# Heating Greenhouses[1]

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A greenhouse has one purpose: to provide and maintain the environment that will result in optimum crop production or maximum profit. This includes an environment for work efficiency as well as for crop growth. This publication is limited to equipment and methods used to control or maintain desirable temperature and other environmental conditions in a greenhouse during those periods when supplemental heat is required. Obviously there are many ways this can be accomplished from the standpoint of equipment used, types of fuel used, type of construction, and management practices followed. Because each operation usually has some unique characteristics such as types of plants produced, level of quality of production strived for, type(s) of house(s) used and management procedures followed, it is important that all of these factors be considered when selecting and installing a heating system.

## Heating Systems

Greenhouse heating systems will be discussed based on the following methods of distributing the heat, heat source and fuel used.

### Unit Space Heater

Unit space heaters, either floor mounted or supported, are normally fueled with natural or bottled gas or fuel oil and use fans for heat distribution. This system requires a relatively moderate capital investment, is easy to install, and provides for easy expansion of facilities. If unit air heaters are used they should be spaced and directed to blanket the entire area with heated air (See Figure 1).

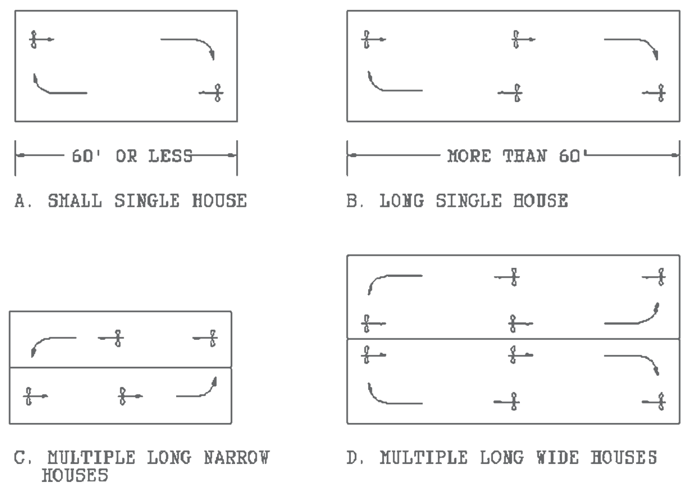


Figure 1. Typical arrangements for fans for horizontal convection air circulation systems.

Something else to consider that is often ignored, either purposely or from a lack of understanding of what consequences might occur, is the use of unvented or improperly vented gas or oil fired units. These units produce carbon dioxide gas, which is necessary for improved plant growth. However, other gases that are harmful to humans (carbon monoxide) and many plants (ethylene, sulphur dioxide and unburned hydrocarbons) are also by-products of combustion. These can cause serious problems if the exhaust gases from unit heaters are not properly vented to the outside (Figure 2) and if adequate intake air is not available for

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combustion. Normal air contains about 300 parts per million of carbon dioxide, while concentrations up to 2000 parts per million have been used in greenhouses. This additional carbon dioxide should come from a commercial carbon dioxide generator (normally using either solid or liquid carbon dioxide), not from combustion. Also, heaters normally operate at night when the plants cannot use the carbon dioxide produced. Another by-product of combustion is water vapor. High nighttime concentrations of carbon dioxide and water vapor in a closed house with a lowered oxygen supply (combustion uses oxygen) are generally considered undesirable from the standpoint of disease control. Test kits are available to measure the levels of carbon dioxide in greenhouses. To assure good air movement to the outside through the vent stack, make sure the vent pipe is of adequate size (check heating unit manufacturer's commendations) and that it extends at least four feet above the highest point of the building (Figure 2). Fresh air intakes sized to accommodate the burner of unit heaters (normally 6 to 8 inches in diameter) are a necessity in tight greenhouses. Also, the proximity of taller buildings or trees that might cause a down draft to greenhouse ventilation stacks or intakes should be avoided.

