



# FACT SHEET

## Planning a Home Greenhouse

Fact Sheet 645

David S. Ross  
Extension agricultural engineer  
Department of Agricultural Engineering

What should a gardener consider when planning to build a small hobby greenhouse? What materials should be used to build it? Does it need heating and cooling? Where can it be placed on the property? There are many considerations, and careful planning is important before a project is started.

Building a home greenhouse does not need to be expensive or timeconsuming. It can be small and simple, with a minimum investment in materials and equipment, or it can be a fully equipped, fancy, automated conservatory. The final choice of the type of greenhouse will depend on the growing space desired, home architecture, available sites, and costs. The greenhouse must, however, provide the proper environment for growing plants.

Regardless of the size and type of greenhouse you choose, consider how much time you have to manage the system. Do not be too ambitious; some new greenhouse owners find they do not have as much time as they thought. On the other hand, it is a misconception that greenhouses require constant attention. The environment can be maintained with minimal upkeep using automatic controls, which operate the heating, ventilation, watering, humidity, and artificial lighting systems when no one is home. A hobbyist should invest in automatic controls and start with easy-to-care-for plants. Sometimes the hobby grows into a business, so give some thought to the possibility of expanding your greenhouse in the future.

Constructing the greenhouse yourself can make the project more enjoyable and less expensive if you are handy with tools. Prefabricated greenhouses can be pur-

chased, or they can be built of simple frames. However, only qualified electricians and plumbers should install the automatic systems.

### Location

The greenhouse should be located where it gets maximum sunlight. The first choice of location is the south or southeast side of a building or shade trees. Sunlight all day is best, but morning sunlight on the east side is sufficient for plants. An east side location captures the most November to February sunlight. The next best sites are southwest and west of major structures, where plants receive sunlight later in the day. North of major structures is the least desirable location and is good only for plants that require little light. Morning sunlight is most desirable because it allows the plant's food production process to begin early; thus, growth is maximized.

Deciduous trees, such as maple and oak, can effectively shade the greenhouse from the intense late afternoon summer sun; however, they should not shade the greenhouse in the morning. Deciduous trees also allow maximum exposure to the winter sun because they shed their leaves in the fall. Evergreen trees that have foliage year round should not be located where they will shade the greenhouse because they will block the less intense winter sun. You should aim to maximize winter sun exposure, particularly if the greenhouse is used all year. Remember that the sun is lower in the southern sky in winter causing long shadows to be cast by buildings and evergreen trees (Figure 1).

Good drainage is another requirement for the site. When necessary, build the greenhouse above the sur-

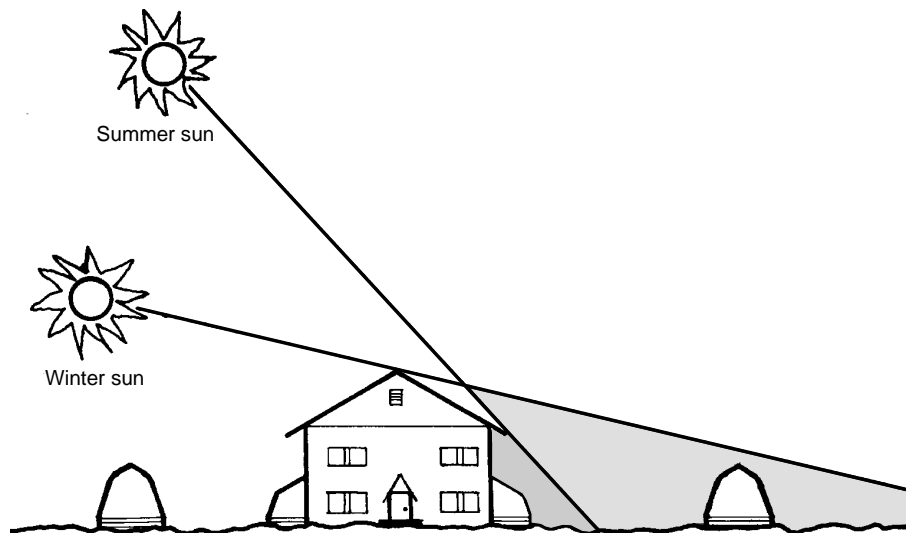


Figure 1. Select location carefully. Note where the shade line occurs in both the winter and summer.

rounding ground so rainwater and irrigation water will drain away. Other site considerations include the light requirements of the plants to be grown; locations of sources of heat, water, and electricity; and shelter from winter wind. Access to the greenhouse should be convenient for both people and utilities. A workplace for potting plants and a storage area for supplies should be nearby.

