Table 5 . . . . Equivalent Full Load Operating Hours of Refrigeration Equipment Used for Summer Cooling May 15 to Oct. 15,[a]

Application	Hr Open for Business	Atlanta	Boston	Chicago	Detroit	Los Angeles	New Orleans	New York	Phila-delphia	Oklaho-ma City	St. Louis	Wash-ington D. C
Barber Shops	1280	1010	650	720	720	680	1080	830	860	1020	890	940
Department Stores	940	840	560	610	610	580	890	700	720	840	750	780
Drug Stores	2100	1630	950	1060	1060	980	1790	1280	1330	1650	1420	1530
Funeral Parlors	600	440	300	330	330	310	470	370	380	440	400	410
Offices	1100	1030	660	720	720	680	1060	840	880	1040	910	960
Restaurant (Short Hour)	1290	970	535	620	620	570	1060	760	800	980	830	880
Restaurant (Long Hour)	2100	1510	820	930	930	850	1690	1170	1210	1530	1300	1400
Speciality Shops (5 & 10)	1090	800	530	590	590	560	860	670	690	810	720	750
Theaters—Continuous	1500	1010	700	750	750	720	1080	850	870	1020	910	950
Theaters—Neighborhood	900	640	420	450	450	430	650	500	620	650	550	580

[a] *Modern Air Conditioning, Heating and Ventilating*, by W. H. Carrier, R. E. Cherne, W. A. Grant, and W. H. Roberts (Pitman Publishing Corp., 1959, p. 519).

maintenance is handled by outside service firms and the cost considered as maintenance. These costs vary considerably with factors such as the type of system and the proficiency of the installing and servicing organization. Therefore, any forecast of maintenance costs should include consideration of the equipment as a part of the engineering study. The charges should be based upon the entire period under study rather than the early years of operation when repairs may be expected to be at a minimum.

Various estimates of maintenance costs vary from 5 to 10 percent of the installation cost. Table 4 is based upon an average of 7½ percent for about a 75-ton installation. This probably would apply to most installations using high-quality equipment. The maintenance cost must be modified for size of job and quality of equipment. With lower-cost equipment, higher maintenance costs can be expected.

The accounting practices of the owner and the rules of the Bureau of Internal Revenue affect the charges for major overhauling or complete replacement which may restore the capital value of certain equipment items. In these cases the expenditure may not necessarily be charged as maintenance but will become a fixed charge spread over the remaining years of equipment life. Table 4 gives some approximate costs for maintaining large air-conditioning installations using high-quality equipment.

LABOR FOR OPERATION

In some cases with the installation of automatic equipment, operating labor may be non-existent, but where such labor is required, the cost is readily calculated. Where operators are required, the expense is often considered maintenance, but since they may have other functions that are not properly charged to operation of the air-conditioning, heating, or ventilating installations, the charges should be properly allocated. The cost of experienced and competent operators is well justified in medium and larger plants by economies that can be achieved in maintenance and energy costs.

ENERGY AND WATER COSTS

Energy costs include the costs for power, water, steam, coal, oil, etc., consumed to operate the system.

From the selected equipment and type of installation, it is possible to segregate the relatively constant power loads and the total brake horsepower. Annual power cost can then be figured from the following formula:

$$\text{annual power cost} = \frac{0.746(\text{bhp})HR}{\eta} \qquad (1)$$

where

bhp = brake horsepower.
H = annual operating hours.
R = power rate, dollars per kwhr.
η = motor efficiency (decimal).

In using Equation 1 it must be pointed out that the electric rate, R, must reflect the proper combination of energy and demand rates. These vary widely between the utility companies, and sometimes the rate structure is such that it is largely the demand charge which determines the proper value of R to use in Equation 1.

Operating Refrigerating Equipment

In an air-conditioning system the refrigerating equipment is usually the largest power consuming item to be considered. Also, the prediction of operating cost is more difficult because the power required for summer cooling is affected by many factors of a variable nature.

Table 5 gives the equivalent full-load operating hours of refrigerating equipment used for summer cooling for the period of May 15th to October 15th. This table was calculated from the following equation:

$$H_e = m(b + cf) \qquad (2)$$

where

H_e = equivalent full load operating hours of refrigeration equipment used for summer cooling during period May 15 to October 15.
m = total hours during period May 15 to October 15 that the establishment is open for business.
b = fraction of maximum load from internal heat under average operating conditions.
c = fraction of maximum load that is due to external sources at maximum design conditions.
f = ratio of the number of hours for a particular city, when the outdoor wet-bulb exceeds 65 F, during the period June 1 to October 1 to the total number of hours during that same period. Total hours are assumed as 8 hr per day period for barber shops, department stores, funeral parlors, offices, short-hour restaurants, and specialty shops, and 12 hr per day period for drug stores, long-hour restaurants, and theaters.

