Extension Circular No. 105 May, 1939

University of Arizona

COLLEGE OF AGRICULTURE

AGRICULTURAL EXTENSION SERVICE

COOLING FOR THE ARIZONA HOME

By
MARTIN L. THORNBURG
AND
PAUL M. THORNBURG

PUBLISHED BY
University of Arizona
TUCSON, ARIZONA

University of Arizona

College of Agriculture, Agricultural Extension Service
CHAS. U. PICKRELL, *Director*

Co-operative extension work in agriculture and home economics, the University of Arizona College of Agriculture and the United States Department of Agriculture co-operating. Distributed in furtherance of the acts of Congress of May 8 and June 30, 1914.

TABLE OF CONTENTS

ILLUSTRATIONS

COOLING FOR THE ARIZONA HOME

By

Martin L. Thornburg and Paul M. Thornburg

INTRODUCTION

Arizona is in the southwestern section of the Rocky Mountain area. The state is relatively large, being some 385 miles in length and 300 miles in width.

The topographical and climatic conditions of Arizona are widely variable. The northeastern portion is a high plateau with an altitude of 6,000 to 8,000 feet above sea level. This area, called the Mogollon Plateau, is divided from the rest of the state by a sharp drop of approximately 1,500 feet. The south, central, and western portions of the state are wide, flat valleys, partly under irrigation. It is in these sections of Arizona that summer cooling of homes is desirable.

There are many local factors which may govern the need for cooling. Elevation, vegetation, lakes, prevailing winds, average precipitation, and maximum and minimum temperatures are all important.

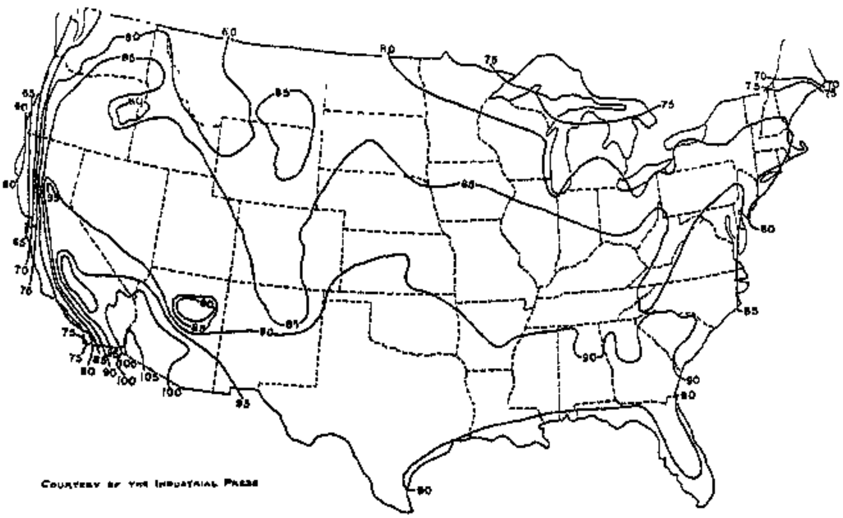

Figure 1.—Average daily maximum temperature for July.

The maximum annual temperatures usually occur during the month of July. Figure 1 shows the average noonday July temperatures for the United States. No attempt has been made to correct for variations caused by local conditions.

These values are the average for the entire month. Higher as well as lower temperatures occur, but the values given are the normal expectancy for every July day at noon.

The minimum temperature usually occurs shortly before sunrise, and the maximum to minimum variation is largely governed by the relative humidity. Figure 2 shows the average noonday July relative humidity for the United States. It is also not corrected for local conditions, and lists the normal expectancy. It will be noted that relative humidity is affected by geographical location rather than elevation.

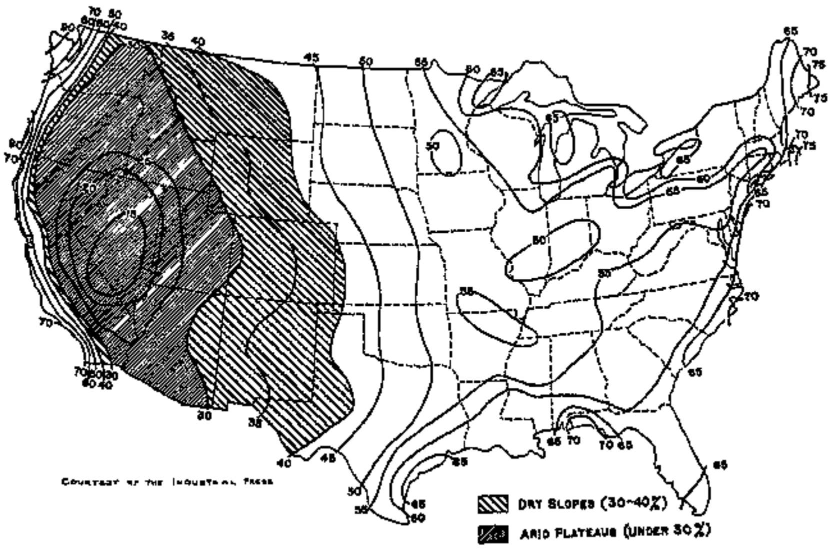

Figure 2.—Mean relative humidity at noon in July.

The maximum temperatures, with the attendant relative humidities, and the length of the summer season influence the selection of equipment for cooling the home. Weather bureau records for three Arizona cities—Phoenix, Tucson, and Yuma—are shown in Tables 1, 2, and 3. These are representative cities for the districts.

These records cover a period of years and show that July temperatures are always maximum for the year, with June and August temperatures approximately the same. Relative humidities, however, are low in June, sharply higher in July, and reach a summer maximum in August. The maximum to minimum temperature change also decreases as the relative humidity rises.

A comparison of these monthly average conditions shows that July and August present the major problems in home comfort. A cooling system should be selected to meet these conditions.

TABLE 1.—MONTHLY AVERAGES OF DAILY MAXIMUM TEMPERATURES FOR MAY TO OCTOBER, 1929-38, INCLUSIVE.*

	May	June	July	Aug.	Sept.	Oct.
Phoenix						
Warmest month	98.9	105.6	107.5	105.3	101.5	91.5
Coolest month	86.0	98.9	103.5	100.1	96.7	85.5
Average month	92.8	102.3	105.3	102.8	98.9	88.6
Tucson						
Warmest month	96.2	101.7	102.0	99.4	96.0	89.4
Coolest month	82.7	96.7	97.4	93.9	91.9	82.6
Average month	89.5	98.7	99.8	96.6	94.4	86.5
Yuma						
Warmest month	99.1	106.0	108.5	107.7	103.2	94.4
Coolest month	87.6	97.7	104.8	102.5	97.7	87.0
Average month	94.0	102.2	106.6	104.9	100.9	89.9

*Data from U.S. Weather Bureau Stations at Phoenix and Yuma and the University of Arizona Weather Station at Tucson.

Another major factor in home cooling is the solar effect or sun load on the home itself. Arizona, with clear air and few clouds, receives a much larger solar effect than almost any other section of the United States. This sun load is directly applied to the roof or walls of the home and in summer reaches an astonishing amount. Roof temperatures may rise 40 degrees F. above the temperatures in the shade. The midsummer noonday sun load on the roof of a five room home is approximately enough to melt 1 ton of ice per hour. A large percentage of this sun load reaches the inside of the home unless the ceiling is insulated and the attic is ventilated.

Heat is reradiated from the ground and buildings during clear nights. This tends to lower the minimum temperature and thus reduces the heat stored in masonry walls and concrete slabs. High relative humidities tend to reduce heat reradiation.

The monthly average of day and night temperature variation is approximately 25 degrees F. minimum. With this variation, night comfort conditions are usually satisfactory. It is the hours between midmorning and midevening that offer the cooling problem.

HUMAN COMFORT[1]

This section is included in the belief that a knowledge of the factors affecting human comfort will enable the reader to reach a more logical conclusion and perhaps a better answer to his own individual problem.

[1]Data from *Heating, Ventilating, and Air Conditioning Guide, 1939*; and H. W. Haggard, *Mechanical Engineering*, Jan., 1939.