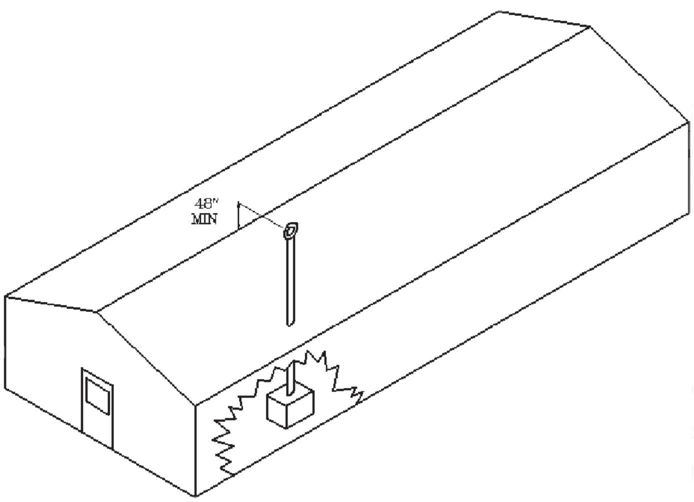



Figure 2. All greenhouse heating units should be vented to the outside. Top of vent sack should be at least 48" above the roof peak.

## Hot Water Systems

Hot water systems utilizing piping that can be perimeter, under benches, or overhead fanforced unit heaters can be used. These require a boiler, valves, and other necessary controls. However, a hot water system is simpler to install and normally requires less maintenance than a steam system. There are slower heating and cooling of pipes, but temperatures are normally more uniform. Hot water systems are mainly used in smaller ranges.

## Steam Heating System

A steam heating system needs a boiler, valves, traps and other controls depending upon the size and type of boiler used. Steam provides rapid heating and cooling of the steam lines and usually less pipe is needed. Lines may be smooth or finned, and about l/3 of the heat should be overhead and about 2/3 along the side walls. Lines can also be arranged under benches or with overhead fan-forced unit heaters. A steam system also allows the use of steam for soil pasteurization. A steam system requires a high initial investment; however, it has a long life expectancy. Steam heating systems are most often used in large ranges as steam can be transported long distances efficiently.

## Unit Radiant Heaters

Unit radiant heaters using gas of the "Salamander" grove heater (return stack) type and which use fuel oil may be used for frost protection (Figure 3). These are not recommended for routine greenhouse heating because they are not thermostatically controlled making temperature control difficult. Also, because they are not vented to the outside of the greenhouse, combustion gases will damage sensitive plant material. They can be used for emergency protection against cold temperatures in southern portions of Florida, but they demand close attention when in operation.

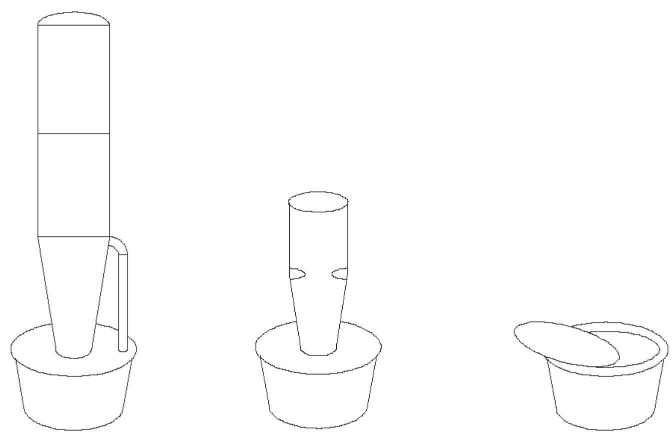


Figure 3. Radiant heaters of these types are not recommended for greenhouse heating.

## Solar Radiant Systems

At present, the initial cost of a quality solar heating system is very high compared to other systems described (Figure 4).

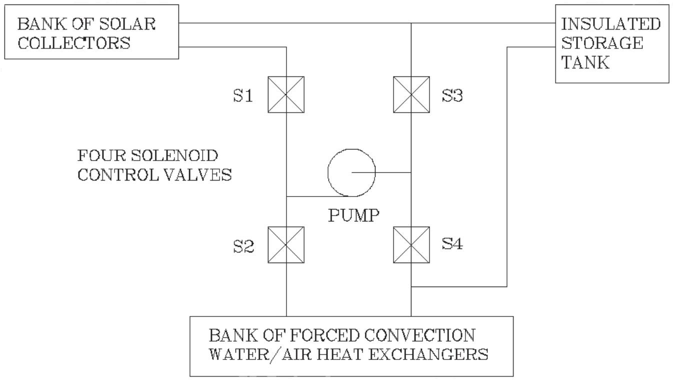



Figure 4. Schematic diagram of a typical greenhouse solar heating system.