It should be pointed out that certain southern cities may have seasons longer than the 5-month period indicated in Table 5. If it is desired to consider a longer season of operation, the ratio of full-load operating hours to hours open for business is smaller; in other words, the *refrigeration load factor* is lower. This is true because the extra increment of days added will be a relatively light load, since the table already includes the more severe part of the season.

The season electrical power cost for refrigerating equipment is then given by the following equation:

$$\text{season power costs} = \frac{0.746(\text{bhp})_t T H_e R}{\eta} \qquad (3)$$

where

$(\text{bhp})_t$ = brake horsepower per ton (see Fig. 1) for *average* load during period. (Due allowance should be made for poorer compressor efficiency at light load.)
T = maximum refrigeration design load, tons.
H_e = equivalent full load refrigeration operating time, hours (from Table 5).
R = power cost, including demand and energy charges, dollars per kwhr.
η = motor efficiency at average load (decimal).

In considering refrigeration power consumption, it should be noted that the use of weather records for a specific year may lead to large inaccuracies in estimating operating costs, since there may be wide variations from year to year, and therefore, average yearly weather records should be used rather than those for any individual year.

If the refrigeration compressor is steam-turbine driven, the same general method can be followed, taking into account average water rate per brake horsepower-hour and the cost of steam.

Condenser Water

Condenser-water cost estimates can also be based on equivalent full-load operating hours of the refrigeration equipment. The varying temperature of the water at its source, as well as the temperature of the discarded water, must, however, be taken into account. In general, when water is purchased, control is provided to hold the leaving water temperature (or condensing temperature) constant; and in such case the entering water temperature becomes the major variable. The gallons per minute per ton can readily be calculated for any water temperature rise.

The following equation for cost of condenser water is useful:

$$B = 0.060\ a\ T\ H_e\ C \qquad (4)$$

where

B = cost of water for refrigeration during period, dollars.
a = average gallons per (minute) (ton).
T = tons of refrigeration at maximum design load.
H_e = equivalent full load refrigeration operating hours (Table 5).
C = water cost, dollars per 1000 gal.

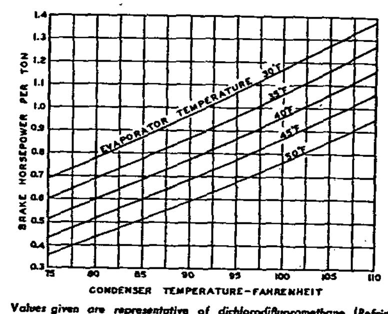
The average gallons per minute per ton must take into account the variable water temperature. When well water is used as a source, and entering and leaving temperatures are considered constant, the average gallons per minute per ton obviously are equal to the design gallons per minute per ton. However, when the source is river or lake water, its maximum seasonal temperature will generally be reached at the same time that the refrigeration load factor is highest. The average gallons per minute per ton should be calculated from known or estimated water temperatures, because they vary through the season. Maximum water main temperatures are given in Chapter 41, but should always be verified locally. In lieu of this tedious work, the average gallons per (minute) (ton) may be taken as 80 percent of design gallons per (minute) (ton) with reasonable accuracy, for the condition of variable temperature of entering water obtained from rivers and lakes.

Cooling towers and evaporative condensers virtually eliminate condensing water charges since the windage and evaporation losses are seldom over two or three percent of the water circulated.

The savings in water consumed often will not in itself justify the installation of water-economizing equipment since the cost for pumping and the fixed or ownership charges may be in excess of the annual cost for once-through condensing operation. If operating costs are to be the basis for selection, then fixed charges should be determined when studying application of this equipment which usually has a shorter life than the other components.

Usually the primary factors influencing the installation of water conservation equipment are the lack of an adequate water supply or local regulations intended to conserve an existing water supply.

Another factor influencing the installation of such equipment is the increasing trend toward the enactment of taxes and service charges for condensing water wasted into city sewers. Certain municipalities will remit the sewer taxes



Values given are representative of dichlorodifluoromethane (Refrigerant 12) reciprocating machines of about 25 tons capacity in air-conditioning applications. Requirements of smaller machines are usually higher, and for larger machines may be lower. Values shown are for liquid refrigerant at condenser temperature (no subcooling). Subcooling of the liquid may decrease these values approximately 0.3 percent to 0.5 percent for each Fahrenheit degree the liquid temperature is lowered.

Fig. 1 . . . . Typical Brake Horsepower Requirements for Refrigeration[a]