuals include similar weather data for many geographic areas.

The electric energy consumption for heating must be added to that required for cooling to obtain a total yearly cost. It is advantageous to compile the hours of operation at the different cooling loads, similar to the procedure followed for the heating computations. Unfortunately, there is no positive way of predicting the operating time of a particular cooling installation. It is generally agreed by most air-conditioning engineers, and has been substantiated in several instances by published field test data, that commercial mechanical air conditioning equipment, during occupied periods, should be operated when the outdoor temperature is 55 F or above, and during other times when the outdoor temperature is 75 F and above, as shown by Fig. 13. Field data can be used as a guide in compiling the hours of operation at partial loads, say 25, 50, 75 and 100 percent. Some judgment must be exercised, however, in using this data and design factors, since the amount of internal heat gain and size of equipment selected, in relation to the calculated load, will influence the partial load operating hours. The use of the equivalent full load hours of compressor operation is not realistic or accurate, even for conventional commercial cooling systems.

It is necessary to know the monthly kilowatt electric demands and the corresponding kilowatt-hour consumption for the base electric load, as well as for the heat pump or any other electric equipment, in order to apply the proper electric tariff. The base loads, shown as columns 1, 2 and 3 of Table 2 may include lighting, elevators, office machinery, exhaust and supply fans, circulating pumps, and similar items which are normally essential to a structure and are not affected by a particular air conditioning design. The heat pump kilowatt demand, during the month, which is required to satisfy the net day and night heat loss or heat gain (whichever is the greater), can be obtained from manufacturer's data. These resulting kilowatt demands are multiplied by a coincident factor to obtain the coincident demands, listed in columns 4 and 7, and which can be directly added to the base load demands to obtain the values listed in column 10. These coincident factors can best be obtained from published data on similar installations.

Operating costs are dependent upon a number of important influencing factors. In order to make sure that all of the items are properly considered, the following procedure has been found very helpful as a guide in obtaining reasonably accurate heating and cooling operating costs of the refrigerating compressors and the associated outdoor air fans, for an air-source, air-sink, commercial and industrial heat pump system. The procedure described here is primarily for air-source heat pumps, but may also be used for water-source systems.

## Procedure for Estimating Energy Requirements For Heat Pump Heating and Cooling

It is necessary to compute the energy requirements for heating and cooling by months in order to apply the proper electric tariff as explained in the section Operating Cost.

### Heating

1. *Calculate the Day and Night Heat Losses, obtain System Capacity data, and plot in the form given by Fig. 12.* The calculated *gross heat loss* is credited with the useful internal gain to obtain the *day heat loss* and with the reduced ventilation requirement for the unoccupied periods for the *night heat loss*. Suggestions are given in the section Heating and Cooling Load Estimates. The system heating capacities at various outdoor temperatures, including the additional heating effect obtained from liquid-gas heat exchangers or liquid subcooling coils, are obtained from manufacturer's published data.

2. *Obtain the Changeover Temperature* (the outdoor temperature

Table 2 .... Suggested Form of Operating Cost Summary for Commercial and Industrial Heat-Pump System

| Period | Base Electric Load (Lighting and Miscellaneous) kw (1) | Base Electric Load (Lighting and Miscellaneous) kwh (2) | Cost of Base Load Dollars (3) | Heat Pump Coincident demand kw (4) | Heat Pump Heat kwh (5) | Heat Pump Cool kwh (6) | Supplemental Resistance Heating (If Used) kw (7) | Supplemental Resistance Heating (If Used) kwh (8) | Total Heating and Cooling kwh (9) | Total Electric Load kw (9) | Total Electric Load kwh (11) | Total Cost Dollars (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JUNE | | | | | | | | | | | | |
| *Fill in one line for each month through MAY* | | | | | | | | | | | | |
| MAY | | | | | | | | | | | | |