## Poly-Tube Systems

Poly-tube or fan-jet systems are frequently used to provide more uniform heat distribution, air movement, and ventilation in greenhouses using any of the above heat source systems. However, they are most frequently installed in conjunction with unit heaters (Figure 5). The velocity of air discharged from openings in the tube should not exceed 1200 to 1800 feet per minute (fpm). The volume of the openings (total) should be 1.5–2.0 times the cross-sectional area of the tube.

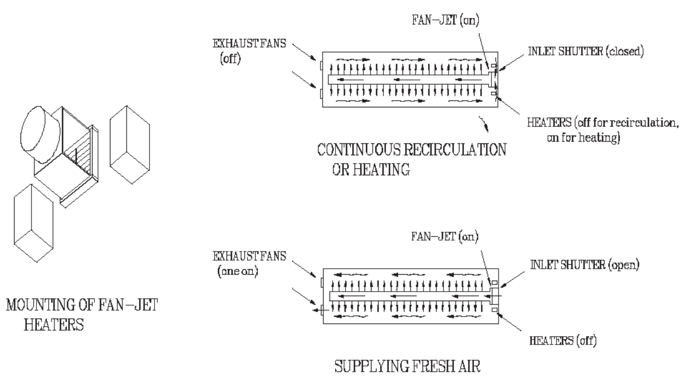



Figure 5. Schematic views of Fan-Jet Poly-Tube Systems.

# Factors to Consider in Selecting a System

As indicated earlier, a dependable source of heat is necessary for temperature control. The best type of system will depend on many factors, several of which have already been mentioned. These factors should be carefully considered before investing in the heating equipment because what is best for one operator may not be best for another.

Before determining the type system to use, it is necessary to calculate the amount of heat that will be required. Remember this should be based on the most adverse conditions that you reasonably expect to encounter. Normally in the central part of Florida, an outside low temperature is 25 to 30°F about 15 to 20°F in north Florida, and around 35°F in south Florida.

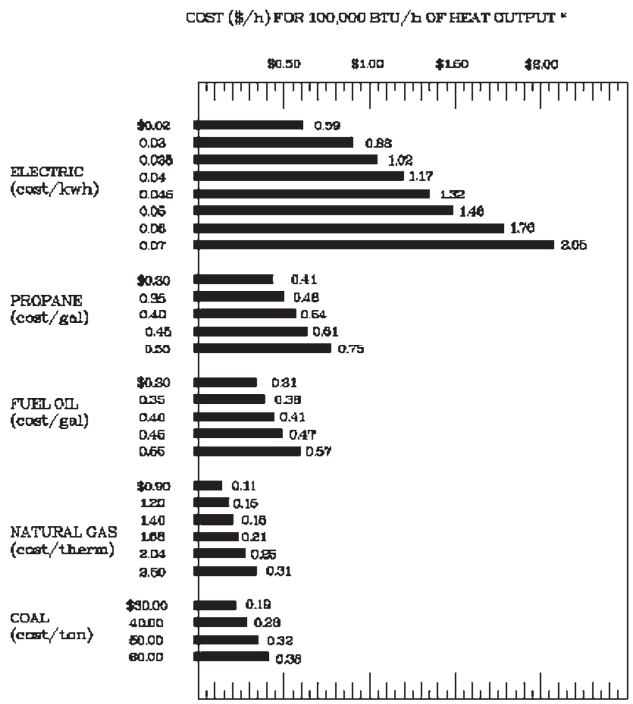
The minimum inside temperature depends on the type of types of plants being grown. Some tropicals cease to grow at 55 to 60°F, and the plants are killed at about 45°F. Decide whether you just want to save the plants from severe injury or if you want normal or near normal growth to continue. Then determine the temperature needed to achieve your objective, subtract the expected minimum adverse temperature for your location, and obtain the differential in °F or which you need to be prepared.

An easy and fairly accurate method for estimating the amount of heat required can be obtained by multiplying the surface area of the greenhouse by the maximum temperature difference to be maintained, and this product times a heat transmission factor that depends on the covering of the greenhouse and is also influenced by quality of construction. A factor of 1.0 to 1.2 is used if the house is covered by a single layer of polyethylene film (PE) or rigid plastic. 1.0 would assume a well built, tight greenhouse, while 1.2 would assume a little less quality construction and more air leakage. The same analogy will be true for the transmission factors used for other materials.

