Farmhouse Design and Equipment for SUMMER COMFORT

AGRICULTURE HANDBOOK NO. 241

Agricultural Research Service
U.S. DEPARTMENT OF AGRICULTURE

Contents

Washington, D.C.

Issued April 1963

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. - Price 15 cents

Farmhouse Design and Equipment for Summer Comfort

By Chester P. Davis, Jr.,[1] and Joseph W. Simons, *Agricultural Engineering Research Division, Agricultural Research Service*[2]

Comfort in the home during hot, summer periods is desirable so that work, recreation, and restful sleep may be enjoyed.

Effective cooling equipment in summer is as important for the modern home as a dependable system for supplying uniform heat in winter.

Depending on location, most farm families spend substantial amounts for heating their homes during the 4 to 8 months of cold weather. In the farm home of today comfortable living can be provided at reasonable cost in the remaining months of moderate to hot weather. In some cases the lower cost cooling methods such as the use of window or attic fans, well water, and evaporative coolers will provide relief from the heat. The most ideal and positive method of cooling is the mechanical refrigeration system. Costs of these systems have come within the financial reach of many farm families.

Regardless of the method used to improve comfort, consideration must be given to temperature, relative humidity, air movement, and cleanliness. High temperatures become almost unbearable when relative humidity is high and there is little air movement. Heat prostration or other illness may occur. However, if temperatures are moderate, higher humidities can be tolerated.

To maintain comfortable temperatures inside a building when it is hot outside, prevent as much heat as possible from reaching the interior and remove the heat that does enter if undesirably high temperatures result. Methods of attaining these requirements include (1) exclusion or reflection of direct radiation from the sun; (2) insulation of the house to reduce heat transfer through walls and ceiling; (3) movement of air within the rooms; (4) ventilating with cooler outside night air; and (5) cooling room air or incoming air by using water, evaporative cooling, or mechanical refrigeration.

SOLAR CONTROL FOR HOUSE-TEMPERATURE REDUCTION

Protection from direct rays of the sun or reflection of the solar heat can do much to reduce temperatures in the house. In houses cooled by mechanical air conditioning or other methods this protection serves to lower the initial investment because of the smaller capacity of equipment required. Operational costs are also reduced.

There are three major methods of obtaining this protection: (1) Orientation of the farmhouse so that the principal glass areas receive maximum protection from the direct rays of the sun; (2) provision for shading the house, particularly glass areas, with roof overhangs, awnings, shutters, louver-type screens, vegetation, or other devices; and (3) utilization of light-colored roofs, exterior walls, and window hangings to reflect solar radiation.

In the United States the sun shines on the roof and south wall of the house most of the day. Glass areas in south walls can be more easily shaded with roof overhangs and similar devices than those in east or west walls on which the sun also shines during part of the day. For this reason, protection against solar heat is easier if the long dimension of the house runs east and west and minimum glass areas are used in east and west walls. This orientation may not be best to utilize prevailing breezes if natural ventilation is used, but it does have the added advantage of best exposure for solar heat in winter.

Ground surfaces around the house affect the amount of radiated and reflected heat (fig. 1). Large concrete or bituminous-covered areas ad-

[1] Died July 1962.

[2] The copyright illustrations are used with permission. Italic numbers in parentheses refer to Literature Cited, p. 16.

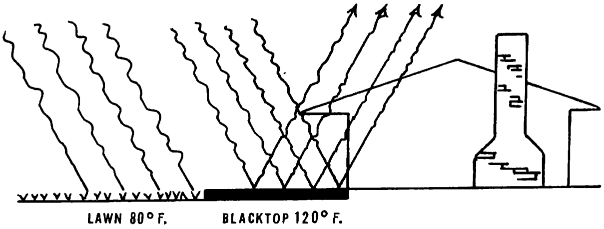

FIGURE 1.—Radiated and reflected heat from lawn and blacktop adjacent to exposed wall of house. (From Fitch (*6*).)

jacent to the house and exposed to the sun should be avoided.

Shading

Plantings of deciduous trees can shade the house in summer and yet permit the sun to penetrate during winter for indoor light and heat. Trees and shrubs should not be planted so close to the house as to shut off breezes if natural ventilation through doors and windows is depended on for cooling.

Metal or canvas awnings reduce by 70 to 75 percent the heat coming through windows. Awnings with open sides are about 15 percent more effective than those with closed sides during periods of maximum solar radiation. Open awnings must be wider than the window to keep the sun from shining in at the sides. Light-colored awnings are more effective than dark ones.

Louver or bar screens are about 90 percent effective in reducing heat through south windows not otherwise shaded, and they are from 55 to 75 percent effective for east and west windows. Inside venetian blinds are from 25 to 50 percent effective, depending on the color, whereas fully drawn inside roller shades are not quite so effective.

Overhangs

Overhangs, or extensions, of the roof over the south wall (fig. 2) are essential and are usually simple to incorporate into the house design. The following guide may be used:

Width of overhang = factor × shadow height (distance below eave of roof)

To determine the roof overhang needed to cast the desired shadow height on a south wall or window, (1) check the latitude (fig. 3) in which you live, (2) select the factor for your latitude from the following tabular data, (3) choose the shadow height desired on the glass area or wall, and (4) multiply the factor by the shadow height selected.

The following factors are used for calculating the width of an overhang for properly shading a south wall or window in various latitudes from April 1 to September 11:

Latitude (°)	*Factor*
25	0. 37
30	. 48
35	. 59
40	. 71
45	. 85
50	1. 02

For example, in a latitude of 35° to shade a glass area extending 5 feet below the eave of the roof, or a horizontal overhang, multiply 5 by the factor 0.59, and the width of the overhang should be approximately 3 feet.

West windows can be effectively shaded by awnings or metal louver screening over the windows for early-afternoon protection and by vertical shading devices opposite the windows for late-afternoon protection. However, if an overhang is preferred (fig. 4) rather than awnings or louver screening, follow the same procedure as for south windows, using the factors for west windows as given in table 1.

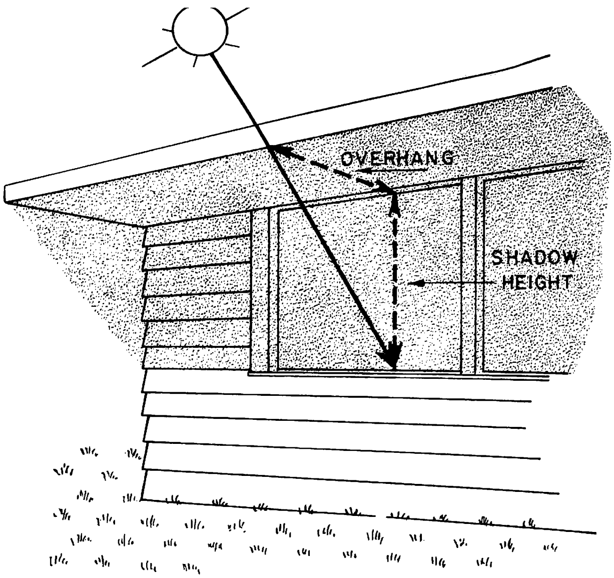

FIGURE 2.—Relationship between width of overhang and shadow height.

TABLE 1.—*Factors for calculating width of overhang over west windows for various times and latitudes from April 1 to September 11*

Time (p.m.)	Factors at latitudes (°) of—					
	25	30	35	40	45	50
1	0. 27	0. 29	0. 31	0. 33	0. 35	0. 38
2	. 62	. 64	. 67	. 71	. 76	. 81
3	1. 07	1. 10	1. 15	1. 21	1. 28	1. 36
4	1. 80	1. 88	1. 96	2. 05	2. 14	2. 34

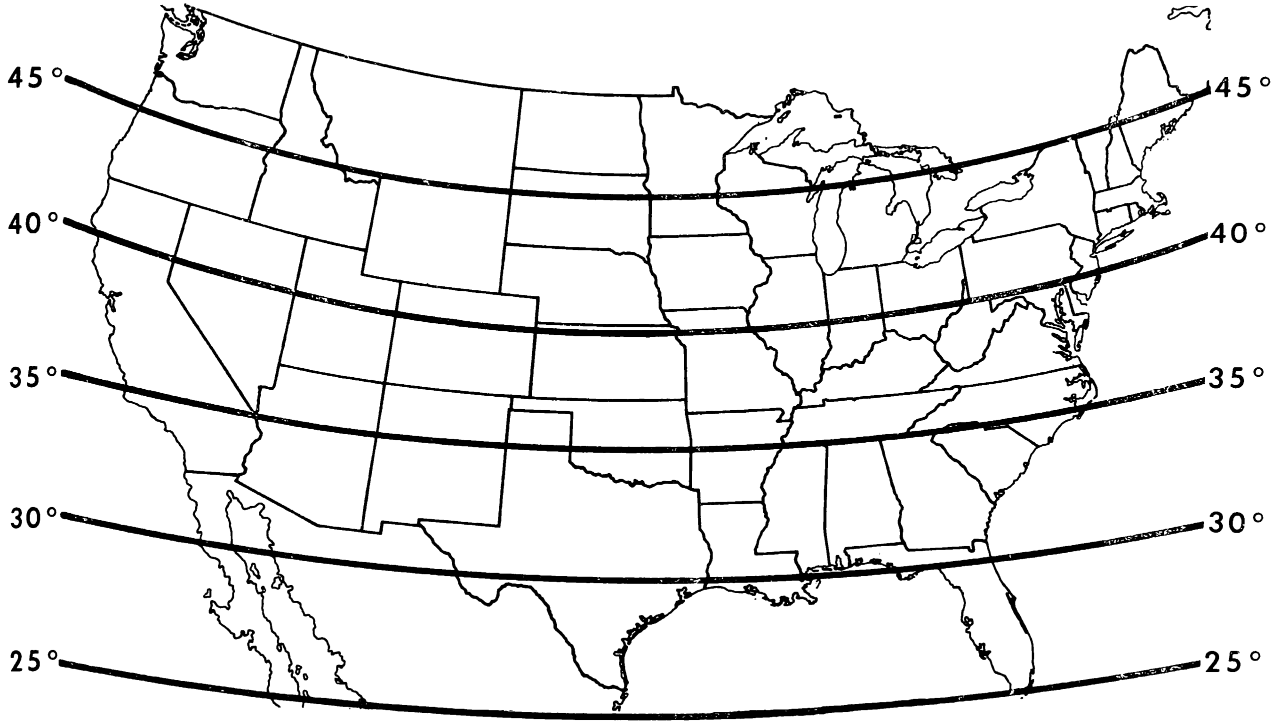

FIGURE 3.—Map of the United States showing latitudes.