## Types of Greenhouses

A home greenhouse can be attached to a house or garage, or it can be a freestanding structure. The chosen site and personal preference can dictate the choices to be considered. An attached greenhouse can be a half greenhouse, a full-size structure, or an extended window structure. There are advantages and disadvantages to each type.

### Attached Greenhouses

**Lean-to.** A lean-to greenhouse is a half greenhouse, split along the peak of the roof, or ridge line (Figure 2). Lean-to's are useful where space is limited to a width of approximately 7 to 12 feet, and they are the least expensive structures. The ridge of the lean-to is attached to a building using one side and an existing doorway, if available. Lean-to's are close to available electricity, water, and heat. The disadvantages include some limitations on space, sunlight, ventilation, and temperature control. The height of the supporting wall limits the potential size of the lean-to. The wider the lean-to, the higher the supporting wall must be. Temperature control is more difficult because the wall that the greenhouse is built on may collect the sun's heat while the translucent cover of the greenhouse may lose heat

rapidly. The lean-to should face the best direction for adequate sun exposure. Finally, consider the location of windows and doors on the supporting structure and that snow, ice, or heavy rain might slide off the roof of the house onto the structure.

**Even-span.** An even-span is a full-size structure that has one gable end attached to another building (Figure 2). It is usually the largest and most costly option, but it provides more usable space and can be lengthened. The even-span has a better shape than a lean-to for air circulation to maintain uniform temperatures during the winter heating season. An even-span can accommodate two to three benches for growing crops.

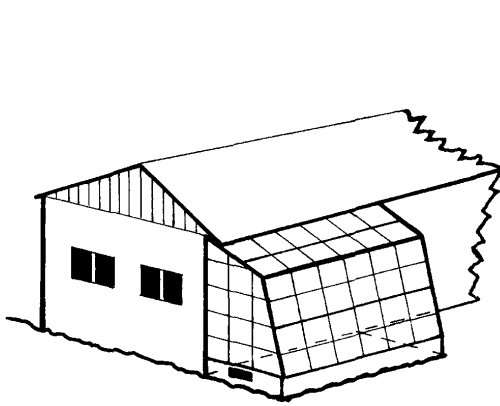
**Window-mounted.** A window-mounted greenhouse can be attached on the south or east side of a house. This glass enclosure gives space for conveniently growing a few plants at relatively low cost (Figure 2). The special window extends outward from the house a foot or so and can contain two or three shelves.

### Freestanding Structures

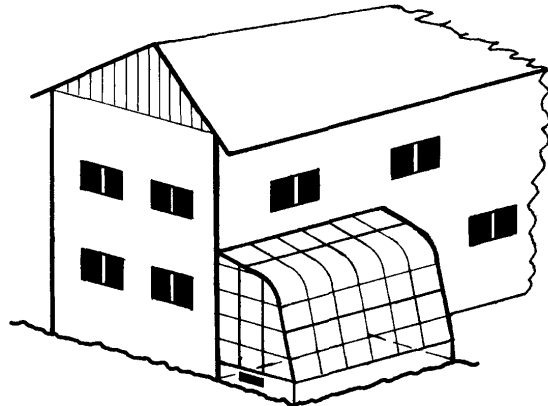
Freestanding greenhouses are separate structures; they can be set apart from other buildings to get more sun and can be made as large or small as desired (Figure 2). A separate heating system is needed, and electricity and water must be installed.

The lowest cost per square foot of growing space is generally available in a freestanding or even-span greenhouse that is 17 to 18 feet wide. It can house a central bench, two side benches, and two walkways. The ratio of cost to the usable growing space is good.