TABLE 2.—MONTHLY AVERAGES OF DAILY RELATIVE HUMIDITY FOR MAY TO OCTOBER, 1929-38, INCLUSIVE.*

	May		June		July		August		September		October	
	12 M.	6 P.M.	12 M.	6 P.M.	12 M.	6 P.M.	12 M.	6 P.M.	12 M.	6 P.M.	12 M.	6 P.M.
Phoenix												
Most humid month	21	18	17	16	31	26	37	34	31	30	28	46
Driest month	12	10	11	8	20	16	24	22	21	18	18	21
Average month	16	14	14	12	25	22	31	27	26	24	23	26
Tucson†												
Most humid month	26	23	24	22	37	38	45	46	41	41	33	31
Driest month	15	12	17	12	26	26	31	30	23	21	20	19
Average month	19	17	20	17	32	31	38	37	33	31	26	24
Yuma												
Most humid month	20	20	21	19	31	27	38	36	31	33	30	40
Driest month	13	11	14	13	24	21	27	24	23	22	19	15
Average month	18	15	18	16	28	25	32	30	28	28	25	28

*Data from U.S. Weather Bureau Stations at Phoenix and Yuma and the University of Arizona Weather Station at Tucson.
†Relative humidity taken at 12:00 M. and 5:00 P.M.

TABLE 3.—NUMBER OF DAYS THE MAXIMUM TEMPERATURE IN TUCSON, ARIZONA, EXCEEDED 89 DEGREES F. AND 99 DEGREES F. FOR MAY TO OCTOBER AND WHOLE YEAR, 1929-38, INCLUSIVE.*

	May	June	July	Aug.	Sept.	Oct.	Whole year
Maximum number of days above 89° F.	27	30	31	31	29	18	155
Maximum number of days above 99° F.	9	16	25	17	12	3	60
Minimum number of days above 89° F.	5	24	28	22	22	6	122
Minimum number of days above 99° F.	0	10	12	4	1	0	41
Average number of days above 89° F.	17.6	27.8	29.8	27.9	24.9	11.1	139.1
Average number of days above 99° F.	2.1	14.6	17.8	10.4	5.1	0.4	50.4

*Data from University of Arizona Weather Station at Tucson.

BODY HEAT LOSSES

The reactions of the human body are very complex, with the nerve centers directing co-ordination of the necessary body functions. One of the most important of these functions is the maintenance of body temperature at a relatively constant level. This level in a healthy body is maintained without conscious thought through a range of surrounding conditions from below 0 degrees F. to over 100 degrees F. This level for adults is usually 98.6 degrees F. in the mouth and 1 to 2 degrees higher in the interior of the body. Time of day, age, and activity may change these values a small amount. The temperature of exposed skin surfaces may be only slightly higher than that of the surrounding air.

The amount of heat produced by an adult, relaxed and warm in bed, is approximately 160 B.T.U. per hour. This heat value rises to 380 B.T.U. per hour when seated at rest, to 1,000 B.T.U. per hour for normal home activity, and to 2,500 B.T.U. per hour for vigorous exercise or hard work. About 80 per cent of this heat is dissipated through the surface of the skin. It is not conducted through the muscles but is carried to the skin surface by the blood stream. Regulation is obtained by variation in the size of blood vessels near the surface. To compensate for this enlargement, arteries in the interior of the body are constricted. This is particularly true in the digestion tract, where digestion is slowed, and in extreme cases may stop altogether.

METHODS OF HEAT REJECTION

The body heat may leave the skin surface by radiation, conduction, convection, and evaporation. Radiation is a function of the fourth powers of the absolute temperatures and decreases rapidly as the temperature of the surroundings increases. It ceases altogether when the surroundings reach body surface temperature. Conduction transmits the heat directly to the air. It is passed on through a heat gradient to the other layers of the surrounding air. Convection is the heating of the particles of air as they pass the surface. These particles then carry the heat away directly. Convection of heat by air is more effective than conduction. Both vary directly with the temperature difference between the skin and the air and decrease at a slower rate than radiation. When the air temperature is higher than the body temperature, both conduction and convection add to the body heat load.

Evaporation of water is the last resource of the body heat control system for the rejection of heat. The rate of evaporation depends on the relative humidity of the air surrounding the skin and decreases to zero when the relative humidity reaches 100 per cent.

All cooling resources of the body fail when the relative humidity is 100 per cent and the air temperature is over 100 degrees F. Even as it approaches these conditions, the heart is overworked and heat prostration may result. The process of evaporation is controlled by the amount of moisture which reaches the skin surface, which is generally only enough to equal the amount evaporated. When the demand for heat removal increases beyond this point, perspiration is the effort of the heat regulating system to try to increase the evaporation. Heat is required to evaporate moisture, and it must come from the nearest source, the surface of the skin.

A fixed condition of temperature and humidity is not desirable for the proper functioning of the body. If the heat control system is not in frequent operation, it loses the flexibility required in an emergency. Other body functions are also likely to slow down. Some variation is therefore invigorating, but extreme conditions may be damaging to the system.

COMFORT ZONE LIMITS

Comfort might be considered as an orderly operation of the body functions. When any particular phase is overworked or inoperative, a disturbance of balance occurs. Within reasonable limits, no particular strain is felt, although a long continuance may lead to a feeling of discomfort.

The age, physical condition, and health of the individual will dictate the best conditions for comfort. The American Society of Heating and Ventilating Engineers, in conjunction with the American Medical Association, conducted a large number of tests. The result was the establishment of the temperature and relative humidity boundaries of the comfort zone. The limits of the summer comfort zone for the central states are shown in Figure 3.

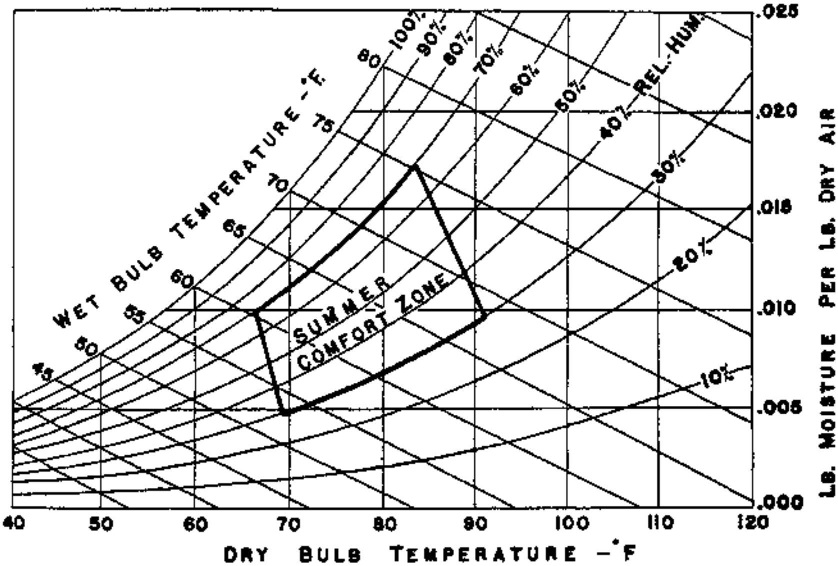

Figure 3.—The summer comfort zone.

The maximum comfort conditions for most persons was found to be near the center.

There has been, as yet, no extensive study made of a summer comfort zone for the Southwest. In this district the average yearly temperatures are higher, and it is probable that a somewhat higher temperature limit on the summer comfort zone would be allowable. High outside air temperatures cause a rapid change in the body cooling functions on entering or leaving an air cooled building. Some railroads have found that on their air conditioned trains the inside temperature should rise somewhat as the outside temperature increases. The upper temperature limit on the summer comfort zone for the Chicago district, as shown in Figure 3, might be considered as normal comfort conditions for Arizona. Several authorities have subscribed to this belief. Experience has shown that one thing is certain: most Arizona people find the maximum degree of comfort under conditions represented by the upper half of the comfort zone.

NEED FOR VENTILATION

Lack of adequate ventilation produces a condition commonly called "bad air." This condition is usually caused by the recipients themselves. Its characteristics are: a small decrease in oxygen content, a small increase in carbon dioxide, a marked increase in both temperature and relative humidity, the presence of organic odors produced by the body and clothing, and a decrease in the ion content of the air. Its effect on the respiratory system is psychological rather than physical, but the increased heat and humidity throw an additional load on the heat regulating system of the body. The net result may be an offensive odor on entering the building, with a feeling of discomfort and general depression after prolonged occupancy.