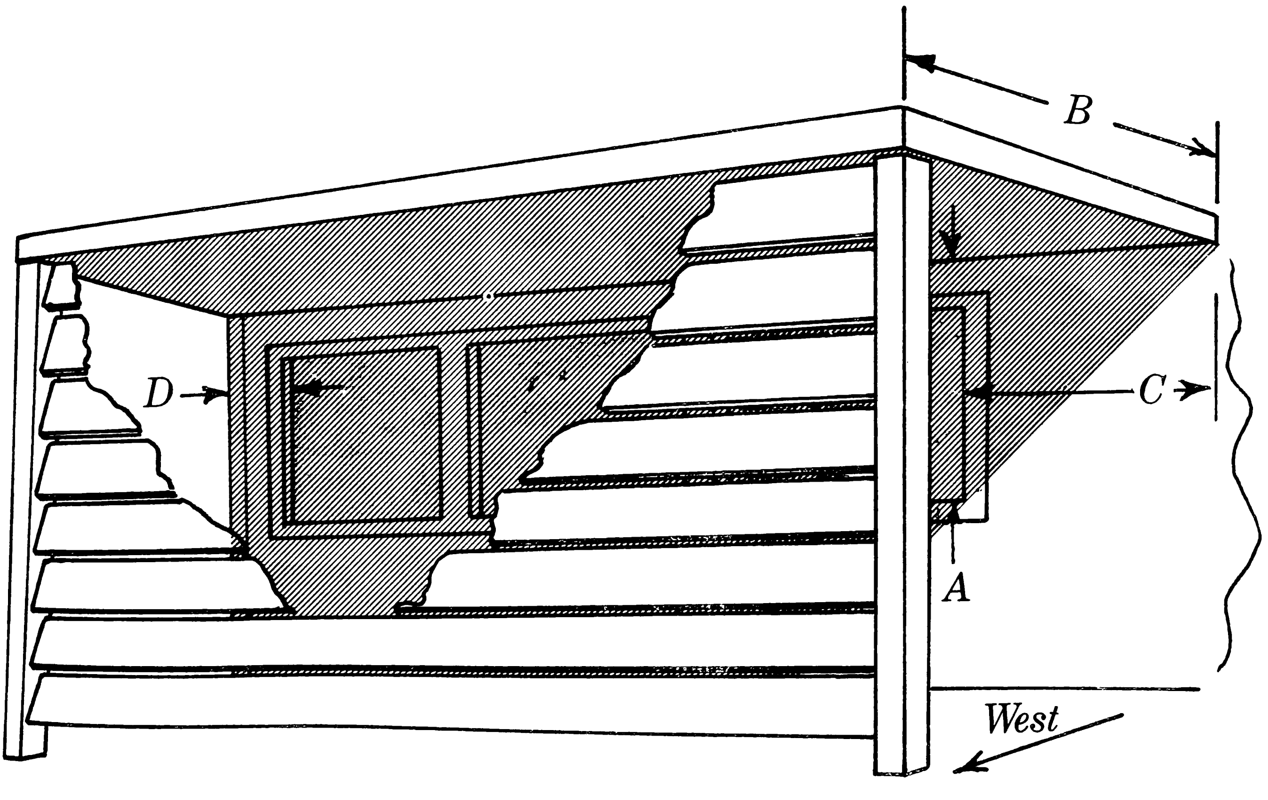

FIGURE 4.—Overhang and vertical shading device for west wall or window. *A*, Shadow height desired; *B*, width of overhang; *C* and *D*, distances overhang must extend south and north, respectively, of window edges.

Using the same example as given for a south wall, 5 feet multiplied by the factor 0.31 for 1 p.m. will give an overhang of 1½ feet. For 2 p.m., 5 multiplied by 0.67 equals 3⅓ feet, and for 3 p.m., 5 multiplied by 1.15 equals 5¾ feet.

It is generally impracticable to build an overhang wide enough to provide proper shading at 4 p.m. unless a patio or porch roof is planned. Therefore, calculate the overhang for 1, 2, or 3 p.m., selecting the one that fits your situation best. Remember that a vertical shading device (fig. 4) must be used in combination with the horizontal overhang when it is desired to limit the width of the overhang. If a walkway is planned between the house and the vertical shading device, the overhang should be sufficiently wide to provide passage for one or two persons or perhaps for lawn equipment such as a wheelbarrow.

The vertical shading device must be placed opposite and run parallel to the window and extend to the edge of the overhang, as shown in figure 4. Vertical shading devices may include shrubs, a lattice covered with vines, a decorative block wall, or a wooden screen. A louvered wooden screen or wall cuts off less light than a solid one, but all the vertical shading devices that are affective in late afternoon will cut off the view to a great extent. Shrubs or vines that lose their leaves in winter permit sunlight in cold weather. Removable screens provide the same advantage.

The length of both the overhang and the vertical shading device must be calculated as well as the overhang of a horizontal shading device. Generally the overhang and the vertical shading device are made the same length. Figure 4 illustrates the distances that the shading device must extend both southward and northward from the edges of the window. To calculate these distances proceed as follows:

1. Use the overhang calculated for 1 p.m. for your particular latitude.

2. Select the proper latitude factor from the following data:

Latitude (°)	*Factor*
25	1.26
30	1.60
35	1.87
40	2.12
45	2.41
50	2.67

3. Multiply the width of the overhang (*B*), which has been calculated in step 1 (above), by the factor selected in step 2. This is the practical distance (*C*) that the overhang and vertical shading device must extend south of the edge of the window.

4. To calculate the distance (*D*) that the shading device must extend north of the edge of the window, multiply the width of the overhang by 0.30. This extra northward extension of the shading device provides late-afternoon protection in early summer.

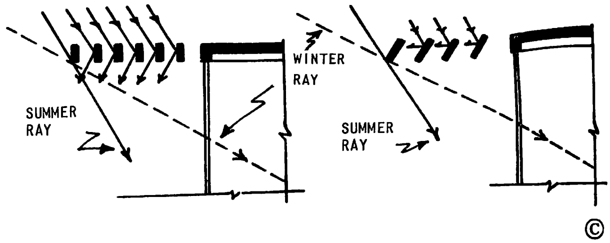

FIGURE 5.—Louvered overhang. (From Ramsey and Sleeper (*8*).)

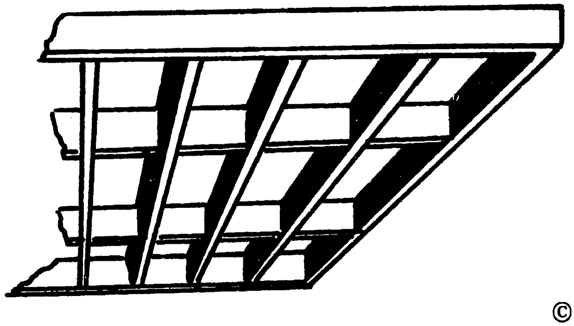

FIGURE 6.—Egg-crate overhang. (From Ramsey and Sleeper (*8*).)

In the preceding example the width (*B*) for 1 p.m. was 1½ feet. This width multiplied by 1.87 for 35° latitude gives 2⅚ feet, which is the distance the shading device must extend southward from the edge of the window. This width also multiplied by 0.30 equals about 6 inches, which is the distance the device should extend northward from the window edge.

Similar calculations can be made for shading east windows. The time factors are interchangeable as follows:

West windows (*p.m.*)	*East windows* (*a.m.*)
1	11
2	10
3	9
4	8

Horizontal louvers (fig. 5) allow movement of air and entry of diffused light. An egg-crate shading device (fig. 6) although more expensive is more effective as it eliminates oblique rays of the sun.

Light Colors

A light-colored roof covering such as composition shingles absorbs only about one-half as much radiated solar heat as a black or dark roof. White marble chips absorb about one-third as much solar heat as dark ones. These figures are generally true in clean atmospheres and where the light color does not darken with age. Light-colored shades, draperies, blinds, other window hangings, and exterior-wall paints also reflect solar heat better than dark ones. Thus, light colors should be used wherever possible for most effective protection against solar heat.

Roof Spray

Air and surface temperatures in the house have been reduced by spraying the roof with water (*9*). The maximum temperature reduction resulted when water was sprayed on a black composition roof and the ceiling was uninsulated, the windows and doors were closed, and the windows were shaded. Benefits were less with the insulated ceiling commonly provided for economical heating in winter. A good water supply, pumped at the rate of from one-fourth to one-half gallon per hour per square foot of roof surface, will likely be required depending on climate, type of roof surface, and method of application. Other means of cooling the interior of the house are probably more satisfactory and economical considering the costs of the installation and operation of the pump and the amount of water required.

INSULATION

Insulation of the walls and ceiling of the house helps to retard entrance of heat from the outside. It has been customary to specify insulation in terms of inches of thickness. A better method is to specify it in terms of resistance (R) to heat flow that will be provided when the insulation is installed. The higher the R value, the greater will be the resistance to heat flow; consequently, the rate of heat flow is less. Some manufacturers are now specifying the R value of their insulation.

To the R value of insulation should be added the R value of construction, which is usually small in comparison with the former. This has been done in tables 2–4 for typical wall, ceiling, and roof construction. For hot-weather comfort and economy in air conditioning it is suggested that the total R value of construction and insulation be not less than 11 for the walls and 17 for the ceiling. If the attic is unoccupied, insulation will normally be installed in the ceiling. In this case and with good natural ventilation in the attic, an R value for the ceiling may be increased by adding 3.0 for the insulation of the roof. Even though the construction of a particular house may be somewhat different from that specified in the tables, an estimate can be made with sufficient accuracy as to whether or not the construction meets the suggested insulation value.

Insulation for residences generally is obtainable in several types, including loose fill, bat, blanket, board, slab, and reflective. Foamed plastic is a new insulation that may become economical for residences. Walls and ceilings of houses already built are often insulated by blowing in loose-fill insulation. Stud spaces should be completely filled by blowing in the insulation from both top and bottom by means of pneumatic equipment. If this is not done, the density of the insulation will not be uniform. Wind or heavy traffic on a nearby road that causes vibration of the structure may result in eventual settling of the insulation and thus some space at the top will be left uninsulated. Loose-fill insulation includes mineral wool (glass, slag, or rock), macerated wood pulp, or treated shredded wood fiber. Sawdust or shavings, although sometimes used, are not generally

TABLE 2.—R *values for typical walls* [1]

Type of wall	Exterior wall finish	Interior wall finish	Total R value of construction and—		
			No insulation	Fibrous insulation (2 inches)	Fibrous insulation (3 inches)
Wood frame	Drop siding (1 by 8), wood sheathing (25/32).	Gypsum board (3/8)	4.0	11.4	15.4
Do	Drop siding (1/2 by 8), insulation-board sheathing (25/32).	Plywood (3/8)	5.2	12.5	16.2
Brick veneer, wood frame	Brick veneer, wood sheathing (25/32).	Gypsum board (3/8), plaster (1/2).	3.8	11.2	14.9
Concrete block, lightweight aggregate.	Concrete block (8)	None	2.9		
Do	do	Gypsum board (3/8) on furring	4.1	11.5	15.2
Brick	Face brick (4), common brick (4).	Plywood (3/8) on furring	3.6	11.0	14.7
Poured concrete	Concrete (6) (140 lbs./cu. ft.)	Gypsum board (3/8) on furring	2.6	10.0	13.7

[1] R values computed from American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (*4*). All measurements in parentheses in inches unless otherwise specified.