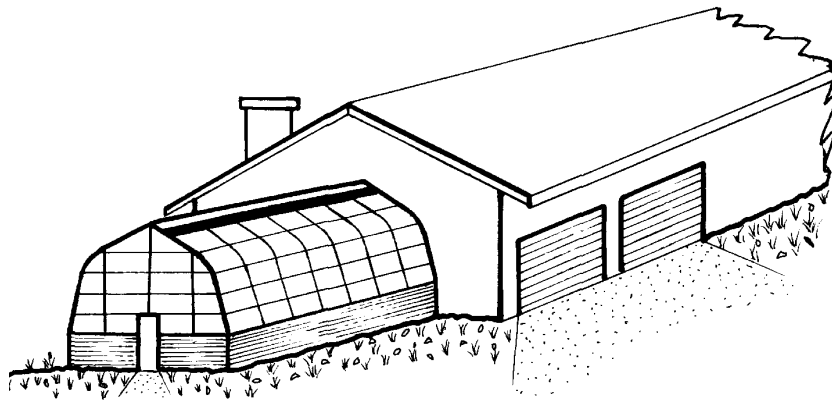
When deciding on the type of structure, be sure to plan for adequate bench space, storage space, and room for future expansion. Large greenhouses are easier to



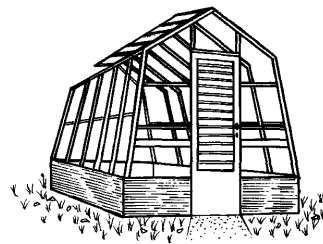
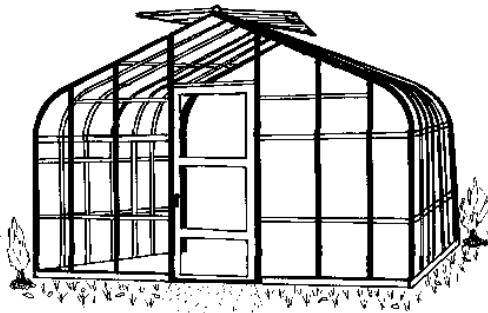
A straight-eave lean-to greenhouse can fit under the roof of a single-story house.



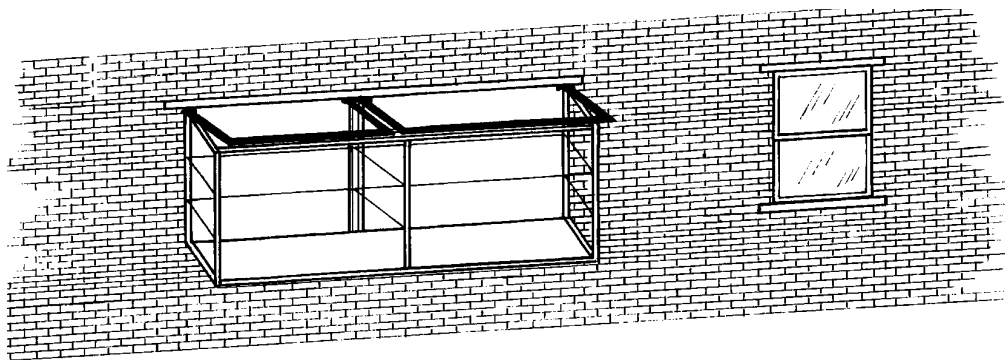
This is an example of a curved-eave lean-to built on a two-story house.



An even-span attached to a garage allows a larger greenhouse in a limited space.



Free-standing greenhouses allow more location choices and can be larger than attached greenhouses.



A window-mounted unit extends a house's growing space.

Figure 2. Different types of greenhouses allow many options.

manage because temperatures in small greenhouses fluctuate more rapidly. Small greenhouses have a large exposed area through which heat is lost or gained, and the air volume inside is relatively small; therefore, the air temperature changes quickly in a small greenhouse. Suggested minimum sizes are 6 feet wide by 10 feet long for a lean-to and 8 or 10 feet wide by 12 feet long for an even-span or freestanding greenhouse.

