any, and flowing air and liquids are potential sources of noise and vibration. The first, and frequently the least expensive and most effective measure in noise reduction, is to put distance between the noise and the listener. Installations of cooling equipment in basements, crawl spaces, utility rooms or attached garages are preferable to those in alcoves or closets adjacent to bedrooms and living rooms. Mounting of units on concrete floors is preferred. Further steps which may be taken to achieve an acceptable low noise level are as follows:

1. Minimize the production of noise and vibration. Use only true, concentric pulleys with smooth belts at the proper tension and use properly balanced blower wheels and other rotating parts, operated at the minimum practical speed. Provide an adequate duct system which promotes smooth air flow at reasonable velocity and is sufficiently rigid in construction so that it does not vibrate unduly.

2. Prevent the transmission of noise and vibration to the house structure and to ducts and piping. Use properly loaded isolation mounts for compressors, even when on concrete floors, and provide vibration isolators on blowers and refrigerant lines and vibration loops in the refrigerant system. Install flexible connections between the cooling unit and the ductwork.

3. Control airborne noise with sound-absorbing material or other acoustical treatment. Install sound-absorbing material within ductwork and, where practicable, use one or more elbows between the equipment and the registers or grilles.

AIR DISTRIBUTION METHODS

Systems should be designed and installed by competent engineers in accordance with authoritative information such as given in the design manuals of the Air-Conditioning and Refrigeration Institute[3] and the National Warm Air Heating and Air Conditioning Association.[4] The sizes of the ducts of year-round air-conditioning systems are often larger than those of equivalent winter heating systems since large quantities of cool air, at 55 F to 65 F, must be circulated through them.

Several manufacturers have developed reliable methods of duct design. Such methods should be used when recommended, since they take into account the specific air-flow and static pressure characteristics of the systems to which they apply. They should, however, be applied with caution to systems and equipment other than those for which they were developed.

Cooled air admitted to rooms from ducts through supply outlets is from 15 F to 25 F colder, and therefore heavier, than the air in the room, and has a natural tendency to drop toward the floor. Unless the supply outlets are properly selected, located, and adjusted, the air distribution is likely to result in a low velocity of cool air falling on the occupants or a high velocity stream of cool air striking a wall or other obstruction and deflecting on the occupants. A further complication is introduced when the same outlets are used for heating in which case the delivered air at temperatures considerably above room temperature has a tendency to rise.

Where cooling is installed with ducts and air outlets that serve the cooling function only, the practice and experience of comfort air conditioning for offices and commercial buildings apply directly to residential installation. Although cooling and heating by means of the same ductwork and air outlets has been common practice in commercial and industrial applications, greater care must be taken in residential applications. It has been found that low air-flow rates (much lower than would be used for cooling systems) are desirable for warm air heating systems.[5] It is therefore recommended that, in a residence located in a moderate or cold climate, provision be made for different air-flow rates for summer and winter. In warmer climates, however, where air conditioning is the primary consideration, the summer air-flow rate may be used the year around.

The registers may be placed either in the high side-wall or in the perimeter location. For the high side-wall applications, it is necessary that the deflection of the air be different for summer than it is for winter to prevent the jet from dropping into the living zone (60 in. above the floor and below) where the velocity should be not greater than 35 fpm. For registers located at the perimeter of the residence,[6] it is not necessary to change the deflection from summer to winter.

The air distribution system should be designed for the largest air-flow rate that is to be used, as outlined in *Manual* 9 of the National Warm Air Heating and Air Conditioning Association. For small-pipe perimeter systems, it is necessary to have more outlets than for the larger duct systems. In some applications, it may be necessary to close off some registers during the winter so that adequate register air velocities will be obtained. These registers would then be opened during the summer to give a sufficient number of outlets.

Recent investigations have shown[7] that the use of perimeter-duct systems for air conditioning gives excellent results, and that objectionable air motion does not occur within the living zone except in the immediate vicinity of the registers. Care must be taken, however, to use only registers or diffusers that are specifically designed for perimeter application. This is necessary to permit the introduction of the air into the room in a pattern that does not cause drafts. Floor diffusers which distribute the air in a fan-shaped pattern along the wall or low side-wall diffusers which blanket the wall are recommended. For supply-air temperatures not more than 15 deg below room-air temperatures, diffuser face velocities of 500 fpm are recommended.[8] For supply-air temperatures 20 deg below room-air temperature, the diffuser face velocity should not be less than 700 fpm.

Many registers designed for outside wall application may not be satisfactory for cooling when applied to low-velocity systems because the cool air is apt to remain at the floor.

Ceiling diffusers may also be used, but they may lead to difficulty during the heating season if the warm air remains at the ceiling, resulting in cold floors.

High return locations at inside walls are very effective with outside wall or floor perimeter distribution systems for both the heating and cooling season. In multi-story or split-level dwellings there should be a minimum of one return on each level with a high central return on the upper level to minimize the effects of hot air rising through halls and stairways to upper levels. With ceiling or high-inside-wall distribution, the returns should be located on the outside walls under windows for best results.