TABLE 3.—R *values for typical ceilings* [1]

Ceiling finish	Type of floor above ceiling	Total *R* value of construction and—		
		No insulation	Fibrous insulation (2 inches)	Fibrous insulation (4 inches)
Gypsum board (3/8)	None	2.2	9.6	17.0
Do	Wood subfloor (25/32)	4.3	11.7	19.1
Gypsum lath (3/8), plaster (1/2)	None	2.3	9.7	17.1
Gypsum board (3/8), acoustical tile (1/2)	do	3.3	10.7	18.1
Wood lath, plaster (1/2)	Wood subfloor (25/32)	4.6	12.0	19.4

[1] See footnote 1, table 2.

recommended as they absorb moisture readily, provide a nesting place for rodents, and require treatment against fire and insects.

Vermiculite [3] (expanded mica) is used most commonly to fill the cores of concrete block and thereby reduces heat loss or gain. It is less than two-thirds as good an insulator as mineral wool. A vermiculite that does not absorb moisture as readily as the old type is now available. It insulates only the core space and does not reduce heat gain or loss through the web sections of the block.

A more effective method of insulating concrete-block or other masonry walls is to fasten furring strips on the inside and apply one of the other types of insulation to the strips. Walls below ground need not be insulated as well as those above ground because of the lower heat gain from the cooler ground.

Concrete-block or masonry walls must be waterproofed to prevent moisture from reaching the insulation. Moisture reduces the effectiveness of the insulation and may shorten its life. Waterproofing the exterior of such walls is best. Materials for waterproofing the interior of existing walls may or may not be effective.

Bat and blanket types of insulation are most commonly used in new construction and sometimes in remodeling. They are generally composed of fibrous mineral wool, wood fiber, or cotton fiber, backed or covered with a treated kraft paper. The backing forms lips that permit easy attachment to studs or joists with the use of a hand stapler.

Board-type insulation, in the form of large sheets, planks, or ceiling tile, usually one-half inch thick, is often used in remodeling because it provides some insulation as well as a finished interior in covering existing surfaces. This type of insulation is about two-thirds to three-fourths as effective an insulator as mineral wool of equal thickness.

Slabs and planks for roof decking or above the deck can be obtained in thicknesses up to 3 inches. Some of these are about three-fourths as good an insulator as mineral wool.

Aluminum foil is the most commonly used reflective-type insulation in house construction. It is light weight and easy to install, but it provides little fire resistance. Its effectiveness depends on the reflectivity of its surfaces and the formation

[3] The mention of a trade product does not imply its endorsement by the U.S. Department of Agriculture over similar products not named.

TABLE 4.—R *values for typical pitched roofs* [1]

Type of roof covering	Ceiling finish applied directly to rafters	Total *R* value of construction [2] and—		
		No insulation	Fibrous insulation (2 inches)	Fibrous insulation (3 inches)
Asphalt shingles, building paper, wood sheathing (25/32).	Gypsum board (3/8), acoustical tile (1/2).	5.0	10.8	18.2
Asphalt shingles, roof-insulation board (2), tongue-and-groove wood (1 5/8).	Rafters exposed	8.7		
Asbestos-cement shingles, building paper, wood sheathing (25/32).	Gypsum board (3/8)	3.5	9.5	17.0
Tile shingles, building paper, wood sheathing (25/32).	Wood lath plaster (1/2)	3.6	9.6	17.0

[1] See footnote 1, table 2. [2] Rafter spaces ventilated above insulation.

of dead air spaces. Conditions in the atmosphere that tend to promote chemical action, deposit dust, or soil the surface will reduce the effectiveness of any exposed reflective surface. To be effective, reflective insulation must face an air space. Reflective insulation may be installed in single sheets between framing members, but to be adequate several sheets with air spaces between are necessary. Installation of individual sheets in this manner is impractical. However, accordion-pleated aluminum-foil insulation with several sheets fastened together is available. When this type is stretched to full width by pulling on the fastening lips, air spaces are formed between the sheets.

Double glazed windows, called insulating glass, also aid in reducing heat from the outside, although if exposed to direct sunlight, they will transmit almost as much solar heat as single glazed windows. Consequently, shading should be provided to reduce solar heat gain.

In the summer some provision must be made for removing the heat that eventually builds up within the house. Fan ventilators, evaporative coolers, or mechanical air conditioners are generally used. If they are not provided, inside conditions during the late afternoon and at night in an insulated house may be far less comfortable than in an uninsulated house.

VAPOR BARRIERS

Summer air cooling for comfort does not normally create serious vapor problems in exterior walls and ceilings. However, serious problems can occur in winter. Moisture passing through the construction from the inside to the outside may condense and cause loss of insulative value and deterioration of the insulation and structure. Therefore the walls of every well-constructed modern dwelling in most areas should have a vapor barrier.

The vapor barrier should be placed between the inside finish and the insulation. Polyethylene, metal sheet or foil, duplex kraft paper with aluminum foil on one side, or duplex kraft paper with asphalt between the laminations may be used. The ordinary asphalt-saturated building paper or felt (15 to 30 pounds) is not satisfactory. Some insulations and building boards are foil backed and this backing provides a vapor barrier if properly applied. Joints in the barrier should be held to a minimum and made by lapping over framing members. Vapor-barrier sealing tape is available to seal joints around pipes and wiring outlet boxes and to repair any holes in the barrier caused by installation. If polyethylene film is used, it should be not less than 0.002 inch (2 mils) thick.

Water-vapor transmission of a barrier is measured in perms, the unit of permeance. A perm equals 1 grain (7,000 grains = 1 pound) of moisture per square foot per hour per inch of mercury vapor-pressure difference. The permeance of a vapor barrier used to protect insulation should not exceed 1 perm.

Paints on the inside surfaces of a house have some value as vapor-barrier materials. Alkyd gloss, semigloss primer-sealer plus enamel, or rubber-resin lacquer paints have low vapor permeance. Two or three coats are necessary to reduce permeance to 1.

Sheathing papers under the outside finish should not be of the vapor-barrier type, so that any moisture entering the wall can escape. Ordinary building papers and felts commonly used are satisfactory for this purpose.

AIR MOVEMENT

Although the temperature may be several degrees cooler inside a house than outside, the house may seem warmer because of lack of air movement. A room fan will create air movement and improve man's comfort, but its cooling effects are reduced when the temperature and humidity are high.

There are many types of fans. They vary in construction, safety, and design. Adjustable floor stands, wall-bracket mounting, oscillation, mechanical shields against accidental contact, and other features should be considered.

Generally, low-cost fans have high speed with fairly low air-moving capacity and no oscillating features, whereas more costly fans are slower, yet have larger blades, which move more air with less noise, and they usually have speed-adjustment and oscillating features.

The fan incorporated as part of the forced-air heating system may be used to provide movement of house air during the summer. Basement air surrounding the furnace may be circulated through the house by operating the furnace fan with the fan chamber open.

NIGHT AIR COOLING WITH ATTIC AND WINDOW FANS

In some sections of the country night temperatures drop rapidly, even though heat records are established during the day. Rapid movement of this cooler night air accomplishes the twofold purpose of displacing warmer inside air and providing air circulation to afford relief to house occupants. With a well-insulated house and sufficiently cool nights, the temperature of the interior air, wall surfaces, and furnishings may be lowered appreciably. By keeping the windows closed,

663900 O—63——2

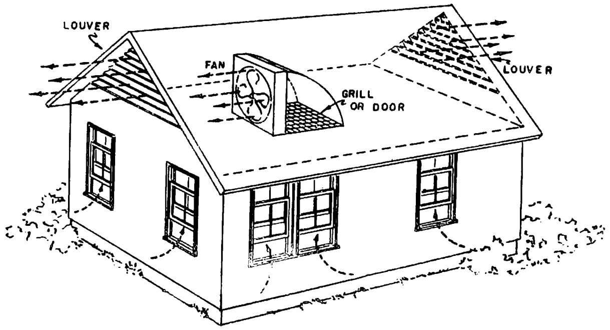

FIGURE 7.—Night air cooling with an attic fan. (From Stover (*11*).)

reasonably comfortable conditions may result during the heat of the following day.

An attic fan (fig. 7) provides a method for utilizing the cooler night air. Forty air changes per hour for the average three-bedroom house can normally be provided by a 30- to 36-inch fan operated by a one-third horsepower electric motor. (See table 5.)

The attic fan, which provides air movement for rooms in the house, could also serve to remove the daytime accumulation of attic heat. Often the unventilated attic air is 25 degrees or more warmer than the outside air. This high temperature is thus responsible for relatively rapid heat flow through the ceiling to the interior of the house, particularly if ceiling insulation has not been used.

If an attic fan is not available for ventilating the house, a small fan may be used to ventilate only the attic space during the day. The fan should be capable of changing the air in the attic at least once each minute and should operate continuously when the temperature of the attic is higher than that of the outside air (*7*).

The air is usually exhausted from the attic to the outside through large louvers at the gable ends of the house, openings in the eaves, or vents in hip roofs.

Window exhaust fans are relatively inexpensive and reasonably effective in providing good air movement. Generally they do not have the capacity of an attic fan. No construction is normally required, as the mounting panel is usually adjustable for the size of installation required. Window fans do not remove accumulated attic heat. They are likely to be noisier because of higher operation speed and close proximity to the occupants and thus more objectionable than attic fans.

Night air cooling does have some serious disadvantages. Chief among these are the dust and pollen, which are likely to be brought into the

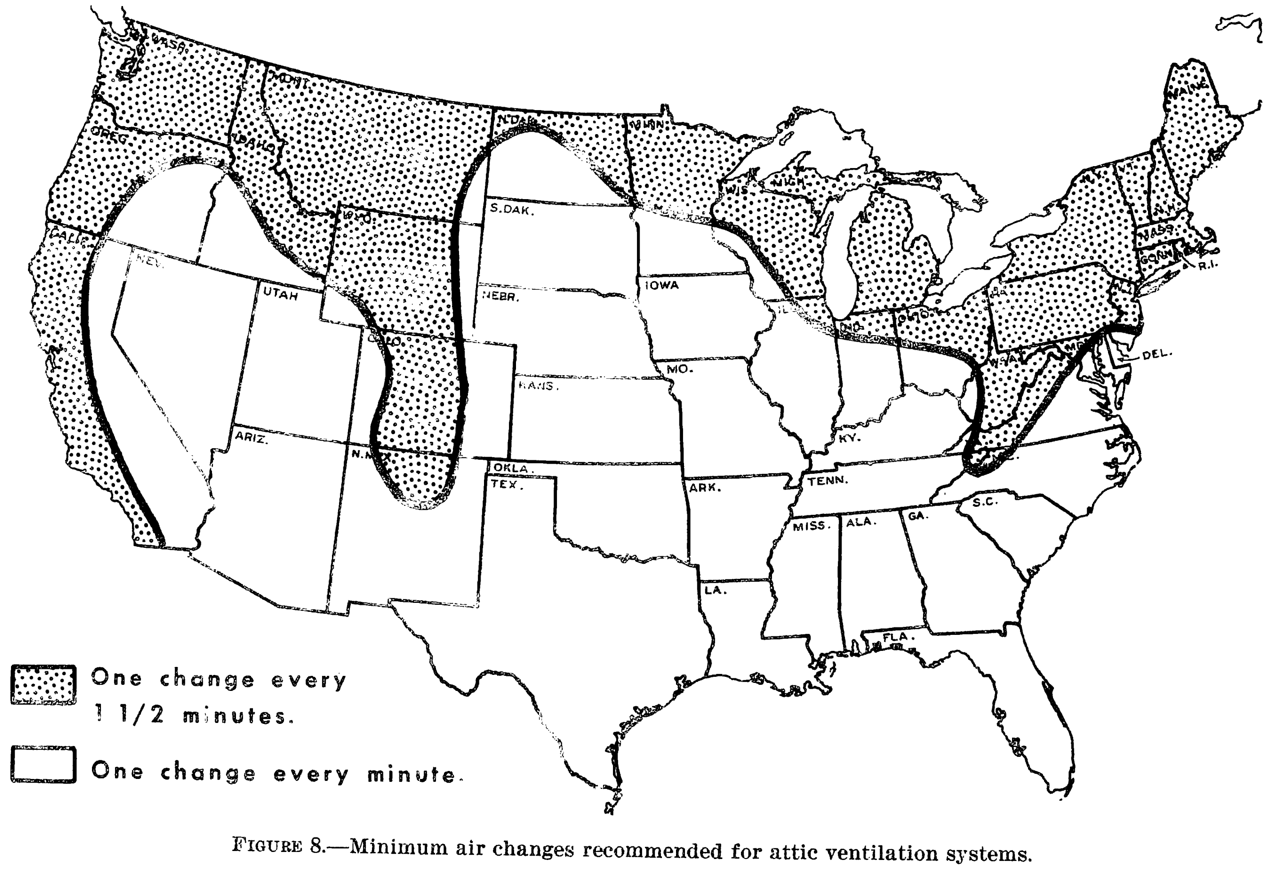

FIGURE 8.—Minimum air changes recommended for attic ventilation systems.