## Structural Materials

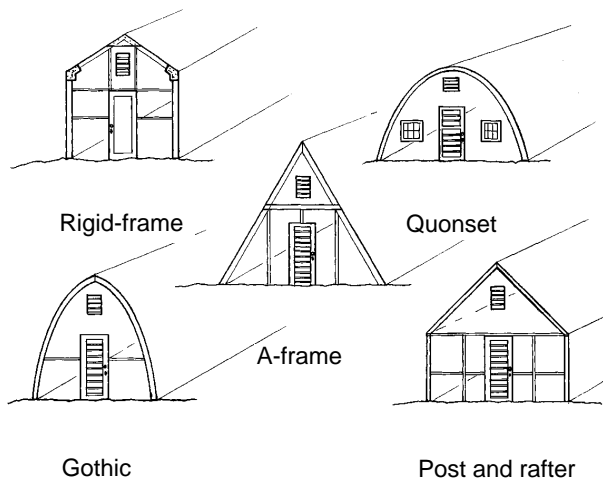
A good selection of commercial greenhouse frames and framing materials is available. The frames are made of wood, galvanized steel, or aluminum. Build-it-yourself greenhouse plans are usually for structures with wood or metal pipe frames. Plastic pipe materials generally are inadequate to meet snow and wind load requirements. Frames can be covered with glass, rigid fiberglass, rigid double-wall plastics, or plastic film. All have advantages and disadvantages. Each of these materials should be considered—it pays to shop around for ideas.

### Frames

Greenhouse frames range from simple to complex, depending on the imagination of the designer and engineering requirements. The following are several common frames (Figure 3).

**Quonset.** The quonset is a simple and efficient construction with an electrical conduit or galvanized steel pipe frame. The frame is circular and usually covered with plastic sheeting. Quonset sidewall height is low, which restricts storage space and headroom.

**Gothic.** The gothic frame construction is similar to that of the quonset but it has a gothic shape (Figure 3). Wooden arches may be used and joined at the ridge. The gothic shape allows more headroom at the sidewall than does the quonset.



**Figure 3.** Greenhouses can have a variety of different structural frames.

**Rigid-frame.** The rigid-frame structure has vertical sidewalls and rafters for a clear-span construction: There are no columns or trusses to support the roof. Glued or nailed plywood gussets connect the sidewall supports to the rafters to make one rigid frame. The conventional gable roof and sidewalls allow maximum interior space and air circulation. A good foundation is required to support the lateral load on the sidewalls.

**Post and rafter and A-frame.** The post and rafter is a simple construction of an embedded post and rafter, but it requires more wood or metal than some other designs. Strong sidewall posts and deep post embedment are required to withstand outward rafter forces and wind pressures. Like the rigid frame, the post and rafter design allows more space along the sidewalls and efficient air circulation. The A-frame is similar to the post and rafter construction except that a collar beam ties the upper parts of the rafters together.

### Coverings

Greenhouse coverings include long-life glass, fiberglass, rigid double-wall plastics, and film plastics with 1- to 3-year lifespans. The type of frame and cover must be matched correctly.

**Glass.** Glass is the traditional covering. It has a pleasing appearance, is inexpensive to maintain, and has a high degree of permanency. An aluminum frame with a glass covering provides a maintenance-free, weather-tight structure that minimizes heat costs and retains humidity. Glass is available in many forms that would be suitable with almost any style or architecture. Tempered glass is frequently used because it is two or three times stronger than regular glass. Small prefabricated glass greenhouses are available for do-it-yourself installation, but most should be built by the manufacturer because they can be difficult to construct.

The disadvantages of glass are that it is easily broken, is initially expensive to build, and requires much better frame construction than fiberglass or plastic. A good foundation is required, and the frames must be strong and must fit well together to support heavy, rigid glass.

**Fiberglass.** Fiberglass is lightweight, strong, and practically hailproof. A good grade of fiberglass should be used because poor grades discolor and reduce light penetration. Use only clear, transparent, or translucent grades for greenhouse construction. Tedlar-coated fiberglass lasts 15 to 20 years. The resin covering the glass fibers will eventually wear off, allowing dirt to be retained by exposed fibers. A new coat of resin is needed after 10 to 15 years. Light penetration is initially as good as glass but can drop off considerably over time with poor grades of fiberglass.

## Environmental Systems

Greenhouses provide a shelter in which a suitable environment is maintained for plants. Solar energy from the sun provides sunlight and some heat, but you must provide a system to regulate the environment in your greenhouse. This is done by using heaters, fans, thermostats, and other equipment.

### Heating

The heating requirements of a greenhouse depend on the desired temperature for the plants grown, the location and construction of the greenhouse, and the total outside exposed area of the structure. As much as 25 percent of the daily heat requirement may come from the sun, but a lightly insulated greenhouse structure will need a great deal of heat on a cold winter night. The heating system must be adequate to maintain the desired day or night temperature.

Usually the home heating system is not adequate to heat an adjacent greenhouse. A 220-volt circuit electric heater, however, is clean, efficient, and works well. Small gas or oil heaters designed to be installed through a masonry wall also work well.