The body system for conditioning the air entering the lungs is small in size and complex in operation. It is located in the nasal cavity of the head and performs all of the functions of a modern air conditioning plant. The entering air is brought to body temperature and approximately 100 per cent relative humidity. Except under extreme conditions, all of the dust and fumes and most of the bacteria are filtered out. This filtering action is effected by a liquid, having some antiseptic properties, which is secreted at the top of the nasal cavity, passes over the membranes in about 12 minutes, and is rejected into the throat. Sneezing accelerates the flow of this liquid when irritation of the membranes is caused by foreign material.

The construction of most Arizona homes provides enough natural ventilation for normal occupancy. This is effected by air infiltration through the cracks around the doors and windows. Complete weather stripping of all openings may require the installation of artificial methods for adequate ventilation.

HEAT INSULATION

It is both easier and cheaper to keep most of the summer heat out of a structure than to remove it after it has entered. The earlier residents of Arizona used an effective method of excluding most of the summer heat. They built houses with thick adobe walls, small windows, and thick dirt roofs. Many old homes thus built are relatively comfortable even in the hottest weather, particularly if all openings are closed during the day and opened at night. The advent of thin walls, large windows, and different types of roofs has materially reduced the heat insulation effect.

Basements under the houses have much the same comfort characteristics as the old type homes. Some ventilation, however, is required in basements at all times.

The production of new heat insulating materials within the last few years has made possible an increased heat exclusion in the modern home. The matter of heat insulation is usually worth investigating. The cost of roof or ceiling insulation of an average five room home will be from $35 to $100, depending on the type of material used and the details of construction. The operating cost of insulation is zero and the depreciation is small. Adequate roof or ceiling insulation may reduce the fuel bill in winter by 1.5 per cent and lower the house temperature from 4 to 10 degrees F. in summer. If the ceiling is insulated the attic should be vented in summer and closed in winter. Modern insulating materials have a small heat storage capacity compared with masonry walls.

LENGTH OF COOLING SEASON

The difference in house construction makes it impossible to determine the number of hours per day and days per year that the home will be entirely comfortable without some means of artificial cooling. A well-insulated house may be very comfortable, an average house fairly comfortable, and a sheet iron house almost unbearable under the same outside conditions. The records of a number of Arizona home installations indicate that a cooling system is used at least a few hours per day when the maximum outside air temperature is 90 degrees F. or more. It probably would be operated from 12 hours per day to continuously when the maximum outside air temperature is 100 degrees F. or more.

The monthly average number of days under these classifications are shown in Table 3 for Tucson. Other localities will probably have relative values. This will not be an exact measure of the cooling desirable. Hot days early in the summer season are likely to be accompanied by low mimimum temperatures and low relative humidity. Summer showers will reverse these conditions.

Heat storage is the property of a structure to retain heat. Massive masonry has excellent heat storage capacity and frame construction very poor capacity. In summer masonry walls reduce the maximum and increase the minimum inside air temperature. As the summer season progresses, the masonry stores some cumulative amounts of heat, and both maximum and minimum inside air temperatures are relatively increased. Frame construction has practically no averaging effect on inside air temperatures and no cumulative heat storage from day to day.

The maximum amount of solar heat is received on June 21, but the maximum temperatures occur later in the summer due to the heat storage capacity of the ground. The relative humidity in June is minimum for the entire year but increases rapidly with the advent of the summer rains and reaches a summer maximum in August (Tables 1, 2, and 3).

Minimum summer comfort is therefore encountered during July and August.

The above conditions explain why the method of computing degree hours, as a measure of the cooling needed, is not applicable to the Arizona climate. Experience has shown that relative humidity is an equally important factor in summer comfort.

Type and material of clothing, as well as personal likes and needs, are also factors that should be considered.

COOLING SYSTEMS

The average July maximum temperatures, with the attendant relative humidities, are shown in Figures 1 and 2. Analysis of these figures indicates that the northeastern section of Arizona will not benefit greatly from home cooling. This district represents about 40 per cent of the state's area but less than 40 per cent of the state's population. There may be occasional warm days in this section, but due to the elevation the nights are usually cool. The rest of Arizona, with the exception of a few scattered mountain areas, has sufficiently high summer temperatures to justify the installation of some method of home cooling.

Plate I.—A typical Arizona home.

The available methods of home cooling in Arizona are more numerous than in most sections of the United States. This is due to the low relative humidity, as shown in Figure 2. The usual methods considered are night cooling, direct evaporation, indirect evaporation, well water, and mechanical refrigeration.

NIGHT COOLING

Night cooling is most effective when the maximum and minimum temperature difference is large. It is often used when the heat insulation of the structure is good, and the outside conditions are not extreme. The usual practice is to open the house at night and utilize a fan to circulate fresh outside air. The house is then closed in the early morning and no additional outside air is introduced. Circulation of air within the house may be obtained with a fan. A heavy occupancy load, or the extensive use of open gas stoves, will raise the inside humidity and make this method of cooling relatively ineffective.

DIRECT EVAPORATION COOLERS

The direct evaporation cooler is commonly known as a window box type of cooler. It is estimated that there are 10,000 of these in use in Arizona at the present time, and that they outnumber all other types of installations by a ten to one ratio. In general, their use is restricted to the districts where the average relative humidity at noon in July is 40 per cent or less[2] (Fig. 2). There are many districts in this indicated area, where the relative humidity would permit, but the maximum temperatures would not justify, their use. In general, however, the number of installations is rapidly increasing. A published report from El Paso, Texas, states that there were three times as many new installations in 1938 as there were in 1937, and a larger increase is expected in 1939.

Coolers of this type are also in general use in parts of New Mexico, Nevada, and California. The advantages of a direct evaporation cooler are its relatively low initial cost and low cost of operation. The initial cost may vary from $10 for a homemade unit to something over $100 for some styles of purchased units. The operation cost will be in the order of 1 cent per hour. The disadvantage is that the humidity in the house may be excessive, if the unit is not well designed and constructed, or when the outside conditions are unfavorable. Also, another limitation is that the cooled air cannot be recirculated.

The operating conditions of the direct evaporation cooler, in relation to the comfort zone, are shown in Figure 4. Point *A* may be taken as outside air conditions. Point *B* represents a desirable air condition leaving the cooler. Point *C* might be a suitable air condition on discharge from the house. Point *D* represents an unsatisfactory air condition in the last room being cooled. The

[2]*Heating & Ventilating*, Oct., 1938.

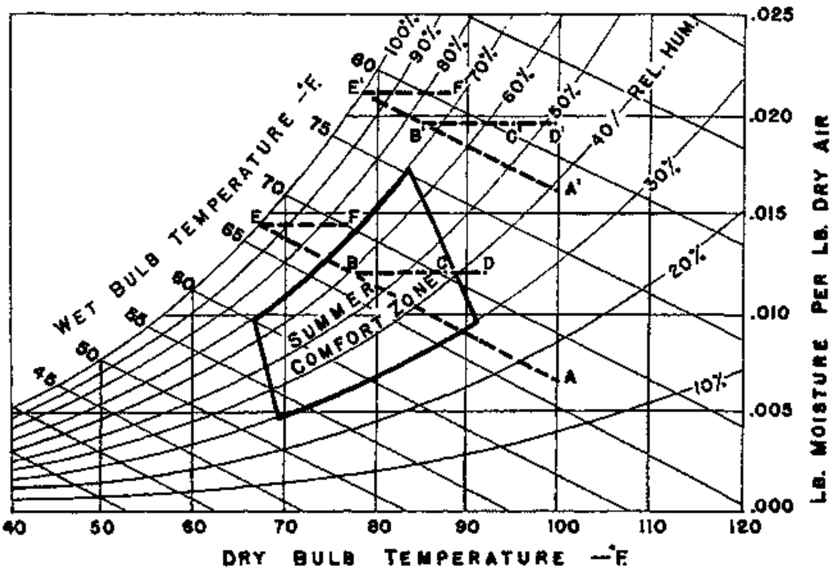

Figure 4.—Performance of the direct evaporation cooler.

maximum air cooling from conditions at *A* with this system is shown by point *E*. The line *E* to *F* then represents air travel through the house and is not satisfactory for human occupancy. Another outside air condition possible is shown by *A′*. The points *B′*, *C′*, *D′*, *E′*, and *F′* represent the corresponding conditions that might be expected from the operation of such a cooler. No condition reached from *A′* would be satisfactory.