TABLE 5.—*Approximate capacities of attic fans and recommended sizes of inlet and outlet openings* [1]

Habitable house volume (cu. ft.)[2]	Fan diameter	Air discharge[3]	Normal horsepower	Recommended fan speed	Inlet opening to attic			Outlet opening from attic	
					Free air opening	Wood grille (60 percent)	Metal grille (80 percent)	Wood louver (50 percent)	Metal louver (80 percent)
	Inches	*Cubic feet per minute*		*R.p.m.*	*Square feet*	*Square feet*	*Square feet*	*Square feet*	*Square feet*
40 AIR CHANGES PER HOUR									
7,400	30	4, 950	1/8	600	8. 25	13. 75	10. 3	16. 5	10. 3
11,000	36	7, 350	1/3	410	12. 25	20. 4	15. 3	24. 5	15. 3
16,000	42	10, 700	1/2	360	17. 85	29. 75	22. 3	35. 7	22. 3
60 AIR CHANGES PER HOUR									
7,400	36	7, 400	1/3	410	12. 3	20. 5	15. 4	24. 6	15. 4
11,000	42	11, 000	1/2	360	18. 3	30. 5	22. 9	36. 6	22. 9
16,000	48	16, 000	3/4	375	26. 7	44. 5	33. 4	53. 4	33. 4

[1] Fan manufacturers and heating, ventilating, and air-conditioning dealers should be consulted as to plans and instructions for installation.

[2] Basement and attic volumes not usually included.

[3] At 1/10-inch static pressure.

house, and the noise. The latter can be minimized by using attic rather than window fans. In some areas nighttime humidity may be sufficiently high to be objectionable if drawn into the house.

The size of the attic or window fan required for night cooling depends largely on the location, volume of the house in cubic feet, and number of air changes needed per hour (fig. 8). Approximate fan capacities and recommended inlet and outlet opening sizes are given in table 5 as a guide for selecting an attic fan.

Costs of the fan and construction incident to installation may approach the cost of a mechanical refrigeration unit. However, operational costs will no doubt be smaller for exhaust cooling with night air. The disadvantages previously given should be considered before selecting a method of cooling the house.

COOLING WITH WELL WATER

Air cooling with well water is another method of low-cost cooling (*10*, *11*). This method is inexpensive if good usage, such as in rural areas, can be made of the water for lawn or garden irrigation or stock watering and if an adequate supply of water at 60° F. or cooler is available near the surface. Pumping costs should not be excessive.

Surveys of ground-water sources indicate suitable well-water temperatures exist in many areas of the United States. However, ground water in the Southern States, especially southern Arizona, New Mexico, and the Central Valley area of California, is generally too warm to be depended on for this type of cooling.

Approximately 1,300 cubic feet of space may be cooled when 1 gallon of water per minute at 60° F. is used. Thus an ordinary-size house will require 6 to 9 gallons of water per minute for conditioning the entire house and proportionately less for individual rooms. Table 6 presents data on approximate cooling capacities and quantities

TABLE 6.—*Cooling capacities and water required at two temperatures for cooling various-size house areas*

Room or house volume (cu. ft.)	Approximate cooling capacity required [1]	Approximate water required [2] when temperature of water is—	
		60° F.	55° F.
	B.t.u. per hour	*Gallons per minute*	*Gallons per minute*
2,000	6, 000	1. 6	1. 0
4,000	11, 750	3. 25	2. 0
6,000	17, 000	4. 5	2. 75
8,000	21, 000	5. 6	3. 4
10,000	25, 000	6. 75	4. 0
12,000	30, 000	8. 1	4. 8

[1] Dependent on wall and roof exposure, window areas, kind and quantity of insulation, and location in the United States.

[2] Assumed that water temperature in heat-exchange coil will reach 67.5° F.

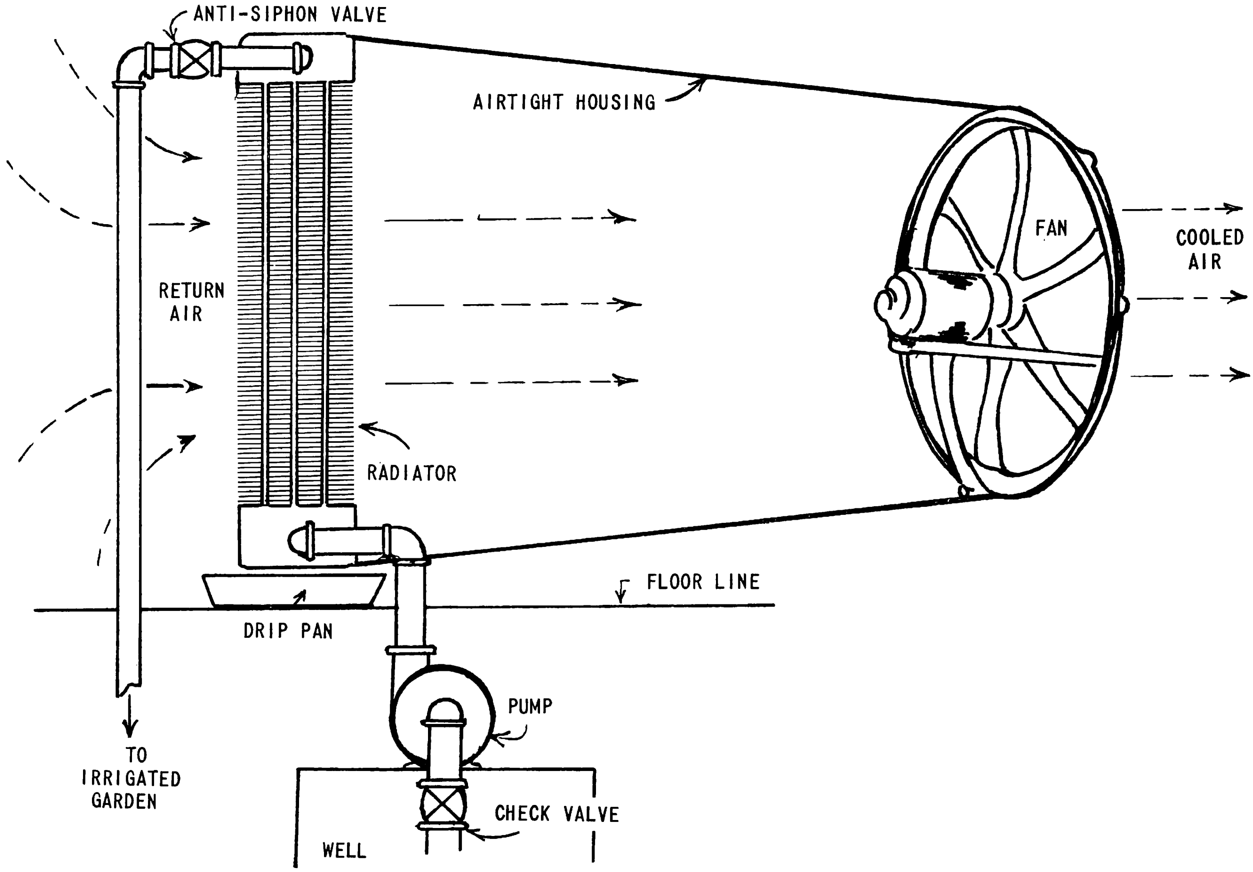

FIGURE 9.—Room cooler using well water to remove heat.

of water required to produce partial summer comfort in a house.

The cooling system provides circulation of water by a pump through a radiator or similar heat-transfer coil (fig. 9). A fan or blower moves the air directly from a room or through ducts from the various rooms of the house through the radiator and back to the space being conditioned. Heat from the warmer air is picked up by the cooling coil, and the cooled air is returned to the room or rooms. Although the equipment is not available as a commercial packaged unit, the components can be obtained and the unit can be assembled locally.

EVAPORATIVE COOLING

In some localities (fig. 10) evaporative cooling may provide satisfactory comfort except during limited periods of high humidity. This type of cooling is used rather extensively in hot, dry areas of the United States, and if properly utilized and maintained, it can provide comfort under some conditions in other areas of the country. However, in many localities only partial relief is obtained (*3, pp. 147–149*).

Although the conditioned air in passing through a material such as excelsior or other good water-absorptive material may not always be in the comfort zone, it may provide partial comfort by reducing interior surface temperatures (fig. 11).

Since evaporative cooling increases the humidity of the air, relatively large quantities of air should be used so that the air does not become fully saturated. An air velocity of 200 to 300 feet per minute through the absorptive material is adequate.

Water usage in evaporative cooling is low compared to cooling with well water. Studies have shown that from 5 to 10 gallons of water per hour are used for the average-size house.

Manufacturers of packaged units recommend as much as 20 to 40 room air changes per hour.