Solar-heated greenhouses were popular briefly during the energy crisis, but they did not prove to be economical to use. Separate solar collection and storage systems are large and require much space. However, greenhouse owners can experiment with heat-collecting methods to reduce fossil-fuel consumption. One method is to paint containers black to attract heat, and fill them with water to retain it. However, because the greenhouse air temperature must be kept at plant-growing temperatures, the greenhouse itself is not a good solar-heat collector.

Heating systems can be fueled by electricity, gas, oil, or wood. The heat can be distributed by forced hot air, radiant heat, hot water, or steam. The choice of a heating system and fuel depends on what is locally available, the production requirements of the plants, cost, and individual choice. For safety purposes, and to prevent harmful gases from contacting plants, all gas, oil, and woodburning systems must be properly vented to the outside. Use fresh-air vents to supply oxygen for burners for complete combustion. Safety controls, such as safety pilots and a gas shutoff switch, should be used as required. Portable kerosene heaters used in homes are risky because some plants are sensitive to gases formed when the fuel is burned.

**Calculating heating system capacity.** Heating systems are rated in British thermal units (Btu) per hour (h). The Btu capacity of the heating system,  $Q$ , can be estimated easily using three factors:

**Double-wall plastic.** Rigid double-layer plastic sheets of acrylic or polycarbonate are available to give long-life, heat-saving covers. These covers have two layers of rigid plastic separated by webs. The double-layer material retains more heat, so energy savings of 30 percent are common. The acrylic is a long-life, nonyellowing material; the polycarbonate normally yellows faster, but usually is protected by a UV-inhibitor coating on the exposed surface. Both materials carry warranties for 10 years on their light transmission qualities. Both can be used on curved surfaces; the polycarbonate material can be curved the most. As a general rule, each layer reduces light by about 10 percent. About 80 percent of the light filters through double-layer plastic, compared with 90 percent for glass.

**Film plastic.** Film-plastic coverings are available in several grades of quality and several different materials. Generally, these are replaced more frequently than other covers. Structural costs are very low because the frame can be lighter and plastic film is inexpensive. Light transmission of these film-plastic coverings is comparable to glass. The films are made of polyethylene (PE), polyvinyl chloride (PVC), copolymers, and other materials. A utility grade of PE that will last about a year is available at local hardware stores. Commercial greenhouse grade PE has ultraviolet inhibitors in it to protect against ultraviolet rays; it lasts 12 to 18 months. Copolymers last 2 to 3 years. New additives have allowed the manufacture of film plastics that block and reflect radiated heat back into the greenhouse, as does glass, which helps reduce heating costs. PVC or vinyl film costs two to five times as much as PE but lasts as long as 5 years. However, it is available only in sheets 4 to 6 feet wide. It attracts dust from the air, so it must be washed occasionally.

## Foundations and Floors

Permanent foundations should be provided for glass, fiberglass, or the double-layer rigid-plastic sheet materials. The manufacturer should provide plans for the foundation construction. Most home greenhouses require a poured concrete foundation similar to those in residential houses. Quonset greenhouses with pipe frames and a plastic cover use posts driven into the ground.

Permanent flooring is not recommended because it may stay wet and slippery from soil mix media. A concrete, gravel, or stone walkway 24 to 36 inches wide can be built for easy access to the plants. The rest of the floor should be covered by several inches of gravel for drainage of excess water. Water also can be sprayed on the gravel to produce humidity in the greenhouse.

1.  $A$  is the total exposed (outside) area of the greenhouse sides, ends, and roof in square feet ( $\text{ft}^2$ ). On a quonset, the sides and roof are one unit; measure the length of the curved rafter (ground to ground) and multiply by the length of the house. The curved end area is  $2$  (ends)  $\times \frac{2}{3} \times \text{height} \times \text{width}$ . Add the sum of the first calculation with that of the second.

2.  $u$  is the heat loss factor that quantifies the rate at which heat energy flows out of the greenhouse. For example, a single cover of plastic or glass has a value of  $1.2 \text{ Btu/h} \times \text{ft}^2 \times ^\circ\text{F}$  (heat loss in Btu's per hour per each square foot of area per degree in Fahrenheit); a double-layer cover has a value of  $0.8 \text{ Btu/h} \times \text{ft}^2 \times ^\circ\text{F}$ . A table of  $u$  values is provided in Extension Bulletin 351 **Greenhouse Heating, Circulation, and Ventilation Systems**. The values allow for some air infiltration but are based on the assumption that the greenhouse is fairly airtight.