INDIRECT EVAPORATION COOLERS

The indirect evaporation cooler is commonly known as the dry air type of evaporation cooler. This type of cooler is also in common use in Arizona homes and is second only in number of installations to the direct evaporation type. Its use is restricted by the same limitations. In this system moisture is not added by the cooler to the air inside of the home. Water is cooled by passing over an evaporation tower. This tower may be either a natural circulation or forced draft tower. The air to the cooling tower is not recirculated or introduced into the home. For this reason the maximum amount of evaporation and the resulting maximum cooling of the water are desirable. The cooled water is then circulated through the inside of a radiator. Air is passed over the radiator surface, cooled, and introduced into the home. Since no moisture is added to the air, recirculation and recooling of the inside air may be desirable.

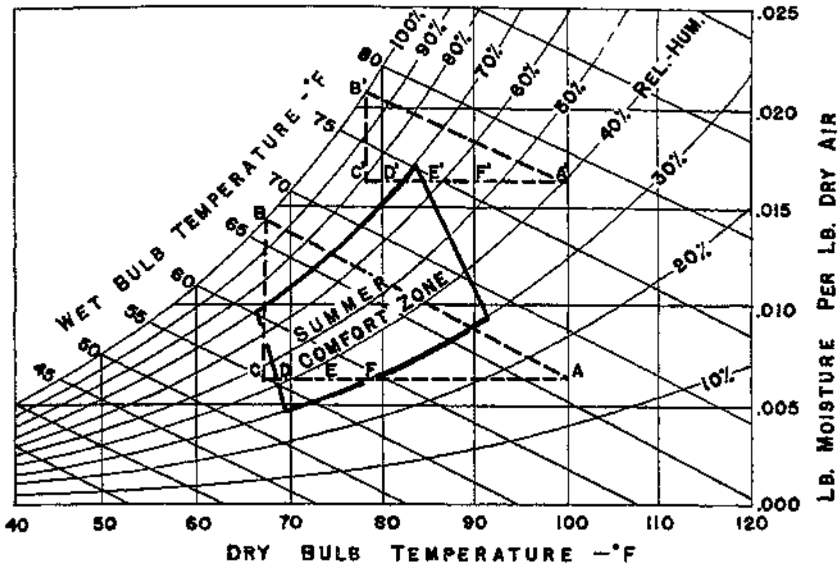

Figure 5.—Performance of the indirect evaporation cooler.

The operating conditions of the indirect evaporation cooler in relation to the comfort zone are shown in Figure 5. Point *A* may be taken as outside air condition. Point *B* represents the minimum dry bulb temperature of the air leaving the tower. This temperature is also the minimum that may be attained by the cooled water leaving the tower. Point *C* represents the theoretical minimum temperature and humidity that could be attained in the home with an indirect evaporation cooler. These conditions, however, are never obtained in actual operation. Point *D* represents the probable water temperature entering the radiator, and point *E* the probable water temperature leaving the radiator. Point *E* may also represent the temperature of the cooled air entering the house, and point *F* the air temperature leaving the house or being recirculated past the radiator surface. The line *E* to *F* is the temperature range of the air within the home. Another outside air condition possible is shown by *A′*. The points *B′*, *C′*, *D′*, *E′*, and *F′* represent corresponding conditions that might be expected from the operation of such a cooler.

The advantage of the indirect evaporation cooler is its ability to obtain approximately the same temperature drop inside of the house as the direct evaporation cooler without raising the moisture content of the air inside of the house. The disadvantages are higher first cost, higher operating expense, and more maintenance. The first cost is from $200 for a one-room size to perhaps $1,000 for a central system. These systems are usually controlled by a thermostat inside the home, and the operating cost may range from 40 to 70 cents per day for the average house. At present the range of the indirect evaporation cooler is somewhat limited under extreme temperature and humidity conditions. A projected research problem at the University of Arizona is the probable extension of this range by variations in the methods of use.

WELL WATER COOLERS

The well water type of cooler has not received the consideration that it should in many localities. It is a very popular type in the north central states where evaporation cooling is not adaptable to homes, but it is also being used in several large commercial installations in the Southwest. An adequate supply of cool well water, available at a reasonable cost, is the major requirement. Where the water is being pumped for other uses, a cooler of this type is particularly adaptable. The installation for cooling the air supplied to the inside of the home is identical with that of the indirect evaporation type. The well replaces the evaporation tower, and the cool well water is supplied directly to the radiator. The well water temperature determines the condition, comparable to the point *D* on Figure 5, that governs the operating range of the rest of the system.

The advantage of the well water cooler is that of the indirect evaporation cooler, with the additional advantage that the well water temperature is independent of outside temperature and humidity conditions. The disadvantage is that the well water temperature may, at times, be above the wet bulb temperature and the operating range restricted. The disposal of the water used may also be a serious problem in certain districts. The total first cost and the operating costs are highly variable, depending on the water conditions.

MECHANICAL REFRIGERATION

Mechanical refrigeration is the most satisfactory system from the viewpoint of the cooling range. This type of cooler operates as a heat pump. Heat is removed from the air inside of the house and is rejected through some medium to the outside. Point *A*, in Figure 6, represents outside conditions; point *B*, the conditions in the home. Within the capacity range of the unit, point *B* is unlimited in position, except that it must be on the horizontal line through *A*, until 100 per cent relative humidity is reached. After this condition is reached, moisture is removed from the inside air along the 100 per cent relative humidity line. Dehumidification lowers the relative humidity inside of the house. The advantage of a mechanical refrigeration cooling system is that any desired air conditions can be obtained. The only disadvantages are initial cost and operating costs. The initial cost may be from $2,000 to $3,000 for a unit of 3 to 5 ton capacity. Mechanical refrigeration is always controlled by a thermostat. The operating cost is

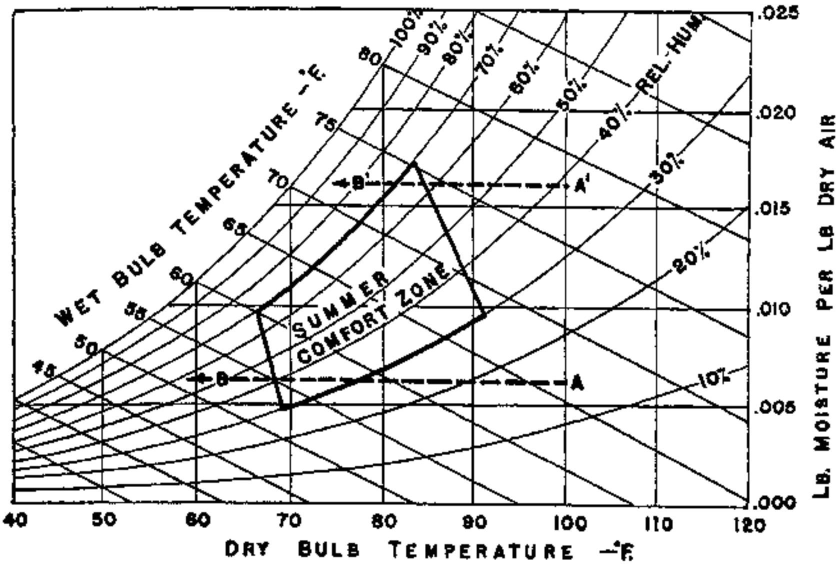

Figure 6.—Performance of the mechanical refrigeration cooler.

highly variable, depending on size, type of house, insulation, and power rates.

Mechanical refrigeration is sometimes used as a booster for indirect evaporation or well water coolers. Installations of this type are not in general use for Arizona home cooling.