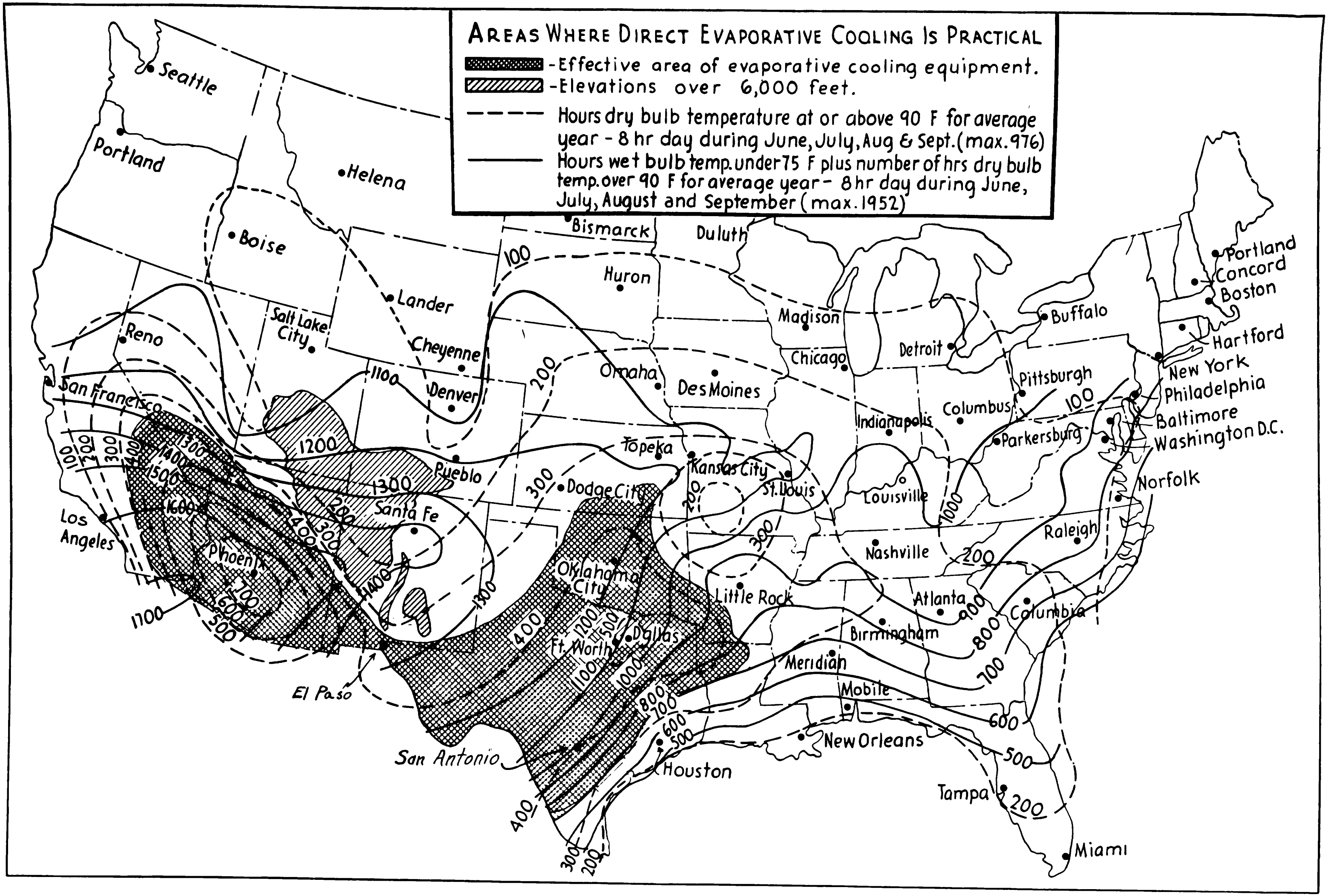

FIGURE 10.—Map of the United States showing general areas most suitable for evaporative cooling. (From Literature Cited (2).)

Table 7 gives some data on evaporative coolers. The resultant positive air movement aids in achieving comfort.

An outlet must be provided of sufficient size to discharge air from the house or rooms to be conditioned. The approximate size of the discharge opening or openings should roughly parallel that of the free air opening for comparable air-discharge rates, as given in table 5.

TABLE 7.—*Evaporative cooler data* [1]

Fan capacity (cu. ft. per minute)	Space cooled	Horsepower required
40 AIR CHANGES PER HOUR [2]		
	Cubic feet	
2,500	3, 750	¼
3,500	5, 250	⅓
5,000	7, 500	½
7,500	11, 250	¾
10,000	15, 000	1
30 AIR CHANGES PER HOUR [3]		
1,875	3, 750	⅙
2,625	5, 250	¼
3,750	7, 500	⅓
5,625	11, 250	½
7,500	15, 000	¾
20 AIR CHANGES PER HOUR [4]		
	Cubic feet	
1,250	3, 750	⅛
1,650	5, 250	⅙
2,500	7, 500	¼
3,450	11, 250	⅓
5,000	15, 000	½

[1] Based on data from Stover (*10*).
[2] Humid eastern Great Plains and Eastern and Southern United States.
[3] Central Great Plains.
[4] Arid Western United States and western Great Plains.

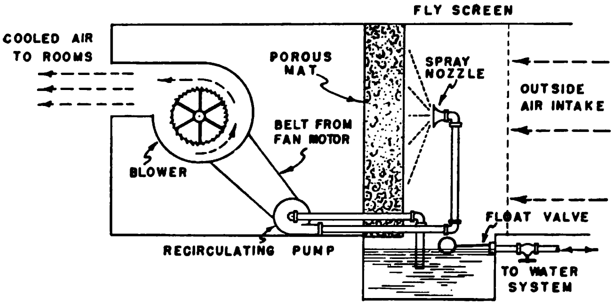

FIGURE 11.—Cooling by evaporation. (From Stover (*11*).)

MECHANICAL REFRIGERATION AIR CONDITIONING

Mechanical refrigeration air conditioning provides the most consistent means of cooling for insured comfort. In uniform environments with air movements of 25 feet per minute, sedentary or slightly active healthy men and women normally clothed are comfortable the year round when the dry-bulb air temperature is within 73° to 77° F. and the relative humidity is 25 to 60 percent (*5*).

Mechanical air conditioners may be window (fig. 12) or portable units or central systems (fig. 13). Air-conditioning units have either air-cooled or water-cooled condensers. Units with air-cooled condensers should be located so that the condensers are shaded from the sun and have unrestricted air circulation over the outdoor coil. Heat removed from the house is rejected either to water by a water-cooled condenser or to outside air by an air-cooled condenser. With either type of condenser the heat must be rejected outside the air-conditioned space.

Operation and Size

In mechanical air conditioners air is passed through electrostatic or mechanical-type filters or both and over a series of refrigerant-cooled coils, where the air is cooled and generally dehumidified. A fan then forces the cooled air into the air-conditioned space either directly or through ducts as in a central system.

Size is measured in terms of British thermal units of cooling or total heat-removal capacity. Careful attention should be paid to matching the capacity of the unit with the requirements of the cooling load. Typical heat-removal or cooling estimate forms for room and central air conditioning are included in the Appendix. You may wish to consult with local equipment or electric-power suppliers relative to using these forms.

Types and Requirements

Window or portable units for room cooling are available in capacities ranging from about 6,000 B.t.u. per hour to 24,000 or more. Although most are designed for conventional window mounting, many are made for mounting in casement windows, walls, or as console units in front of windows. The lightweight portable air conditioner is a recent innovation. Most of the room units have air-cooled condensers.

Central air-conditioning systems are becoming more popular. Major components may be obtained in factory-made assemblies, which can be matching components for winter heating, or they

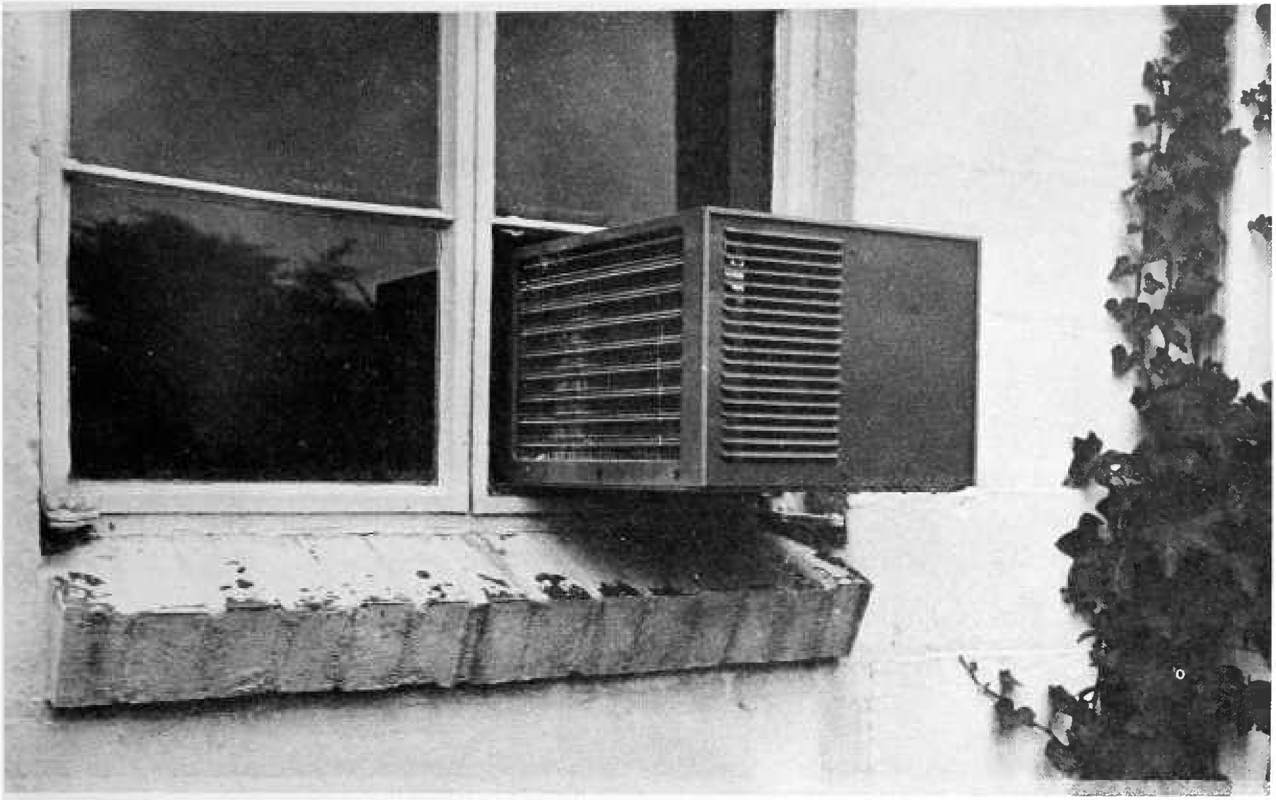

FIGURE 12.—Window air-conditioning unit for individual room.

may be obtained in separate parts and combined on the job into an integrated system. The summer conditioning equipment may be obtained separately and added to existing heating systems. Chillers may be combined with hot-water heating systems to provide cold water for circulation to rooms (fig. 14). Other changes must be made simultaneously in the hot-water system, such as the addition of suitable valves, provision for removal of condensate drip, insulation of piping to prevent sweating, and change of room radiators to convectors.

Year-round air conditioners require less space than a separate heating plant plus a separate summer air conditioner. Usually the heating and cooling units of the year-round system operate independently of each other. The air circulated by a fan shifts from the cooling to the heating unit of the equipment or passes through both. Only one of these units is active at any one time, and both are interlocked to prevent simultaneous operation.

Electrical Characteristics

Room air conditioners are normally designed for 115-, 208-, or 230-volt operation. The National Electric Code effectively limits ratings of 115-volt circuits to 7.5 amperes for coolers on a multiple-outlet branch and to 12 amperes for single-outlet branch circuits regardless of nominal compressor horsepower. Conditioners requiring above 12 amperes will normally be wired for 208- or 230-volt operation.