3.  $(T_i - T_o)$  is the maximum temperature difference between the lowest outside temperature ( $T_o$ ) in your region and the temperature to be maintained in the greenhouse ( $T_i$ ). For example, the maximum difference will usually occur in the early morning with the occurrence of a  $0^\circ\text{F}$  to  $-5^\circ\text{F}$  outside temperature while a  $60^\circ\text{F}$  inside temperature is maintained. Plan for a temperature differential of  $60$  to  $65^\circ\text{F}$ . The following equation summarizes this description:  $Q = A \times u \times (T_i - T_o)$ .

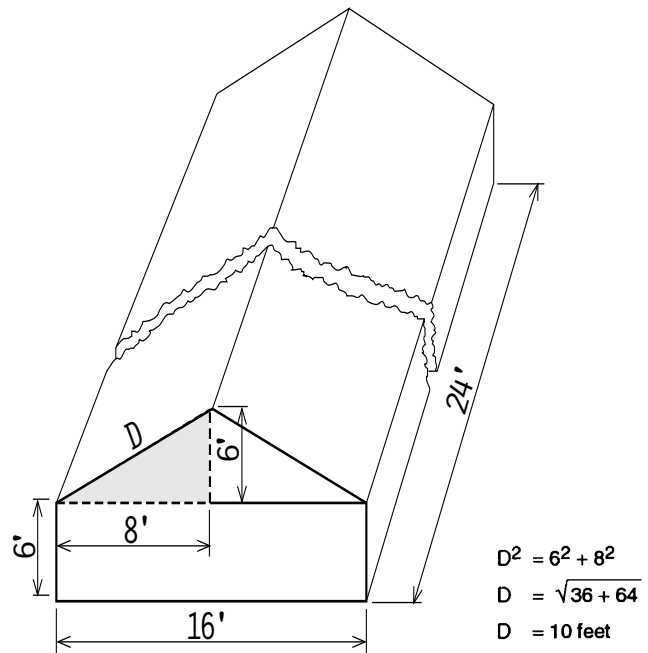
**Example.** If a rigid-frame or post and rafter freestanding greenhouse  $16$  feet wide by  $24$  feet long,  $12$  feet high at the ridge, with  $6$  feet side-walls, is covered with single-layer glass from the ground to the ridge, what size gas heater would be needed to maintain  $60^\circ\text{F}$  on the coldest winter night ( $0^\circ\text{F}$ )? Calculate the total outside area (Figure 4):

two long sides	$2 \times 6 \text{ ft} \times 24 \text{ ft} = 288 \text{ ft}^2$
two ends	$2 \times 6 \text{ ft} \times 16 \text{ ft} = 192 \text{ ft}^2$
roof	$2 \times 10 \text{ ft} \times 24 \text{ ft} = 480 \text{ ft}^2$
gable ends	$2 \times 6 \text{ ft} \times 8 \text{ ft} = 96 \text{ ft}^2$
	$A = 1,056 \text{ ft}^2$

Select the proper heat loss factor,  $u = 1.2 \text{ Btu/h} \times \text{ft}^2 \times ^\circ\text{F}$ . The temperature differential is  $60^\circ\text{F} - 0^\circ\text{F} = 60^\circ\text{F}$ .

$Q = 1,056 \times 1.2 \times 60 = 76,032 \text{ Btu/h}$  (furnace output).

Although this is a relatively small greenhouse, the furnace output is equivalent to that in a small residence such as a townhouse. The actual furnace rated capacity takes into account the efficiency of the furnace and is called the furnace input fuel rating.



**Figure 4.** Use the greenhouse's dimensions to determine the necessary heating system capacity.

This discussion is a bit technical, but these factors must be considered when choosing a greenhouse. Note the effect of each value on the outcome. When different materials are used in the construction of the walls or roof, heat loss must be calculated for each. For electrical heating, convert Btu/h to kilowatts by dividing Btu/h by 3,413. If a wood, gas, or oil burner is located in the greenhouse, a fresh-air inlet is recommended to maintain an oxygen supply to the burner. Place a piece of plastic pipe through the outside cover to ensure that oxygen gets to the burner combustion air intake. The inlet pipe should be the diameter of the flue pipe. A piece of plastic pipe about the size of the flue pipe through the outside cover to a point near the burner combustion air intake would be adequate. This ensures adequate air for combustion in an airtight greenhouse. Unvented heaters (no chimney) using propane gas or kerosene are not recommended.