THE DIRECT EVAPORATION COOLER

HISTORY

The origin of direct evaporation cooling is not definitely known. It seems to have been developed independently in many countries and in rather ancient times. It is definitely known that the early Indians in Arizona used the principle in their water ollas, and it is probable that a wet blanket was also used for human cooling. The wet sheet or blanket was extensively used by the early settlers in arid regions when they desired to sleep in the hot summer daytime. Wet fabric drapes were also hung in open doors and windows on the windward side of the house. From the other side of the world, India, comes a similar and more extensive report on direct evaporation cooling. During certain seasons of the year parts of India have a trade wind known as the monsoon. This trade wind is rather fixed in direction and steady in amount. Porches and verandas were constructed on the windward side of the houses and shaded with woven grass matting. Probably the cooling effect of evaporation after a shower was the origin of the idea there. Later development was the pouring of water over the matting to secure cooling and the subsequent placing of drip buckets to provide a steady source of moisture. Matting of certain types of grass was preferred on account of the pleasing tang or fragrance that they added to the air. No new principles of operation have been developed since that time, but modern equipment has added to the control and use.

THEORY

The theory of evaporation cooling is a natural phenomenon. For any one temperature there is only one complete balance of air and moisture. This balance is known as 100 per cent relative humidity and denotes complete saturation. If the source of moisture is removed and the temperature rises, the air is no longer saturated, and an unbalanced condition exists. The relative humidity is now the per cent relation of the amount of moisture present to the amount for balanced saturation. Any cooling of the air below saturation temperature results in moisture condensation and precipitation. When moisture is present and the relative humidity is less than 100 per cent, evaporation of the moisture results. This evaporation is, in reality, merely boiling at low temperature. The heat required to evaporate at ordinary temperature is more than is required at high temperatures. This heat, to evaporate, must come from the nearest sources, which are the water and the surrounding air. When the quantity of water is small, a minimum water temperature, known as the wet bulb temperature, is soon reached, and the balance of the heat for evaporation must come from the surrounding air. The heat required to evaporate 1 pound of water at ordinary temperatures is approximately the same as the amount required to melt 7 pounds of ice. This gives a rough estimate of the amount of cooling available from evaporation.

Compared with boiling, evaporation is a slow process. To be effective the air must be in contact with a large water surface for a short length of time or with a small water surface for a long period of time. The first method is much to be preferred for evaporation cooling, because it requires much the smaller unit for the same cooling capacity. Any method that will provide this large contact surface will have the same effectiveness. The two types used are direct spray and moistened pad.

SPRAYS VS. PADS

The direct spray places water into the air in the form of small particles. Evaporation takes place from the surfaces while they are held in suspension. The surface area of these water particles is large compared with the quantity. Advantages of the spray evaporation are: (1) there is no pad required, (2) the spray acts as a filter, (3) there is no possibility of an odor, and (4) when the sprays are turned off, the fan can act as a ventilator of night air.

The disadvantages are: (1) a pump is required for recirculation of the water, (2) concentration of the salts in the water may clog the nozzles used to secure a fine spray, and (3) the carry-over of water particles into the house is probable unless a filter is used or the air velocities are low. Spray type evaporation for direct evaporation cooling is not in common use, although there is some possibility of future application.

The moistened pad is operated by supplying water uniformly at the top. The water passes down through the pad and maintains a moistened surface. The pad surface is permanent in location and presents a relatively large wetted surface to the air. The advantages of a moistened pad are: (1) slow passage of the water provides lengthy evaporation time, (2) the pad acts as a partial air filter, (3) less water is handled and at a lower pressure, (4) freedom from small spray nozzle trouble, (5) less chance for spray carry-over with proper operation, and (6) ease of manufacture at a low cost. The disadvantages are: (1) a relatively large size is required and (2) the possibility of objectionable odors from some filtered materials or from mildew when improperly operated.

REQUIREMENTS OF PAD MATERIALS

The pad filter material should possess the following properties:

1. Ability to absorb water.
2. Be finely divided.
3. Freedom from objectionable odors when wet.
4. Freedom from corrosive or discoloring compounds.
5. Freedom from grease and oil.
6. Minimum weight.
7. Maximum strength and flexibility.
8. Resistance to decomposition in use.
9. Low initial cost.
10. Easily maintained in place.

Many materials have been used for pad packing material, but as yet the ideal material has not been found. Cottonwood or aspen excelsior seems to answer most of the requirements and is the material most commonly used. Further consideration of pads with regard to size, air velocities, thickness, choice of materials, and construction details is given on page 27.

COOLER SELECTION

If direct evaporation cooling of the home is to be effective, there are two principal errors that should be avoided. These errors are attempting to cool a large house with a small unit and the use of large, thick, heavy packed pads with fan units of low capacity.

The capacity of the unit selected should match the total portion of the house that is to be cooled. A common practice is to install a unit large enough for only one or two rooms and then attempt to extend the cooling effect to the rest of the house. The usual result of such a practice is that the last room through which the

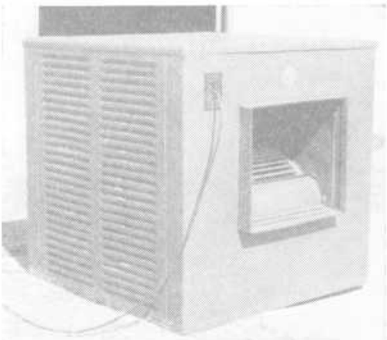

Plate II.—A direct evaporation cooler.

air passes will probably be less comfortable than if no cooling was attempted. This condition is represented by point *D* on Figure 4. The heat load to be removed from a house may be calculated, an air exit to inlet temperature ratio fixed, and the air quantity required under the worst operating conditions determined. This procedure is followed for commercial installations, but the expense entailed for such a survey by a competent observer makes most home installations a matter of "rule of thumb." These general rules should be followed for home installations. For an adobe or brick house with a ventilated attic but no ceiling insulation, and an average window area, the volume of the portion of the house to be cooled is divided by three to obtain the free air rating of the fan unit required. If the attic is ventilated and the ceiling insulated, the division by three may be changed to a division by four. If the ceiling is well insulated, the major portion of the heat enters the house by way of the windows. Awnings or outside shade will reduce this heat so entering. Excessive internal friction to air flow inside of the house and drawing the air from the lee side and discharging it on the windward side of the house will necessitate a larger fan capacity than calculated. In case of doubt, the selection of the larger capacity unit is recommended. A frame house without ceiling insulation, shade, or awnings presents the worst problem. For a house of this type, it is recommended that the volume to be cooled should be divided by two to obtain fan unit free air capacity. Except for drafts, the larger the capacity of the direct evaporation cooling unit, the better. A small increase in initial cost and operating expense will probably be repaid in added comfort. A multiple speed unit is to be preferred because of the flexibility to meet a wide range of operating conditions. Construction details for those who desire to build their own direct evaporation cooler are included on pages 26 to 30.

Where purchase from a reliable firm is contemplated, the firm will usually furnish a reliable man to inspect the house and recommend a size and location for satisfactory operation.

METHODS OF TESTING

The final proof of satisfactory operation is the location of points *B* and *C* in Figure 4. Point *A* is obtained by holding a dry thermometer in the shade outside of the house; point *E* by wrapping a small cotton cloth around the thermometer bulb, dipping the cloth in water, and holding the thermometer in the entering air

1 foot from the fan until a minimum reading is obtained. Point *B* is obtained by removing the cloth and holding the bare dry thermometer in the same position as for point *E*. Point *C* is obtained by holding the dry thermometer in the air leaving the house. The readings should be taken as near the same time as possible. If the temperature difference between point *B* and point *C* is more than 10 degrees, the unit is too small for the volume that is being cooled. An ideal unit is one that gives satisfactory operation under average outside conditions at second speed. This unit will be economical and quiet to operate and will give an added capacity at high speed when outside conditions are unfavorable. An additional low speed has the added advantage that there will be times when only a small amount of cooling is required for comfort.

There are many false and misleading claims made for direct evaporation coolers. There are times when no cooler of this type, regardless of size, will be entirely satisfactory, as shown by *A′*, *B′*, *C′*, *D′*, *E′*, and *F′* in Figure 4.

