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, closets, or attics 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. Double stud walls with sound isolation blanket between the two free standing walls have been successfully used between utility rooms and bedrooms to provide improved sound isolation.

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.

In locating components outdoors, careful consideration should be given so that the sound level and air discharges will not become an aggravation to neighboring property owners. Components should be located far enough away from the structure so that sound reverberations will not occur. Particular care is required when the adjoining property does not consist of an air-conditioned structure and where the owner depends on open windows to provide an acceptable level of comfort. Hot air should not be discharged into neighboring property, shrubs or open windows.

AIR DISTRIBUTION METHODS

Systems should be designed and installed in accordance with authoritative information such as given in the design manuals of the National Warm Air Heating and Air Conditioning Association.[5] The sizes of the ducts of year-round air-conditioning systems are usually larger than those of equivalent winter heating systems since air is supplied for cooling purposes between 15 and 25 F deg below room temperature.

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. Under any circumstance, careful consideration must be given to the type of supply outlets selected and their locations in order to effect satisfactory room air distribution.

For new construction, it is customary to give careful consideration to combining the heating and cooling functions in the same air circulating system. This works out very well for the usual single story and ranch type homes. The usual practice is to estimate both the cooling and heating requirements and to supply cooling and heating elements of adequate size, with an air distribution system designed for the larger air quantity required.

In the case of one or two-story homes, the heating and cooling loads will not be proportionately the same for all rooms. Generally, the design concept is to make separate preliminary calculations for the heating and cooling air distribution requirements and then to make the necessary adjustments to achieve a compromise solution. For example, it may be necessary to have additional cooling supply outlets in one or more of the upstairs bedrooms or in other rooms which have large glass areas facing south or west, or which have unusually high internal heat loads such as in kitchens.

It is important to consider certain technical and economic aspects of residential air conditioning. An elaborately zoned air distribution system rarely can be justified economically. However, since the diurnal load variation is primarily influenced by external weather effects, the cooling load in each room changes from hour to hour during the operation of the system. In order to obtain ultimate conditions of comfort, these factors make it almost mandatory that the owner perform seasonal or even more frequent adjustments to the air distribution system. Such adjustments may involve the opening of additional outlets in the upstairs bedrooms during the cooling cycle and the throttling or closing of heating outlets in some rooms during the winter. On deluxe applications some additional refinements may be economically justified. One such refinement could be the installation of a heating and cooling system based primarily on heating requirements, with additional independent cooling ducts or self-contained units serving some or all of the second floor rooms. Another solution would be the inclusion of zone controls for rooms which have unusual load variations or high internal heat gains during the summer cooling season. When considering zoning, however, careful consideration must be given to the operating characteristics of both the heating and cooling equipment. For example, a reduction in the air quantity to one or more rooms may result in reducing the air flow across the evaporator to such a degree that it may freeze. A reduced air volume to a given room could reduce the velocity of air from the supply outlet causing an unsatisfactory air distribution pattern in the room.

In split level houses, both the heating and cooling processes are complicated by the internal gravity circulation that takes place through the large openings between the various levels. In many split level houses, the upper bedrooms tend to overheat in the winter. Double sets of outlets, both at the upper levels and the lower levels, have been used with some success with the owner opening some and closing others from season to season. National Warm Air Heating and Air Conditioning *Manual* 9 recommends operation with returns located high in each room while keeping doors closed.

In existing homes, the amount of cooling that can be added is limited by the air handling capacity of the existing furnace and duct system. While this is frequently satisfactory for normal occupancy, it is usually less than the owner would like to have in the higher cost home where large party entertainment could be a usual occurrence. In all cases where cooling is added to existing homes, the supply-air outlets must be checked for acceptable cooling air distribution. If the outlets are not already arranged for upward distribution of air, new upward deflection grilles should be installed if excessive cooling stratification is to be avoided. The importance of arranging for an upward throw at an effective velocity cannot be overstressed in converting existing heating systems with floor or baseboard outlets to do a combined heating and cooling function. It is not necessary to change the deflection from summer to winter for registers located at the perimeter of a residence.[6] Registers located at the inside walls of rooms have also been found to operate satisfactorily without change of deflection from summer to winter.

In some cases, the owners of residential air conditioning systems prefer the minimum of perceptible air motion. Ceiling outlets having multi-directional vanes, and perimeter baseboard outlets having multiple slots or orifices, have been found effective in meeting these requirements.

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

Item of Power Load	Type of Heat Rejection[a] Water Cooled Condenser			
	City Water	Atmospheric Cooling Tower	Mechanical Draft Cooling Tower	Air-Cooled Condenser
Refrigeration Compressor	1.00	1.00	1.00	1.15
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	1.40

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

CONTROLS

Control devices and systems and their application in residential air conditioning are discussed in Chapter 13 of the 1961 Guide And Data Book.

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,[7] and difference in preferred indoor temperatures.[8] 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 with an air-cooled condenser will be 1.4 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[9] 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 the condensing method, values obtained from the manufacturer should be used in preference to those in Table 1.

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

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.[10] Approximate values can be obtained from degree-day maps.[11,12] The daily range of temperatures for various localities is also required with this method.[13] 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

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		