## Air Circulation

Installing circulating fans in your greenhouse is a good investment. During the winter when the greenhouse is heated, you need to maintain air circulation so that temperatures remain uniform throughout the greenhouse. Without air-mixing fans, the warm air rises to the top and cool air settles around the plants on the floor.

Small fans with a cubic-foot-per-minute ( $\text{ft}^3/\text{min}$ ) air-moving capacity equal to one quarter of the air volume of the greenhouse are sufficient. For small greenhouses (less than 60 feet long), place the fans in diagonally opposite corners but out from the ends and sides. The goal is to develop a circular (oval) pattern of air movement. Operate the fans continuously during the winter. Turn these fans off during the summer when the greenhouse will need to be ventilated.

The fan in a forced-air heating system can sometimes be used to provide continuous air circulation. The fan must be wired to an on/off switch so it can run continuously, separate from the thermostatically controlled burner.

## Ventilation

Ventilation is the exchange of inside air for outside air to control temperature, remove moisture, or replenish carbon dioxide ( $\text{CO}_2$ ). Several ventilation systems can be used. Be careful when mixing parts of two systems.

Natural ventilation uses roof vents on the ridge line with side inlet vents (louvers). Warm air rises on convective currents to escape through the top, drawing cool air in through the sides.

Mechanical ventilation uses an exhaust fan to move air out one end of the greenhouse while outside air enters the other end through motorized inlet louvers. Exhaust fans should be sized to exchange the total volume of air in the greenhouse each minute.

The total volume of air in a medium to large greenhouse can be estimated by multiplying the floor area times 8.0 (the average height of a greenhouse). A small greenhouse (less than 5,000  $\text{ft}^3$  in air volume) should have an exhaust-fan capacity estimated by multiplying the floor area by 12.

The capacity of the exhaust fan should be selected at one-eighth of an inch static water pressure. The static pressure rating accounts for air resistance through the louvers, fans, and greenhouse and is usually shown in the fan selection chart.

Ventilation requirements vary with the weather and season. One must decide how much the greenhouse will be used. In summer, 1 to 1½ air volume changes per minute are needed. Small greenhouses need the larger amount. In winter, 20 to 30 percent of one air volume exchange per minute is sufficient for mixing in cool air without chilling the plants.

One single-speed fan cannot meet this criteria. Two single-speed fans are better. A combination of a single-speed fan and a two-speed fan allows three ventilation rates that best satisfy year round needs. A single-stage

and a two-stage thermostat are needed to control the operation.

A two-speed motor on low speed delivers about 70 percent of its full capacity. If the two fans have the same capacity rating, then the low-speed fan supplies about 35 percent of the combined total. This rate of ventilation is reasonable for the winter. In spring, the fan operates on high speed. In summer, both fans operate on high speed.

Refer to the earlier example of a small greenhouse. A 16-foot wide by 24-foot long house would need an estimated  $\text{ft}^3$  per minute (cubic feet per minute; CFM) total capacity; that is,  $16 \times 24 \times 12$   $\text{ft}^3$  per minute. For use all year, select two fans to deliver 2,300  $\text{ft}^3$  per minute each, one fan to have two speeds so that the low-speed rating is about 1,600  $\text{ft}^3$  per minute and the high speed is 2,300  $\text{ft}^3$  per minute. Adding the second fan, the third ventilation rate is the sum of both fans on high speed, or 4,600  $\text{ft}^3$  per minute.

Some glass greenhouses are sold with a manual ridge vent, even when a mechanical system is specified. The manual system can be a backup system, but it does not take the place of a motorized louver. Do not take shortcuts in developing an automatic control system.