COOLER LOCATION

The location of the cooler, in relation to the house, is of considerable importance. Occasionally there is only one possible location, but usually there are several, and each should receive consideration as a desirable choice. North and south exposures are practically free from sun effect. The west receives the maximum effect when the heat load of the house is at the peak. The heat from the sun falling directly on 10 square feet of area requires approximately ¼ ton of refrigeration for dissipation. This amount of heat on the pad is transmitted directly to the inside of the house. This sun effect raises the temperature of the entering air 1 or 2 degrees or increases the relative humidity an appreciable amount. If a western exposure is the only one possible, some shade should be provided for the cooler. The only advantage of a western exposure is that the usual prevailing summer winds are from that direction, and the capacity of the unit is helped rather than hindered.

The question of air distribution and circulation inside of the house is sometimes more important than cooler location.

The cooler is usually located to supply air to the portion of the house most commonly used. In general, this is the living room or dining room. Coolers should never be located so that heat and cooking odors will be carried to other portions of the house. The best possible arrangement for distribution would be a cooler unit for each room. This is not economical, and multiple units are rarely used except when local cooling is desired in some remote room. When various portions of the house are in use at certain times only, a split direction system of air flow may be used. For example, a cooler might supply cooled air continuously to the living room and dining room of a house. Part of the time this air would then be passed through the kitchen and discharged from

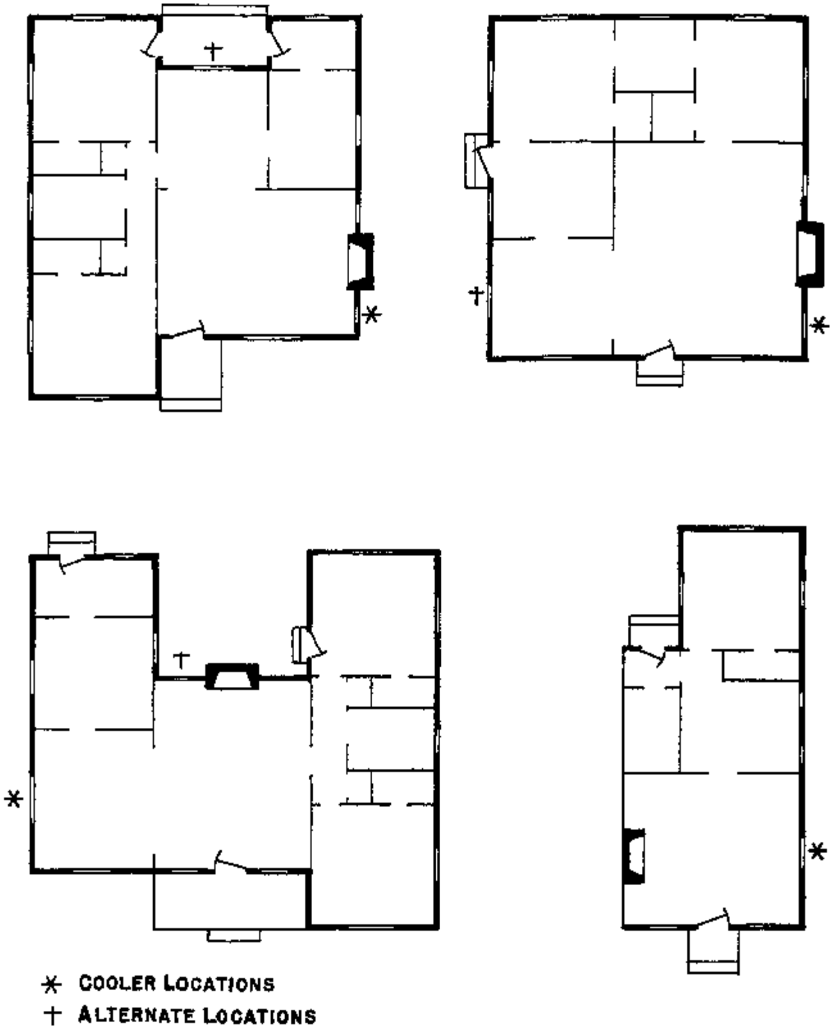

Figure 7.—Possible cooler locations.

the house. At other times the air would be passed through the bedrooms and then discharged.

It is recommended that the cooled air inlet be located as high as is feasible, usually the top part of the window. Guide vanes in the entering air stream should be used to even the distribution and reduce drafts. Unit operating noise may be a factor in unit location, but many modern low speed units are relatively quiet. Looks, water supply, water disposal, power outlets, and service conditions may modify the final choice of cooler location. Where water disposal is a serious problem, such as in congested areas, a recirculation pump may be used to advantage. Recirculation of the water over the pad will result in a saving of 8 or 10 gallons of water per hour with a gain in cooling effectiveness of 4 to 5 per cent but a power increase of approximately 10 per cent. When water is recirculated, the unit should be drained at frequent intervals to remove accumulated dirt and concentrated salts.

COOLER OPERATING CHARACTERISTICS

The cooler unit should be checked for operating characteristics. Wet and dry bulb thermometers are usually available wherever manufactured units are sold, and the readings require only a few minutes. The relation of wet bulb temperature, relative humidity, and dry bulb temperature is shown in Table 4. The vertical columns show the relative humidities for the wet bulb temperature marked at the top. The dry bulb temperatures for these relative humidities are shown at the left. An example of its use is as follows. An outside air temperature of 100 degrees F. and a wet bulb temperature of 70 degrees F. will intersect in the square with a relative humidity value of 22 per cent. All of the values in the vertical column above this square are possible cooler outlet relative humidities, with the accompanying dry bulb temperatures on the left. The relative humidity immediately under the diagonal line, 69 per cent, with the attendant dry bulb temperature of 77 degrees F. indicate satisfactory cooler operation. It should be noted that as the dry bulb temperature value decreases the relative humidity increases and at a rapidly increasing rate. A humidity indicator may be used to check the cooling unit. Its reading at the cooler outlet should be about 70 per cent. Care should be taken that sufficient time is allowed, for some of the humidity indicators adjust very slowly. Humidity indicators are not as reliable as wet and dry bulb thermometers and may need frequent adjustment. If the relative humidity of the cooler outlet air is too high, the unit is not suited for the home.

FANS AND BLOWERS

Two general types of power units are used in evaporation coolers. When the shaft is parallel to the air discharged, it is called a fan. When the shaft is not parallel to the air discharged, it is called a blower.

When a fan is used, wide overlapping blades are in most cases quieter and give better performance than the narrow or airplane type. Office or circulation fans are not satisfactory for cooler use.

Fans are rated in free air capacity at a given speed. This rating includes the air handled as a vortex by the tip when the fan is not surrounded by a shroud. The resistance to air flow is also small under these conditions. Numerous tests have shown that the actual air delivered through a cooler to a normal house with an adequate outlet will be approximately two thirds of the free

TABLE 4.—RELATIVE HUMIDITY AS DETERMINED BY WET AND DRY BULB TEMPERATURES.

Dry bulb temper-ature	Wet bulb temperature																				
	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
70	56	60	64	68	72	77	81	85	90	95	100										
71	52	56	60	64	68	72	77	81	85	90	95	100									
72	49	53	57	61	65	69	73	77	82	86	90	95	100								
73	46	49	53	57	61	65	69	73	77	82	86	91	96	100							
74	43	46	50	54	58	62	66	70	74	78	82	86	91	96	100						
75	40	44	47	51	54	58	62	66	70	74	78	82	86	91	96	100					
76	38	41	44	48	51	55	59	62	66	70	74	78	82	87	91	96	100				
77	35	38	42	45	48	52	56	59	63	67	70	74	78	82	87	91	96	100			
78	33	36	39	42	46	49	52	56	60	63	67	71	75	79	83	87	91	96	100		
79	31	34	37	40	43	46	50	53	56	60	64	67	71	75	79	83	87	91	96	100	
80	29	32	34	38	41	44	47	50	54	57	61	64	68	72	75	79	83	87	92	96	100
81	27	30	32	35	38	42	45	48	51	54	58	61	65	68	72	76	80	84	88	92	96
82	25	28	30	33	36	39	42	45	48	51	55	58	62	65	69	73	76	80	84	88	92
83	23	26	28	31	34	37	40	43	46	49	52	55	59	62	65	69	73	76	80	84	88
84	22	24	26	29	32	35	37	40	43	46	49	52	56	59	62	65	69	73	77	80	84
85	20	22	25	27	30	33	35	38	41	44	47	50	53	56	59	63	66	70	73	77	80
86	18	20	23	26	28	31	34	36	39	42	44	47	51	54	57	60	63	67	70	73	77
87	17	19	21	24	26	29	32	34	37	40	42	45	48	51	54	57	60	64	67	70	74
88	16	18	20	22	24	27	30	32	35	37	40	43	46	48	51	54	58	61	64	68	71
89	14	16	19	21	23	26	28	30	33	36	38	41	43	46	49	52	55	58	61	64	68
90	13	15	18	20	22	24	26	28	31	34	36	38	41	44	47	50	52	55	58	61	65
91	12	14	16	18	20	22	24	27	29	32	34	37	39	42	44	47	50	53	56	59	62

