extend to other facilities beyond the equipment being discussed here, it is important that only an equitable share of the group's time be charged to maintenance.

Extraordinary repairs are quite often handled by separate maintenance divisions and the expense charged back to air conditioning, heating, and ventilating. In other cases, all 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 percent 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

TABLE 4. APPROXIMATE MAINTENANCE COST FOR LARGE AIR CONDITIONING INSTALLATIONS, USING HIGH QUALITY EQUIPMENT[a]

| | DOLLARS PER (TON)(YEAR) |
|---|---|
| Repairs for refrigeration machinery | 1.07 |
| Refrigerant | 0.40 |
| Oil and grease | 0.11 |
| Painting (Water boxes and dehumidifiers) | 0.45 |
| Filters, clean and re-oil 4 times per year | 1.50 |
| Controls, outside service | 0.26 |
| Cleaning air conditioners | 1.38 |
| Total | 5.17 |

[a] Estimated for 1955.

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 No. 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 which 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:

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

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 |
|---|---|---|---|---|---|---|---|
| Barber Shops | 1280 | 1010 | 650 | 720 | 720 | 680 | 1080 |
| Department Stores | 940 | 840 | 560 | 610 | 610 | 580 | 890 |
| Drug Stores | 2100 | 1630 | 950 | 1060 | 1060 | 980 | 1790 |
| Funeral Parlors | 600 | 440 | 300 | 330 | 330 | 310 | 470 |
| Offices | 940 | 870 | 560 | 620 | 620 | 580 | 900 |
| Restaurant (Short Hour) | 1290 | 970 | 535 | 620 | 620 | 570 | 1060 |
| Restaurant (Long Hour) | 2100 | 1510 | 820 | 930 | 930 | 850 | 1690 |
| Specialty Shops (5 & 10) | 1090 | 800 | 530 | 590 | 590 | 560 | 860 |
| Theaters—Continuous | 1500 | 1010 | 700 | 750 | 750 | 720 | 1080 |
| Theaters—Neighborhood | 900 | 640 | 420 | 450 | 450 | 430 | 650 |

| APPLICATION | HR OPEN FOR BUSINESS | NEW YORK | PHILADELPHIA | OKLAHOMA CITY | ST. LOUIS | WASHINGTON D.C. |
|---|---|---|---|---|---|---|
| Barber Shops | 1280 | 830 | 860 | 1020 | 890 | 940 |
| Department Stores | 940 | 700 | 720 | 840 | 750 | 780 |
| Drug Stores | 2100 | 1280 | 1330 | 1650 | 1420 | 1530 |
| Funeral Parlors | 600 | 370 | 380 | 440 | 400 | 410 |
| Offices | 940 | 710 | 740 | 880 | 770 | 810 |
| Restaurant (Short Hour) | 1290 | 760 | 800 | 980 | 830 | 880 |
| Restaurant (Long Hour) | 2100 | 1170 | 1210 | 1530 | 1300 | 1400 |
| Specialty Shops (5 & 10) | 1090 | 670 | 690 | 810 | 720 | 750 |
| Theaters—Continuous | 1500 | 850 | 870 | 1020 | 910 | 950 |
| Thearers—Neighborhood | 900 | 500 | 520 | 650 | 550 | 580 |

[a] *Modern Air Conditioning, Heating and Ventilating*, by W. H. Carrier, R. E. Cherne and W. A. Grant Pitman Publishing Corp. 1940, p. 73).

*where*

bhp = brake horsepower.
$H$ = annual operating hours.
$R$ = power rate, dollars per kwhr.
$\eta$ = 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