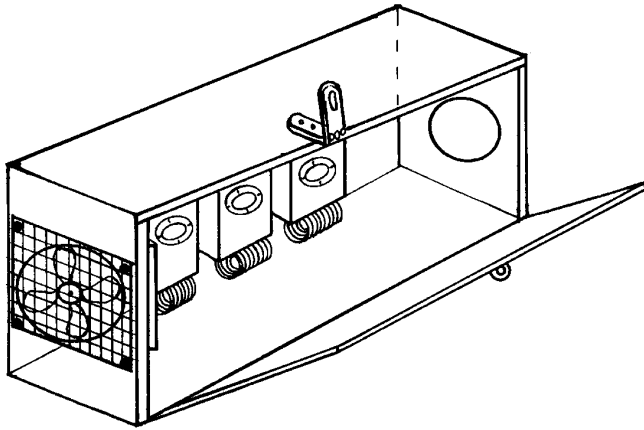
## Cooling

Air movement by ventilation alone may not be adequate in the middle of the summer; the air temperature may need to be lowered with evaporative cooling. Also, the light intensity may be too great for the plants. During the summer, evaporative cooling, shade cloth, or paint may be necessary. Shade materials include roll-up screens of wood or aluminum, vinyl netting, and paint.

Small package evaporative coolers have a fan and evaporative pad in one box to evaporate water, which cools air and increases humidity. Heat is removed from the air to change water from liquid to a vapor. Moist, cooler air enters the greenhouse while heated air passes out through roof vents or exhaust louvers. The evaporative cooler works best when the humidity of the outside air is low. The system can be used without water evaporation to provide the ventilation of the greenhouse. Size the evaporative cooler capacity at 1.0 to 1.5 times the volume of the greenhouse. An alternative system, used in commercial greenhouses, places the pads on the air inlets at one end of the greenhouse and uses the exhaust fans at the other end of the greenhouse to pull the air through the house.

## Controllers/Automation

Automatic control is essential to maintain a reasonable environment in the greenhouse. On a winter day with varying amounts of sunlight and clouds, the tem-



**Figure 5.** Thermostats in the middle of the greenhouse in a shaded, white, and aspirated box

perature can fluctuate greatly; close supervision would be required if a manual ventilation system were in use. Therefore, unless close monitoring is possible, both hobbyists and commercial operators should have automated systems with thermostats or other sensors.

Thermostats can be used to control individual units, or a central controller with one temperature sensor can be used. In either case, the sensor or sensors should be shaded from the sun, located about plant height away from the sidewalls, and have constant airflow over them. An aspirated box is suggested; the box houses each sensor and has a small fan that moves greenhouse air through the box and over the sensor (Figure 5). The box should be painted white so it will reflect solar heat and allow accurate readings of the air temperature.

## Watering Systems

A water supply is essential. Hand watering is acceptable for most greenhouse crops if someone is available when the task needs to be done; however, many hobbyists work away from home during the day. A variety of automatic watering systems is available to help to do the task over short periods of time. Bear in mind, the

small greenhouse is likely to have a variety of plant materials, containers, and soil mixes that need different amounts of water.

Time clocks or mechanical evaporation sensors can be used to control automatic watering systems. Mist sprays can be used to create humidity or to moisten seedlings. Watering kits can be obtained to water plants in flats, benches, or pots.

## CO<sub>2</sub> and Light

Carbon dioxide (CO<sub>2</sub>) and light are essential for plant growth. As the sun rises in the morning to provide light, the plants begin to produce food energy (photosynthesis). The level of CO<sub>2</sub> drops in the greenhouse as it is used by the plants. Ventilation replenishes the CO<sub>2</sub> in the greenhouse. Because CO<sub>2</sub> and light complement each other, electric lighting combined with CO<sub>2</sub> injection are used to increase yields of vegetable and flowering crops. Bottled CO<sub>2</sub>, dry ice, and combustion of sulfur-free fuels can be used as CO<sub>2</sub> sources. Commercial greenhouses use such methods.

## Alternative Growing Structures

A greenhouse is not always needed for growing plants. Plants can be germinated in one's home in a warm place under fluorescent lamps. The lamps must be close together and not far above the plants.

A cold frame or hotbed can be used outdoors to continue the growth of young seedlings until the weather allows planting in a garden. A hotbed is similar to the cold frame, but it has a source of heat to maintain proper temperatures.

## For More Information

For more information on environmental control systems, refer to Extension Bulletin 351 **Greenhouse Heating, Circulation, and Ventilation Systems**. For further discussion of hotbeds and cold frames, see Fact Sheet 633 *Hotbeds and Cold Frames for Starting Annual Plants*, also available from your county Cooperative Extension Service office.