CONTROLS

Control devices and systems and their application in residential air conditioning are discussed in Chapter 43, Automatic Control.

OPERATING COSTS

The operating cost of residential cooling equipment during a particular summer depends on variables such as the amounts of sunshine and rain, the number of abnormally hot or cool days, the efficiency of the equipment, and the local power rate. It is also influenced by human factors such as operation of equipment only during the hottest weather, opening windows at night,[9] and difference in preferred indoor

Table 1 . . . Approximate kw Input per 12,000 Btuh Cooling Capacity

Item of Power Load	Type of Heat Rejection* Water Cooled Condenser			
	City Water	Atmospheric Cooling Tower	Mechanical Draft Cooling Tower	Air-Cooled Condenser
Refrigeration Compressor	1.00	1.00	1.00	1.35
Blower for Air Conditioner	0.10	0.10	0.10	0.10
Blower for Rejection Air	—	—	0.15	0.15
Pump, Cooling Water	—	0.15	0.15	—
Total kw per 12,000 Btuh	1.10	1.25	1.40	1.60

* Other heat rejection means include wells, spray ponds, evaporative condensers, water coils in the ground, finned water coils in air, etc.

temperatures.[10] Nevertheless, it is important that lending agencies and prospective buyers of equipment be given a reasonably accurate estimate of the operating cost during normal summer weather and under usual operating conditions. Adjustments can then be made for any special conditions anticipated. The approximate electrical power inputs for the various motorized components in mechanical cycle air conditioners are shown in Table 1.

Power cost per hour can be estimated by multiplying the estimated power per ton, the cooling capacity in tons and the cost per kilowatt-hour. Thus the estimated cost per hour for a 3-ton air conditioner cooled with city water will be 1.1 kw × 3 tons × the power rate. It is essential to use the correct step of the utility residential rate structure to get a good estimate. The basis of the method used[11] requires the use of a table of the estimated annual hours of operation for properly sized equipment in typical cities. See Table 2.

The values in Table 2 have been substantiated by utility records of actual performance in several major cities when the average indoor temperature is maintained at 80 F. Low indoor temperatures increase operating cost as do weather conditions above normal.

Water usage is another important factor with water-cooled equipment. Various manufacturers have published water usage data for their equipment at varying summer water temperatures. Representative water consumption values are given in Table 3.

For a given application the power rate and water rate may be obtained from the local utilities. Since the average power requirement depends on the particular equipment used and

Table 2 . . . . Estimated Annual Hours of Operation for Properly Sized Equipment in Typical Cities during Normal Cooling Season

City	Hours	City	Hours
Atlanta, Ga.	750	Jacksonville, Fla.	1600
Boston, Mass.	200	Minneapolis, Minn.	350
Chicago, Ill.	400	New Orleans, La.	1500
Cleveland, Ohio	450	New York, N. Y.	350
Dallas, Texas	1400	St. Louis, Mo.	1000
Fresno, Calif.	900	Washington, D. C.	800

Table 3 . . . . Water Usage for Water-Cooled Equipment

Summer Water Temperature, Normal Extremes F	Gallons Per (Hour) (Ton)	Summer Water Temperature, Normal Extremes F	Gallons Per (Hour) (Ton)
55	34	75	58
60	39	80	70
65	44	85	88
70	50		

the condensing method, values obtained from the manufacturer should be used in preference to those in Table 1.

If the evaporator fan cycles with the compressor, the power requirement as found from Table 1 also represents the total power requirement for air-cooled condenser applications. For continuous fan operation the number of hours of compressor operation should be subtracted from the number of hours in the cooling season to obtain the extra hours of fan operation. This value may then be used with the appropriate value of power consumption and power cost for the fan motor only, to find the added power cost for continuous fan operation and the result should then be added to the power cost during compressor operation.

For water-cooled condenser applications the water cost, as determined from the operating hours, water rate, and manufacturer's data on equipment water usage, is added to the power cost to obtain the estimated total operating cost.

Another method has been developed using cooling degree days above 70 F as a criterion but tabulated values of cooling degree days for various localities are not available.[12] Approximate values can be obtained from degree-day maps.[13, 14] The daily range of temperatures for various localities is also required with this method.[15] It is important that the method used in estimating operating cost be consistent with the method used in calculating the heat gain of the structure.

EFFECTS ON FUTURE HOUSE DESIGN

Air conditioning, like automatic heating, has brought about improved practice in residential construction, particularly in those regions where cooling is of primary importance. Although it is true that construction practices which reduce the heating load also reduce the cooling load, there are certain considerations that are unique in their effect upon the cooling load. Special attention should be paid to window orientation and shading. South windows may be shaded by awnings or roof overhangs, but it is not practicable to shade large window areas having an east or west orientation except by exterior solar screening of some type. The use of insulation in the walls and ceiling of the residence will reduce the cooling load appreciably. In addition, attention should be paid to adequate ventilation of the attic. Double-glazed and weather-stripped windows, heat-absorbing glass, planned shade tree locations, and light-colored exterior wall and roof surfaces, also help to reduce the cooling load.

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