Power Requirements

Power requirements for operation of air- and water-cooled air conditioners vary in proportion to the required cooling capacity. Table 8 relates this requirement to approximate room size. The upper range of floor area should be associated with moderate outdoor summer temperatures, good insulation, and good construction practices, particularly with regard to orientation and shaded glass areas.

In using table 8 the following information and instructions should be noted. The cool floors are assumed to be over cool basements, air-conditioned rooms, sealed crawl spaces, or on slabs. The warm floors are over unconditioned spaces or well-ventilated crawl spaces. Blinds, shades, or curtains must be used to prevent direct sunlight from entering the rooms. Rooms connected by archways or open doorways should be treated as single rooms.

To select an air conditioner for residential living areas, calculate the room floor area and check

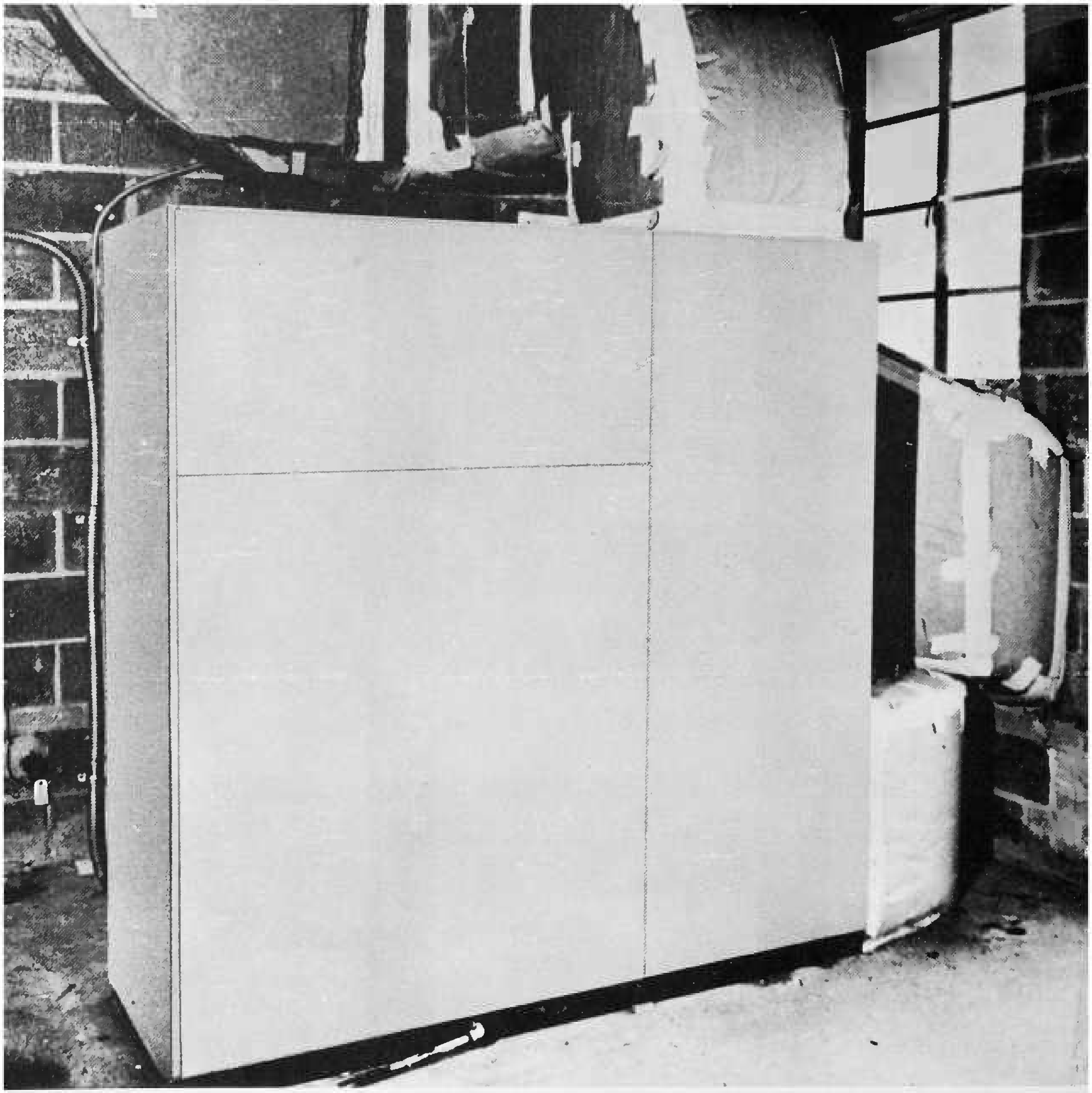

FIGURE 13.—Packaged unit for central air conditioning.

on such items as insulation and room exposure, and then locate in table 8 the corresponding required cooling capacity (B.t.u.) for the floor area. The selection made applies to single rooms of average construction with average glass areas and receiving average sunshine. To select a central air conditioner for multiple rooms or an entire house, determine the average floor area and select the corresponding required cooling capacity (B.t.u.) from this table. These capacities are based on areas that are to be comfort conditioned in localities where temperatures do not usually exceed 95° F. In those areas where air-conditioning estimates are based on 100°, a unit with about 15 percent greater capacity should be selected.

In general, air-cooled units have slightly larger power requirements than water-cooled units. This disadvantage may be offset in the latter type unit by lower water-supply and disposal costs or use of cooling towers as additional equipment.

It is desirable to check with your local utility company concerning their rates and regulations, local codes and ordinances relative to the capacity of your electrical system, and regulations concerning air conditioners. It is often necessary to install larger service drop and entrance wiring as well as switches to enlarge distribution panel equipment.

Controls

Generally air conditioners come with built-in thermostats or provision is made for wiring to a remotely located temperature control. Some of the small window or portable units are not thermostat equipped, but a thermostat may be available as optional equipment.

Water-Cooled Condensers

The water-cooled condenser requires large quantities of water to which heat is rejected. Approximately 75 to 150 gallons of water per hour for each 12,000 B.t.u. of cooling capacity must be supplied. Often this water can be used effectively in yard and garden irrigation. Where plentiful supplies are not present, a water-conserving cooling tower may be installed to cool the circulating water so that it can be reused. This tower is commonly located out of doors. It should be away from

TABLE 8.—*Room air-conditioner selection guide* [1]

Required cooling capacity (B.t.u.)	Floor area of rooms with following exposures and with—										Typical power required
	Ceiling under warm living space or insulated ceiling under attic					Uninsulated ceiling under attic					
	North and east	East and south	South and west	West and north	Average	North and east	East and south	South and west	West and north	Average	
	Square feet	*Square feet*	*Square feet*	*Square feet*	*Square feet*	*Square feet*	*Square feet*	*Square feet*	*Square feet*	*Square feet*	*Kilowatts*
FLOORS COOL AND ADJOINING ROOMS AIR CONDITIONED											
28,000	1,870	1,790	1,650	1,730	1,760	1,030	990	940	970	985	4.0
23,000	1,430	1,360	1,250	1,320	1,340	790	760	720	740	755	3.4
18,000	1,110	1,050	950	1,010	1,030	610	580	550	570	580	2.75
16,000	980	930	840	890	910	540	520	490	510	515	2.45
14,000	830	790	710	750	770	460	440	410	430	435	2.20
12,000	670	630	560	600	615	370	350	330	340	350	1.95
9,800	480	450	390	420	435	270	250	230	240	250	1.75
8,800	410	380	330	360	370	240	220	200	210	220	1.4
7,700	340	320	270	300	310	200	190	170	180	185	1.25
6,000	230	210	180	200	205	140	130	120	120	130	.9
FLOORS COOL AND ADJOINING ROOMS NOT AIR CONDITIONED											
28,000	1,680	1,600	1,520	1,590	--------	950	920	880	910	--------	4.0
23,000	1,270	1,210	1,140	1,190	--------	730	710	670	690	--------	3.4
18,000	970	920	860	900	--------	560	540	510	530	--------	2.75
16,000	860	820	750	790	--------	490	470	440	460	--------	2.45
14,000	720	680	620	660	--------	410	390	370	385	--------	2.20
12,000	580	540	480	520	--------	330	310	290	305	--------	1.95
9,800	400	370	330	360	--------	240	230	210	220	--------	1.75
8,800	340	310	280	300	--------	210	200	180	190	--------	1.4
7,700	280	250	220	240	--------	170	160	150	155	--------	1.25
6,000	190	170	150	160	--------	120	110	100	105	--------	.9
FLOORS WARM AND ADJOINING ROOMS NOT AIR CONDITIONED											
28,000	1,230	1,170	1,100	1,140	--------	790	770	750	760	--------	4.0
23,000	930	880	830	870	--------	600	580	560	570	--------	3.4
18,000	720	680	630	660	--------	460	440	420	430	--------	2.75
16,000	630	590	560	580	--------	410	390	370	380	--------	2.45
14,000	530	500	460	480	--------	350	330	310	320	--------	2.20
12,000	420	400	360	390	--------	280	270	250	260	--------	1.95
9,800	300	280	250	270	--------	200	190	180	190	--------	1.75
8,800	250	230	210	220	--------	180	170	150	160	--------	1.4
7,700	210	200	180	190	--------	150	140	130	140	--------	1.25
6,000	140	130	120	130	--------	105	105	100	100	--------	.9

[1] Based on data in Chrysler Airtemp Room Air Conditioners (*1*).

living and bedroom areas because of some noise inherent in its operation.

Heat Pumps

Another system of mechanical refrigeration air conditioning is the electrically powered heat pump. In addition to removing heat from the house in summer, the equipment is capable of supplying heat in winter to provide year-round comfort. This heat may be taken from or rejected to the water or outside air. Ordinarily the heat pump is sized to handle the summer cooling load and is supplemented with an electrical resistance-type heater to handle the winter heat load.

Operating costs for cooling are comparable to those for other mechanical refrigeration air-conditioning systems. For heating, comparative costs with combustion-type fuels should be considered.

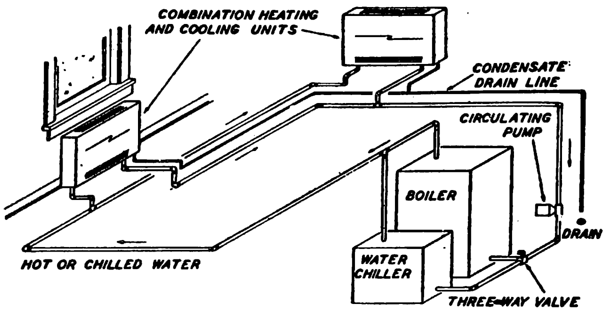

FIGURE 14.—Combination summer air-conditioning and hot-water heating system. Chilled water is circulated in summer through the same pipes used in winter for circulating hot water. (From American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (*4*).)

LITERATURE CITED

(1) ANONYMOUS.
(n.d.) CHRYSLER AIRTEMP ROOM AIR CONDITIONERS. Form LL-476, 12 pp. Airtemp Div., Chrysler Corp., Dayton, Ohio.

(2) ———
1941. EVAPORATIVE COOLING MAP. Heating, Piping and Air Conditioning 13(1) : 43-44.

(3) ———
1960. EVAPORATIVE COOLING—WHEN AND HOW TO USE IT. HPAC Engineering Data File. Heating, Piping and Air Conditioning 32 (3) : 141-158.