Also, wind velocity affects the transmission factor; the higher the wind velocity, the greater the heat loss. Use a factor of 0.75 to 0. if the house is covered with a double layer of PE film with an air space of at least 3/4" but not more than 4". Use a factor of between 1.1 to 1.4 if the house is glass glazed. Add 10 percent to the values obtained if the house is located in a windy location and there are many leaks for air infiltration. For example, a 30' x 120' gable greenhouse with 6' side walls will have about 5750 square feet of surface area through which heat can move. If this house were covered with rigid plastic and a 40°F temperature difference were to be maintained (65°F at an outside low of 25°F, the heating system would have to supply 5750 x 40 x 1.2 = 276,000 BTU per hour.

If this house were very tightly constructed and fairly large panels were used, and if the house were protected by a wind break of some kind, then you can use a lower heat transmission factor of about 1.0. Then the heating input required would be 5750 x 40 x 1.0 = 230,000 BTU/hr. (It should be noted that the "heat transmission factors" used take into consideration factors such as air infiltration and wind effects, which means that the term as defined herein does not conform to the strict definition of heat transfer coefficient). This BTU/hr figure can be used to determine pipe length in steam and hot water systems or the size of unit heaters. If a central boiler is used, add at least 25 percent to determine boiler size to allow for heat losses in the distribution system. One boiler horsepower equals a heat output of about 33,500 BTU/hr.

Another factor to consider is the efficiency of the heating unit. Most manufacturers of heating equipment show both input and output BTU/hr. Calculations on equipment size must be based on output capacity. The choice of fuel for heating is often a problem of economics, but future availability may be equally or more of a consideration. However, the fuel that will provide a dependable source of heat at the lowest cost is generally the one to use (Figure 6).




* FUEL HEAT VALUES AND COMBUSTION EFFICIENCIES ARE AS FOLLOWS:

| FUEL | ESTIMATED EFFFICIENCY PERCENT | HEAT VALUE (BTU PER UNIT) |
|---|---|---|
| COAL (BITUMINOUS) | 60 | 13,000 BTU/lb |
| NATURAL GAS | 80 | 1,000 BTU/therm |
| PROPANE | 80 | 92,000 BTU/gal |
| FUEL OIL, NO 2 | 70 | 138,000 BTU/gal |
| ELECTRICITY | 100 | 3,413 BTU/kwh |

Figure 6. Comparison of fuel costs for equivalent heat output.

In conclusion, the successful heating of greenhouses is dependent upon correct sizing and installation of the heating system, proper controls and methods of obtaining uniform heat distribution. The type of greenhouse construction, crops to be grown, and temperature levels to be maintained are all important factors to consider in the selection and design of any greenhouse heating system. For these and other reasons, only persons thoroughly familiar with greenhouse heating systems and their application to your specific requirements should be allowed to design and supervise the installation of your heating system.

## Recommendations

In general, the following recommendations should be observed:

1. The heating system should allow for easy expansion of the range in the future, and the system should have sufficient capacity to offset the heat loss from the greenhouse under the most severe conditions. Normally, design for temperatures slightly above minimum 15 to 25 year lows as shown by local weather records.

2. Provide an adequate system of automatic controls or be prepared for extensive manual control during severe weather. The most important control in most heating systems is the thermostat, which is used to control the operation of the heating system. For this reason, the thermostat should be placed at plant level, and shielded from direct rays of the sun, and it should sense "line air." Sensing "line air" is accomplished by placing the thermostat in a small box or enclosure ventilated by a very small capacity fan. Thermostats for greenhouses should be accurate to within at least 2–3°F. To be sure of this degree of accuracy, they must be calibrated against a dependable thermostat several times a year. An inexpensive maximum-minimum record thermometer can easily provide a check on the accuracy of the thermostatic control and is well worth the investment. It is not enough to have good control over the heating system. An operator must know what degree of temperature control is necessary for the type of plants being produced. If flowering plants, for example, are being grown, their flowering is usually timed for a certain holiday season. Temperature control can be essential to the success or failure in this kind of operation.

3. If possible, select a heating system that will allow you to convert from one fuel source to another.