TABLE 4.—RELATIVE HUMIDITY AS DETERMINED BY WET AND DRY BULB TEMPERATURES—*Continued.*

Dry bulb temper-ature	Wet bulb temperature																				
	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
92	11	13	15	17	19	21	23	25	28	30	32	35	37	40	42	45	48	50	53	56	59
93	10	12	14	16	18	20	22	24	26	28	30	33	36	38	40	43	46	48	51	54	56
94		10	12	14	16	18	20	22	24	27	29	31	34	36	38	41	44	46	48	51	54
95			11	13	15	17	19	21	23	26	28	30	32	34	37	39	42	44	46	49	52
96			10	12	14	16	18	20	22	24	26	28	30	32	35	37	40	42	44	47	50
97				11	13	15	17	19	21	23	25	27	29	31	33	36	38	40	42	45	48
98				10	12	14	16	18	20	22	23	26	28	30	32	34	36	38	40	43	46
99					11	13	14	16	18	20	22	24	26	28	30	32	34	36	39	41	44
100					10	12	13	15	17	19	20	22	24	26	28	30	33	35	37	40	42
101						11	12	14	16	18	19	21	23	25	27	29	31	34	36	38	40
102						10	11	13	14	16	18	20	22	24	26	28	30	32	34	36	38
103							11	12	13	15	17	19	21	23	24	26	28	30	32	34	36
104							10	12	13	14	16	18	19	22	23	25	27	29	31	33	35
105								11	12	14	15	17	18	20	22	24	26	28	30	32	34
106								10	12	13	14	16	18	19	21	23	24	26	28	30	32
107									11	12	13	15	17	18	20	22	23	25	27	28	30
108									10	11	13	14	16	18	19	20	22	24	26	27	29
109										11	12	14	15	17	18	20	21	23	24	26	28
110										10	12	13	14	16	17	19	20	22	23	25	26
111											11	12	13	14	16	18	19	21	22	24	25
112											10	11	12	14	15	17	18	20	21	23	24

air rating. If the outlet is small, the location poor, or the wind direction is wrong, the capacity will be decreased still further.

When a blower is used, the free air rating listed is the normal expectancy through a well-designed installation. As the air resistance is increased, the output of a blower decreases but at a slower rate than that of a fan. Blowers are usually turned at a lower speed than fans and are quieter in operation. There are, however, many shapes of blower blades with different operating characteristics. The shape of blade and the peripheral speed of the tip will determine the static head against which they will operate. The initial cost of a small blower is higher than that of a comparable fan, but this cost difference decreases with the size. In large capacities the blower is the usual choice.

Small, constant speed motors usually turn either 1,140 or 1,750 r.p.m. Speed reduction below these listed can be obtained only on certain types of motors. Fan or blower output capacity will vary directly with the revolutions per minute at which it is operated. The noise and power consumption are less at the lower speeds. Slow speed motors are higher in first cost and more economical in operation. The cheaper high speed motor might, however, be the best choice for occasional use.

The shape of the pads, general dimensions of the box, methods of water distribution, and types of power units will vary with the manufacturer. If the cooler unit will provide the proper temperature and humidity, is of sufficient capacity, and is well constructed, the individual requirements, tastes, and prices may then be considered.

CONSTRUCTION AND OPERATION DETAILS OF THE DIRECT EVAPORATION COOLER

SAMPLE CALCULATIONS FOR A COOLER

An example of a direct evaporation cooler selection is as follows: the house is of brick with a floor area of 800 square feet and 9-foot ceilings. The attic is ventilated, but the ceiling is not insulated. The windows are average in size and number. There is a normal amount of shade in the yard.

The house volume equals 7,200 cubic feet and divided by a factor of three for this type of house gives 2,400 cubic feet per minute as the free air rating of the fan unit. A possible selection might be a 16-inch high pitch fan with a free air capacity of 2,400 to 2,800 cubic feet per minute, directly connected to a 1/6 or 1/8 horsepower 1,750 r.p.m. electric motor. Another selection might be a 16-inch fan of the same capacity when directly connected to a 1,140 r.p.m. electric motor. A third selection might be a small blower, belted to an electric motor. Since a blower is rated on the actual air delivered, a capacity of 1,700 to 1,800 cubic feet per minute would be a comparable size. When a blower is selected, it is imperative that the correct pulley diameters be used, as the blower output is directly proportional to the speed.

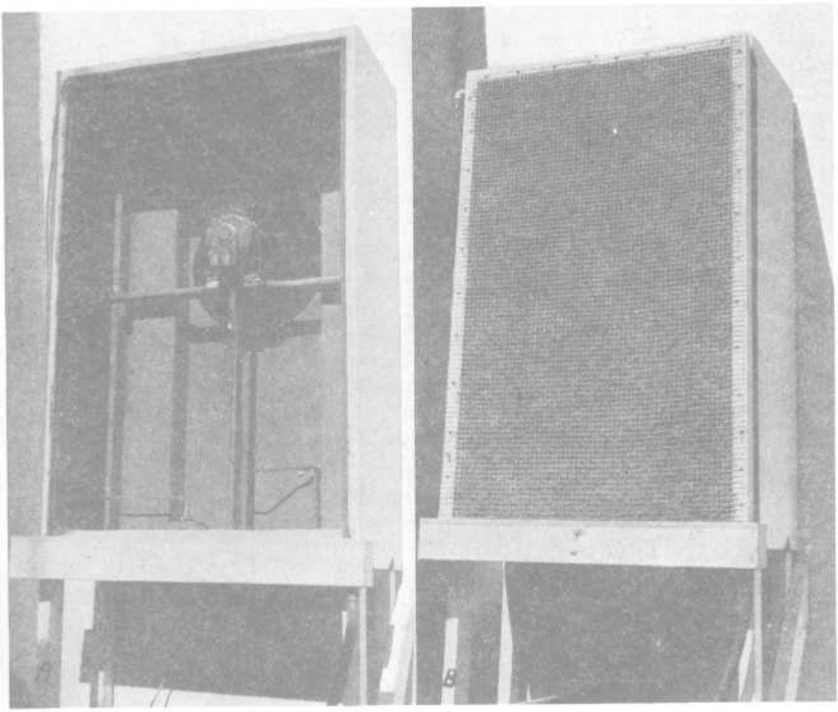

Plate III.—A homemade cooler: *A*, interior of box showing wiring, spacing, motor supports, and box stripping and bracing; *B*, same unit with pad in place.

Some types of motors permit the use of a variable speed control. This provides a flexibility to meet changing weather conditions and is recommended whenever possible. If the unit is not equipped with a speed control by the manufacturer, a competent electrician should be consulted before such a control is installed.

PAD CONSTRUCTION DETAILS

The free air capacity of the fan, approximately 2,500 cubic feet per minute, divided by 250 gives an inside pad area of 10 square feet. This same pad area should be used for the blower selection.

The dimensions of the pad might vary depending on the window size, such as 30 x 48 inches; 36 x 40 inches, etc. It is not essential that the pad dimensions exactly conform to the window size. If the window opening is large enough to accommodate the fan selected or the blower discharge duct, a satisfactory installation can be made.

The pad should be made approximately 2 inches in thickness. Tests and experience have shown that this is enough to provide adequate cooling, and a greater depth usually results in excessive moisture in the air entering the house, difficulty in keeping the excelsior filling from settling, increased danger of souring, and water distribution trouble. The framework of the pad is usually made of 2 x 2-inch wood and should be given two coats of linseed oil or paint to prevent warping and rotting. One side is permanently covered with ½-inch mesh hardware cloth or fine meshed chicken wire. The first is preferable, as it will not stretch, and the frame rigidity is increased. The other side should not be covered until the pad has been packed.