(4) AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.
1960. HEATING VENTILATING AIR CONDITIONING GUIDE 1960. Ed. 38, 792 pp. New York.

(5) FAHNESTOCK, M. K., and WERDEN, J. E.
1956. ENVIRONMENT, COMFORT, HEALTH AND PEOPLE. Refrig. Engin. 64(2) : 43-49.

(6) FITCH, J. M.
1950. BUILDINGS DESIGNED FOR CLIMATE CONTROL. *In* National Academy of Sciences, Weather and the Building Industry. 158 pp. Washington, D.C.

(7) GRUB, WALTER.
1959. COOLER HOMES FROM ATTIC VENTILATION. Ala. Polytech. Inst., Agr. Expt. Sta., Leaflet 63, 3 pp.

(8) RAMSEY, C. G., and SLEEPER, H. R.
1956. ARCHITECTURAL GRAPHIC STANDARDS. Ed. 5, 758 pp. New York.

(9) SIMONS, J. W., and LANHAM, F. B.
1942. FACTORS AFFECTING TEMPERATURES IN SOUTHERN FARMHOUSES. U.S. Dept. Agr. Tech. Bul. 822, 91 pp. (Revised 1951.)

(10) STOVER, H. E.
1949. THE ATTIC FAN FOR HOME COOLING. Rural Electrif. 8, 4 pp. Engin. Ext. Dept., Kans. State Col., Manhattan.

(11) ———
(n.d.) SUMMER COMFORT FOR THE HOME. Rural Electrif. 14, 8 pp. Engin. Ext. Dept., Kans. State Col., Manhattan.

(12) STROCK, CLIFFORD, ed.
1959. HANDBOOK OF AIR CONDITIONING, HEATING AND VENTILATING. 1112 pp. New York.

APPENDIX

Cooling-Load Estimate Form for Room Air Conditioners

Cooling-load estimate form for room air conditioners (form I) represents recommended practice for members of the Room Air-Conditioner Section of the Air-Conditioning and Refrigeration Institute. This estimate is suitable for comfort air-conditioning jobs not requiring specific conditions of temperature and humidity. It may be used for all areas of the United States except where the outside design temperatures (*12*) are above 95° F. dry bulb and 78° wet bulb, as indicated in figures 15 and 16. For the few exceptional localities this form should be modified or other forms should be used.

On graph paper with about ¼-inch squares, sketch the room, showing the location and size of windows, doors, and other openings. Carefully determine the directions and indicate north on the sketch by an arrow. For most air-conditioning jobs each square of the graph paper could represent 1 foot of room measurement.

The following directions apply to the nine items on form I. The quantity entered each time should be multiplied by the factor given and the product should be entered in the last column.

1. *Windows exposed to sun.*—Under quantity insert the total square feet of window area for the unshaded exposure having the largest cooling load. For windows shaded by inside shades or venetian blinds, multiply the quantity by the fac-

Form I.—*Cooling-load estimate for room air conditioners*

No.	*Item*	*Quantity*		*Factor*			*Cooling load*
				Inside shades	*Outside awnings*		*B.t.u. per hour*
1.	Windows exposed to sun, facing—						
	a. East, southeast, or south	__ sq. ft.	×	45	25	=	______
	b. Southwest	__ sq. ft.	×	65	40	=	______
	c. West	__ sq. ft.	×	100	60	=	______
	d. Northwest	__ sq. ft.	×	35	25	=	______
	(Use only exposure with largest cooling load.)						
2.	Windows facing north or in shade (Use all windows not included in item 1.)	__ sq. ft.	×	14		=	______
3.	Walls (based on lineal feet of wall):						
	a. Light construction, exposed to sun	__ ft.	×	90		=	______
	b. Heavy construction, exposed to sun	__ ft.	×	50		=	______
	c. Shaded walls or partitions	__ ft.	×	30		=	______
	(Include all walls not used in 3a or 3b.)						
	(In 3a and 3b use for only that exposure given in item 1.)						
4.	Roof or ceiling (use one only):						
	a. Roof uninsulated	__ sq. ft.	×	16		=	______
	b. Roof with 1 inch or more of insulation	__ sq. ft.	×	7		=	______
	c. Ceiling with occupied space above	__ sq. ft.	×	3		=	______
	d. Ceiling with attic space above	__ sq. ft.	×	10		=	______
5.	Floor: (Disregard item 5 if floor directly on ground or over unheated basement.)	__ sq. ft.	×	3		=	______
6.	People and ventilation (number of people)	__	×	900		=	______
7.	Lights and electrical equipment in use	__ watts	×	3		=	______
8.	Doors and arches continuously open to unconditioned space (lineal feet of width)	__ ft.	×	300		=	______
9.	Total cooling load to be used for selection of room air conditioner(s)	--------	--	---		---	______

tor for inside shades. For windows shaded by outside awnings or by both outside awnings and inside shades or venetian blinds, use the factor for outside awnings. Only one number should be entered in the last column for item 1.

2. *Windows facing north or in shade.*—Insert the total square feet of window area of all windows not included in item 1.

3. *Walls.*—For 3a or 3b insert the length of the wall that had the largest cooling load in item 1. The total length of all walls and partitions not included for 3a or 3b should be inserted for 3c. The factors are based on a wall 9 feet high and are applicable to walls of usual heights and average construction. An uninsulated frame wall or a masonry wall 8 inches or less in thickness is considered light construction. An insulated frame wall or a masonry wall 12 inches or more in thickness is considered heavy construction.

4. *Roof or ceiling.*—Insert the total square feet of roof or ceiling area for 4a, 4b, 4c, or 4d. Use one only.

5. *Floor.*—This item can be ignored if the floor is on the ground or over an unheated basement. Otherwise, insert the total square feet of floor area.

6. *People and ventilation.*—Estimate the number of people who normally occupy the space to be air conditioned and enter this number under quantity. The factor includes the normal cooling load per person and approximately 15 c.f.m. of ventilation air per person.

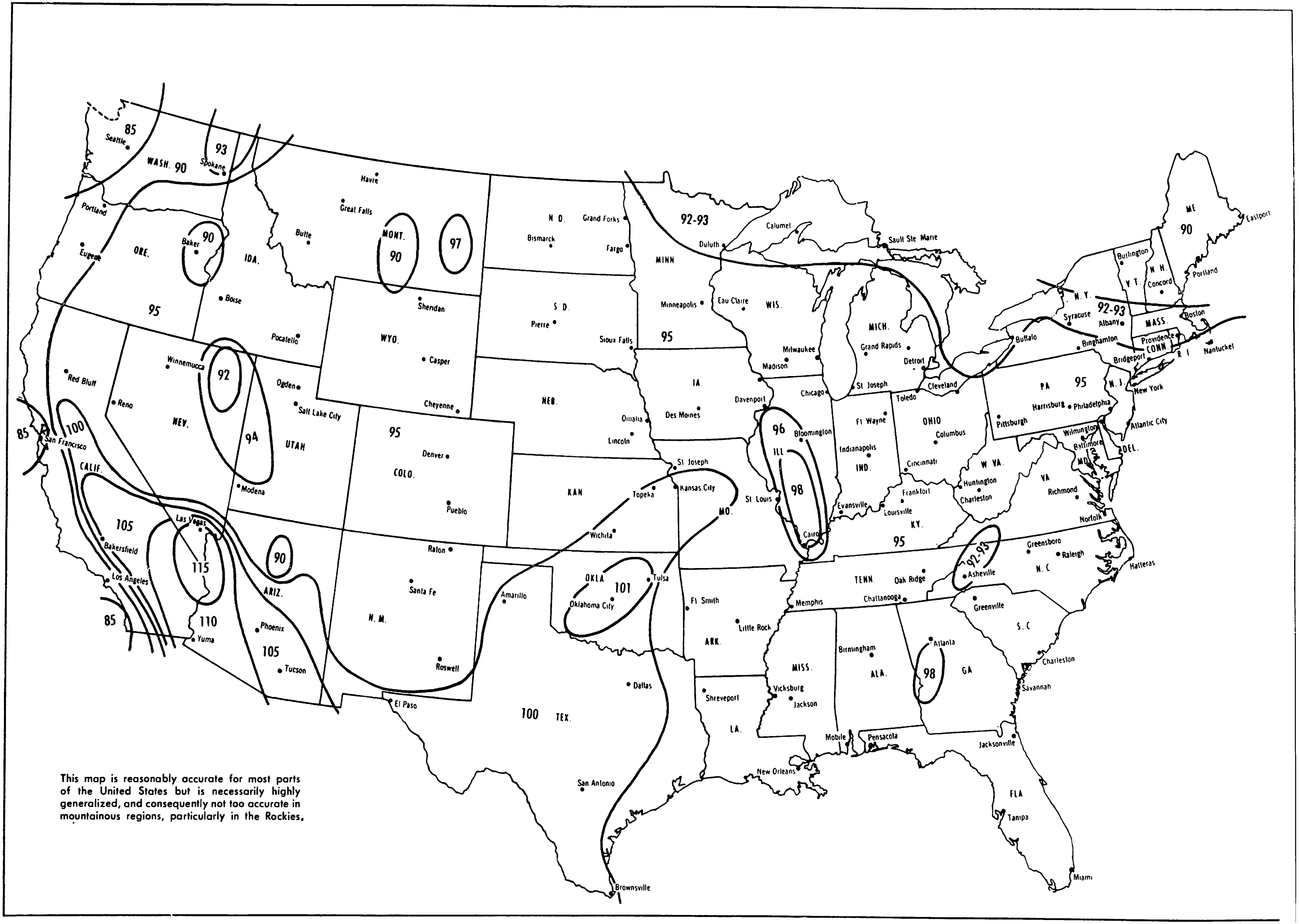

FIGURE 15.—Map of the United States showing outside dry-bulb design temperatures (°F.) in summer based on standards of Air-Conditioning and Refrigeration Institute. (From Strock (*12*).)