Covering the sides as well as the front of the box with evaporation pads will reduce the size of the front pad and the box required. The total net pad area should be the same in both cases, and care should be taken that all pads are uniform in density and thickness. When side pads are used, they should be located at least 8 inches from the outer edge of the fan. Their addition increases the difficulty of securing uniform water distribution over the pads and complicates box construction. Long, narrow side pads are not recommended. When odd shaped or multiple pads are used, it is particularly important that the cooler suitability should be checked with a humidity indicator or wet bulb and dry bulb thermometers.

WATER SUPPLY AND DISPOSAL

The distribution pipe is located at the top of the pad. A satisfactory one can be made from ½-inch copper tubing closed at one end and fitted with a reducer and threaded tubing connection at the other. Holes, 1/16 inch in diameter and 1 inch apart, should be drilled in a line along one side. The holes should be turned up to aid water distribution. The supply pipe should be very loosely wrapped with wool cloth or lightweight felt. A cloth sleeve, somewhat larger in diameter than the pipe, is sometimes used instead of wrappings. In either case the covering should be very porous and should not be fitted tight enough to restrict the flow of water. The supply pipe should be checked for level when the cooler is installed.

The water line should be 1/4 or 5/16-inch copper tubing, and a needle type valve should be installed in it for adjustment purposes. It is desirable to place the needle valve control handle on the inside panel of the cooler. This permits starting, stopping, and adjusting the cooler operation from the inside of the house. A needle valve, such as is used in automobile gasoline lines, has proved satisfactory in use. When a recirculation pump is used, a float level valve in the drip trough replaces the needle valve. No valve of any type should ever be placed between the pump and the pad distribution pipe, and no water adjustment is necessary when starting or stopping the cooler. It is also impossible to adjust the amount of water supplied to the pad by a recirculation pump.

The drip trough is constructed of lightweight galvanized iron This trough is 2 inches longer than the outside dimension of the pad, 3½ inches wide, and 4 inches deep. A drip apron 4 inches wide and the full inside width of the box in length serves as one edge of the trough and extends back into the box on a 30 degree angle. This apron catches the side drip of the pad and returns the water to the trough. A hose connection should be soldered into the bottom of the trough for the waste water drain, if a recirculation pump is not used.

When the disposal of waste water is a serious problem, the installation of a recirculation pump is recommended. The present quotation on a recirculation pump, installed with sump and fittings, is approximately $20.

PACKING THE PAD

The pad frame should be placed open side up on trestles, with an electric light underneath, and if it is 10 square feet in area and 2 inches thick, it should be carefully packed with 1½ pounds of cottonwood or aspen excelsior. The excelsior should be carefully pulled apart before packing, and all snarls should be rejected. Probably 2 pounds should be purchased, and the best 1½ pounds should be used. The light underneath will show any dense spots or voids in packing. These should be eliminated. Extreme care should be taken that the packing is placed in a uniform manner. Poor packing results in poor water distribution at the lower end of the pad.

The packed pad should not be moved until the hardware cloth or chicken wire cover has been placed on the frame and secured with brass screws and washers. The pad should then be sewed through at 6-inch intervals with either strong string or light copper wire. This keeps the excelsior from shifting inside of the pad. Excelsior ends protruding through the wire covers should be cut off, as each end usually results in a water drip off of the pad.

BOX CONSTRUCTION

The box may be constructed of a wood frame covered with fiberboard or light galvanized iron. Both have advantages and disadvantages. The box frame must support the motor and a fan or blower so that box supports other than the window frame should be provided. The box depth should be 18 to 24 inches. Tests have shown that good air distribution through the pad can be obtained with this depth. The general shape of the box is usually governed by local conditions. Screens should be removed, and steel sash windows should either be removed or have one or more glass panes taken out when the cooler is installed. It is recommended that when fiberboard is used it should receive one coat of shellac and one or two coats of paint or enamel. This will partially waterproof the material and will improve the appearance. The inside panel is exposed to the room and is usually painted a different color from the rest of the box.

The cross members that support the power unit should be rigid enough to reduce vibration to a minimum yet offer as little air resistance as possible. Small steel angles or hardwood have proved satisfactory. The entire power unit should be cushioned on soft rubber, and all hold-down bolts should be insulated from the supports with the same material. Small rubber tubing may be used to cover the body of the bolts.

Sponge rubber strips, ½ inch square and gummed on one side, should be placed between the pad frame and the box. Small drainage slots should be left at the bottom corners. These strips act as an air seal and water stop between the box and the pad. Strips of the same material may be placed between the box and the window frame or wall for the same purpose. They will also tend to reduce vibration noise.

Bolts and screws should be used whenever possible. Nails should never be used to attach the pad to the box. It is recommended that window measurements be made and a complete sketch of the cooler drawn before any material is purchased or construction started. This procedure will eliminate most of the mistakes and will simplify construction.

RECOMMENDATIONS FOR COOLER INSTALLATION AND OPERATION

The following recommendations are made for box cooler installation and operation:

1. Sketch a floor plan of the house and study the way air will be circulated for different cooler locations. Remember that air flow and water flow are very similar.
2. Do not plan to cool an entire large house with a small unit. Such a unit may be used to cool one or two rooms, but be sure that the air does not enter the rest of the house.
3. Check the selected cooler location for window size and water and electrical connections.
4. Place the cooler box in position and check the water supply pipe for level. Make any necessary adjustment before the box is permanently secured in place.
5. Do not install the power unit until the box has been permanently fastened in place. Check the fan or blower position with regard to the opening in the inside panel. Be sure that all electrical connections are securely made and insulated with tape.
6. The water connections may now be made and the pad secured in place. Turn on the water supply valve, and check for water leakage and water distribution over the pad. Minor distribution difficulties may be corrected by slightly shifting the excelsior in the pad with an ice pick or piece of wire.
7. The cooler is now ready to operate. Open a door or window and start the power unit. Try various doors and windows as a discharge outlet, to secure the best air circulation through the

house. It is often desirable to shift the outlet location for changes in wind direction and house usage. Split circulation may be obtained by using two outlets. Remember, however, that the total discharge opening area must be equal to that of one window.

8. After the cooler has been operated long enough to stabilize conditions inside of the house, it may be checked for suitability as outlined in the section on direct evaporation coolers. It is recommended that the cooler suitability check be made when the outside temperature is high.

9. Heavy masonry walls act as storage reservoirs for heat or cold. The unit should, therefore, be started about 2 hours before it is actually needed.

10. The power unit should never be started until the pad has been thoroughly wetted. If the unit is started with a dry pad, the accumulated dust and pollen on the pad will be brought into the house. It is advisable to flush the pad once a week or after a dust storm. A hose spray may be used if it is directed at an angle to the pad.

11. Once the pad is soaked, the supply valve should be regulated so that the pad is kept wet all over with the minimum amount of waste water.

12. If the pad is allowed to dry completely once a week, it probably will not sour. Once the pad is sour, it is advisable to remove all of the excelsior and repack with new material. It has been reported that when the sour condition is not too extreme, it may be corrected by the following procedure. Flush the pad with water; then pour 1 pint of a solution (one half water and one half Chlorox, Purex, or a similar compound) along the supply pipe and allow the pad to stand for 15 minutes before again flushing. If this procedure does not sweeten the pad, it must be repacked.

13. Inspect the cooler at frequent intervals for shifting of the excelsior in the pad and stoppage of the waste pipe by refuse and dirt.

14. Oil the motor at regular intervals with a good grade of oil. Small amounts of oil at frequent intervals are better than larger amounts at long intervals.

15. It is recommended that the windows and doors be opened if the cooler unit is stopped for the night, unless dust is a problem.

16. A cooler operated during a dust storm, with the discharge outlet partly closed, will keep most of the dust out of the house.

17. Direct evaporation coolers offer some relief from dust and pollen to persons suffering from hay fever. They are not recommended for persons suffering from rheumatism and arthritis. In doubtful cases consult your physician before installing one.

18. The operating cost of a direct evaporation cooler for a four or five room house should be approximately 1 cent per hour. For the same amount of cooling this is the least expensive type on the market. It is the most popular type of home cooler in the Southwest, and the number of installations is rapidly increasing.