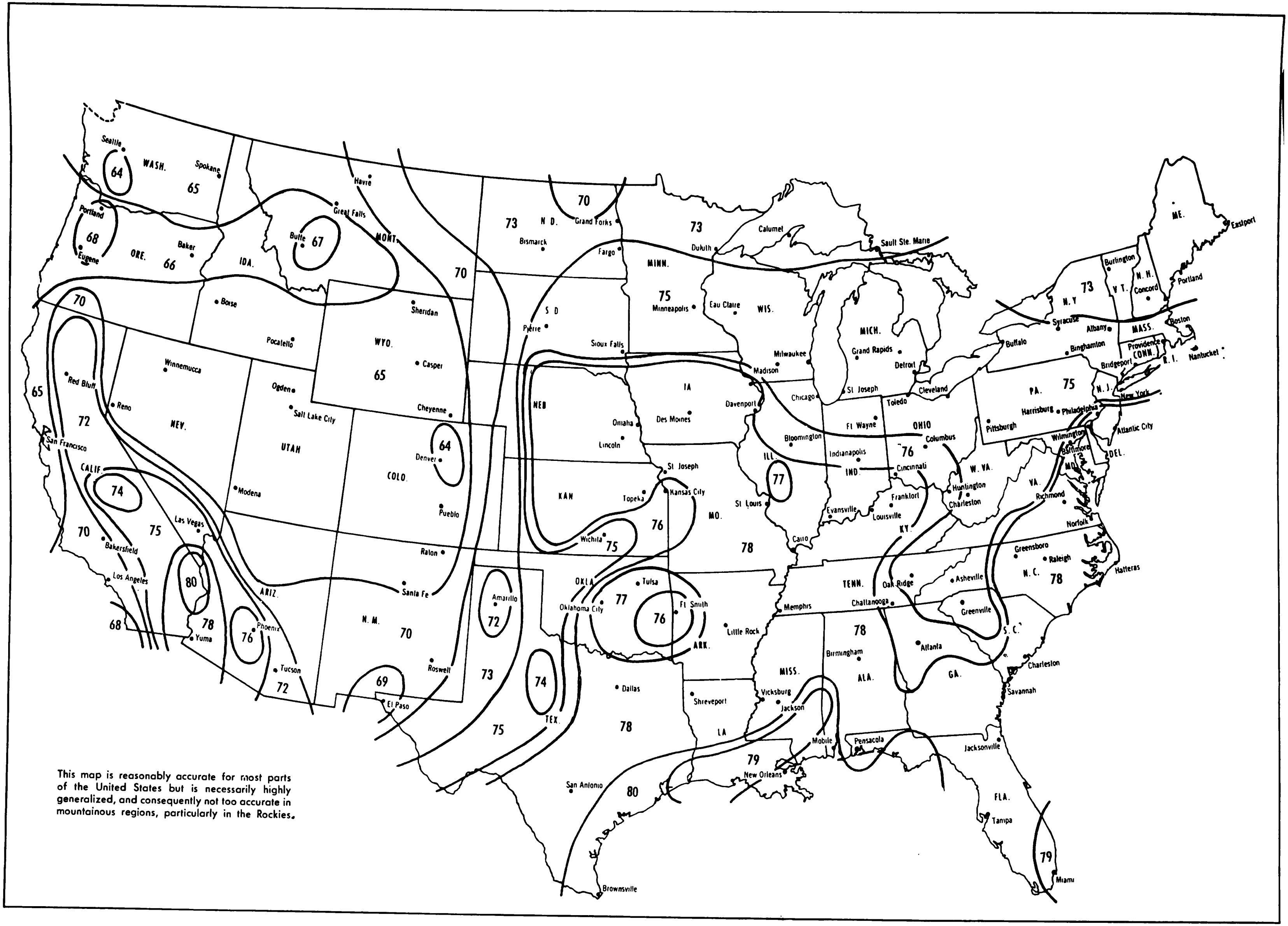

FIGURE 16.—Map of the United States showing outside wet-bulb design temperatures (°F.) in summer based on standards of Air-Conditioning and Refrigeration Institute. (From Strock (*12*).)

7. *Lights and electrical equipment.*—Insert the total number of watts for lights and electrical equipment that will be in use when the room air conditioner is turned on and the sun is shining.

8. *Doors and arches.*—Insert the width of any door or arch that is continuously open to an unconditioned space.

9. *Total cooling load.*—Add the cooling loads (B.t.u.) of items 1 through 8. One or more room air conditioners with capacities equal to or greater than this total cooling load should be selected.

Cooling-Load Estimate Form for Central Air Conditioners

The cooling-load estimate form for central air conditioners (form II) represents recommended practice for members of the Self-Contained Air-Conditioner Section of the Air-Conditioning and Refrigeration Institute. This estimate is suitable for comfort air-conditioning jobs not requiring specific conditions of temperature and humidity.

The following directions refer to the 12 items on form II. The quantity entered each time should be multiplied by the factor given or indicated and the product should be entered in the last column.

1. *People.*—Insert the number of people normally occupying the space after the air conditioner is installed. If all are engaged in the same activity, the number should be inserted for 1a or 1b. If some are more actively engaged than others, the total number should be properly divided for 1a and 1b. If it is a space that would be occupied by a large number of people for only a few minutes and then a smaller number for the remaining time, use the largest number of people

FORM II.—*Cooling-load estimate for central air conditioners*

No.	*Item*	*Quantity*		*Factor*		*Cooling load* (*B.t.u. per hour*)	
1.	People:						
	a. Number sitting or moving slowly	—	×	400	=	____	
	b. Number working, dancing, or similar activity	—	×	660	=	____	
2.	Windows exposed to sun (Use exposure with largest window area.)	— sq. ft.	×	—[1]	=	____	
3.	Lights and electrical appliances (Include only those appliances not listed under other heat sources on p. 21.)	— watts	×	3.4	=	____	
4.	Other heat sources			—[2]	=	____	
5.	Subtotal (sum of items 1 through 4)			---	--	____	____
6.	Windows not included in item 2	— sq. ft.	×	—[3]	=	____	
7.	Walls and partitions less windows	— sq. ft.	×	—[3]	=	____	
	Walls and partitions less windows	— sq. ft.	×	—[3]	=	____	
	Walls and partitions less windows	— sq. ft.	×	—[3]	=	____	
8.	Floor	— sq. ft.	×	—[3]	=	____	
9.	Ceiling	— sq. ft.	×	—[3]	=	____	
10.	Ventilation or infiltration	— c.f.m.[4]	×	—[4]	=	____	
11.	Subtotal (sum of items 6 through 10)					____	____
12.	Total cooling load to be used for selection of central air conditioner (items 5 and 11)					-----	____

[1] See table 9.
[2] See directions for item 4.
[3] See table 10.
[4] See directions for item 10.

Table 9.—*Cooling-load factors for windows exposed to sun*[1]

Description of windows	Factors for windows with exposures of—						
	NE.	E.	SE.	S.	SW.	W.	NW.
Clear glass (single or double), no protection	110	180	160	105	160	180	110
Completely shaded by awnings	30	50	45	30	45	50	30
With light-colored inside shades or venetian blinds	65	110	95	60	95	110	65
Glass brick, no protection	44	72	64	42	64	72	44

[1] Data to be used in completing form II for central air conditioners.

that would be present for approximately 15 minutes.

2. *Windows exposed to sun.*—Insert the maximum total square feet of window area on any one wall of the space exposed to direct sunshine. Refer to table 9 for the proper factor, and insert it on the line indicated. If all the windows are on the north wall or on a wall shaded completely from the sun by an adjacent building, no entry should be made for this item.

3. *Lights and electrical appliances.*—Insert the total number of watts in use, not including the watts consumed by appliances listed under item 4.

4. *Other heat sources.*—To calculate the cooling load due to gas and electrical appliances and motor-driven apparatus, complete the following computation and insert the total on the line indicated in item 4.

Heat source	*Quantity*		*Factor*		*Cooling load B.t.u. per hour*
Electric motors ---- total name-plate horsepower	______	×	2800	=	______
Gas burners ---- number	______	×	6000	=	______
Glass coffee makers ---- do	______	×	900	=	______

5. *Subtotal.*—After checking the products of the first four items, add them and carry this subtotal to the line at the right.

6. *Windows not included in item 2.*—Insert the total square feet of windows not included in item 2. In table 10 select the factor for these windows under the outside dry-bulb design temperature for the given locality (see fig. 15). Insert this factor on the line indicated in item 6.

7. *Walls and partitions.*—Three lines are provided for this item, as it is quite possible that several wall constructions may be used on a particular space. Each time subtract the area of the windows from the total wall or partition area and insert the total net wall or partition area. In table 10 select the proper wall or partition factors shown under the design temperature already established. Insert these factors on the proper lines indicated in item 7.

8. *Floor.*—Insert the total square feet of floor area. Refer to table 10 for the factor to be inserted on the line indicated.

9. *Ceiling.*—Insert the total square feet of ceiling area. Refer to table 10 for the factor that fits the conditions of the building. Adjust this factor if the ceiling is insulated. For example, to obtain the adjusted factor for a 4-, 2-, or 1-inch insulation, multiply the factor in the table by 0.2, 0.3, or 0.4, respectively. Insert the factor or adjusted factor on the line indicated.

10. *Ventilation or infiltration.*—To calculate the requirements for both ventilation and infiltration, use the largest quantity in cubic feet per minute. Use no less than the amount required by local ordinance and no less than the amount drawn from the space if exhaust fans are used.

To determine the quantity for ventilation in item 10, complete the following computation:

Smoking	*Number of occupants*[1]		*Factor*		*Cubic feet per minute*
None	______	×	7½	=	______
Light	______	×	15	=	______
Heavy	______	×	40	=	______

[1] Must equal number used in item 1, form II.

TABLE 10.—*Cooling-load factors for windows, walls, floors, and ceiling at various outside dry-bulb design temperatures* [1]

Part of building	Factors at temperatures (° F.) of—																		
	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104
Windows (no sun)	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Walls:																			
Heavy masonry	2	3	3	3	3	4	4	4	4	5	5	5	5	6	6	6	6	6	7
Average masonry	3	3	3	3	4	4	4	4	5	5	5	6	6	6	6	7	7	7	7
Insulated masonry or frame	1	2	2	2	2	2	3	3	3	3	3	3	4	4	4	4	4	4	5
Average frame	2	3	3	3	4	4	4	4	5	5	5	5	6	6	6	6	7	7	7
Partition,[2] inside:																			
Single thickness	5	5	6	7	7	8	8	8	9	10	10	11	11	12	12	13	14	14	15
Double thickness	3	3	3	4	4	4	4	5	5	5	6	6	6	6	7	7	7	8	8
Glass brick (no sun exposure)	4	4	5	5	5	6	6	7	7	8	8	8	9	9	10	10	10	11	11
Floor	2	2	2	2	3	3	3	3	3	4	4	4	4	4	5	5	5	5	5
Ceiling under—																			
Unventilated attic	11	11	11	12	12	12	12	13	13	13	13	14	14	14	15	15	15	15	16
Ventilated attic	7	7	8	8	9	9	10	10	10	11	11	12	12	13	13	14	14	14	15
Flat roof	13	13	14	14	14	15	15	15	16	16	16	17	17	17	18	18	18	19	19

[1] Data to be used in completing form II for central air conditioners.
[2] Only used if house is partially air conditioned.

To determine the quantity for infiltration in item 10, compute the following equation:

$$\text{Cubic feet per minute} = \frac{\text{room height} \times \text{length} \times \text{width} \times \text{wall factor}}{60}$$

The wall factors for a room with one, two, or three or more outside walls are 1, 1.5, and 2, respectively. The infiltration does not include the amount that will enter the space if doors or windows remain open.

Insert the number of cubic feet per minute for ventilation or infiltration on the line provided in item 10. Select the ventilation or infiltration factor for the outside wet-bulb design temperature of the specified locality (see fig. 16) from the following data:

°F.	*Factor*
64	0
65	1
66	3
67	5
68	8
69	11
70	14
71	17
72	20
73	23
74	27
75	30
76	33
77	37
78	41
79	45
80	49

11. *Subtotal.*—After checking the products of items 6 through 10, add them and carry this subtotal to the line at the right.

12. *Total cooling load.*—Add the subtotals of items 5 and 11. A central air conditioner with a capacity equal to or greater than this total cooling load must be selected to obtain comfort conditions within the specified space.

U.S. GOVERNMENT PRINTING OFFICE: 1961 O—663900