GREENHOUSE HEATING EQUIPMENT SELECTION SPREADSHEET

The Greenhouse Heating Equipment Selection Spreadsheet (GHS) is a tool for evaluating the performance of various types of heating systems for greenhouses. Specifically, seven systems are considered: unit heaters (UH), finned pipe (FP), bare tube (BT), fan coil units (FC), combination fan coil/bare tube (FC/BT), low-temperature unit heaters (GLW), and propane unit heaters (PP).

The spreadsheet is comprised of seven individual areas, the primary input and output and six additional areas each of which covers one of the system types described above. One portion of the spreadsheet covers both the fan coil and fan coil/bare tube system input output.

The primary input contains 16 individual input items covering supply water temperature, greenhouse size and construction materials, and economics data. The primary output is divided into two areas. The first provides information concerning the peak heat loss of the greenhouse. The second area contains a table which provides information about the economics of the various types of heating systems for the greenhouse under consideration. Values for both capital and operating costs are displayed. The far right hand column of the table indicates total annual costs (owning, maintenance and electrical costs) for each of the systems per square foot of greenhouse floor area. These values can be compared to determine the lowest cost system for the particular application. The remaining six sections cover the details of each of the individual systems and the costs associated with them.

The costs calculated on the individual system screens and finally for the primary output table, consider only the costs of the terminal heating equipment and branch lines. Because all six systems are compared at the same supply water temperature and delta T, the costs for the central equipment and piping would be the same. The only variation in cost for individual systems is for the terminal equipment itself.

It is necessary to be familiar with greenhouse heating systems and hydronic design before using this spreadsheet. Users may wish to request the "Greenhouse Chapter" publication from the Geo-Heat Center, geoheat@oit.edu or 541-885-1750. Users unfamiliar with the equipment are advised to review this material prior to using the spreadsheet.

Primary Input

1. Supply Water Temperature (°F). Enter the supply water temperature which will be available to the heating equipment in the greenhouse. This temperature will be less than the well production temperature because of losses in delivery and across the heat exchanger (assuming an isolation plate heat exchanger is used). If a plate-type heat exchanger is used, a value of 5 to 10°F less than well temperature should be entered.

2. Delta T (°F). Enter the design temperature drop for the system. All heating equipment is compared in the spreadsheet using this temperature drop.

3. Floor Area (ft^2). Enter the floor area of the greenhouse to be evaluated. If the development is very large, it may be useful to break the total area up into smaller units.

4. Wall Area (ft^2). Enter the total wall area of the greenhouse under consideration. This value is used to calculate heat loss for the structure.

5. Wall "U" (Btu/hr ft^2 °F). Enter the overall U value for the wall material of the greenhouse. This value is used to calculate heat loss for the structure.

6. Roof Area (ft^2). Enter the total surface area of the roof of the greenhouse. This value is used in the calculation of the structure's heat loss.

7. Roof "U" (Btu/hr ft^2 °F). Enter the overall U value for the roof covering material. This value is used in the calculation of the structure's heat loss.

8. Inside Design Temperature (°F). Enter the inside temperature to be maintained under maximum heating load conditions. This value is used in the determination of design temperature difference for heat loss calculation.

9. Outside Design Temperature (°F). Enter the outside temperature for which the heating system will be designed. This value in conjunction with Input #9 is used to calculate the design temperature difference for heat loss calculations.

10. Average Ceiling Height (ft). Enter the value which best reflects the average ceiling height inside the greenhouse. This figure is used in the determination of the volume of the house for infiltration heat loss calculation.

11. Air Change Rate (changes/hr). Enter the value for the number of air changes per hour appropriate to the type of greenhouse construction planned. This value is used in the calculation of the infiltration heating load.

12. Degree Days. Enter the number of heating degree days appropriate to the climate where the greenhouse is to be located. This value is used to determine the number of full load hours over which the heating system will operate. Operating hours are then used in the determination of electricity use (fans) for the system.

13. Electric Rate ($/kWh). Enter the electric rate which will be appropriate to the greenhouse operation. This value is used in the calculation of annual electrical cost for the heating system.

14. Interest Rate (as decimal). Enter the rate at which purchase of the heating system will be made (mortgage rate). This value is used in the calculation of the owning costs of the system.

15. Loan Term (years). Enter the number of years for which the financing will run (mortgage term). This value is used in the calculation of owning cost for the system.

16. Labor Rate. Enter the cost per hour of labor to be used for installation of the equipment.

Primary Output

1. Peak Heat Loss (Btu/hr). This is the design heat loss for the greenhouse. It is the value which the heating system must supply to maintain inside temperature at the design outdoor temperature condition.

   = Wall Loss + Roof Loss + Infiltration

2. Wall Loss (Btu/hr). This is the heat loss associated with the walls of the greenhouse.

   = Wall Area * (Inside Design Temperature - Outside Design Temperature) * Wall "U"

3. Roof Loss (Btu/hr). This is the heat loss associated with the roof of the greenhouse.

   = Roof Area * (Inside Design Temperature - Outside Design Temperature) * Roof "U"

4. Infiltration Loss (Btu/hr). This is the heat loss associated with the leakage of cold air into the greenhouse.

   = (Greenhouse Floor Area * Average Ceiling Height * Air Change Rate) * .018 * (Inside Design Temperature - Outside Design Temperature)

5. Loss per Square Foot (Btu/hr ft^2). The peak heat loss divided by floor area.

   = Peak Heat Loss ÷ Floor Area

The following section is the primary output of the spreadsheet. It compares the overall costs for seven different heating systems: Unit Heaters (UH), Finned Pipe (FP), Bare Tubing (BT), Fan Coil (FC), combination Fan Coil/Bare Tubing (FC/BT), Low-Temperature Unit Heaters (GLW), and Gas-Fired Unit Heaters (GUH). In each case, the capital cost per square foot is displayed followed by the annual cost (again per square foot of floor area) of maintenance, electricity and ownership. The three annual costs are then summed to arrive at a total annual cost per square foot. Each column is described individually below:

System Type

As described above.

Capital Cost. This is the capital cost for only the terminal equipment of the heating system. Since the spreadsheet is arranged to compare the system using a common ? T and supply water temperature, the cost of the main mechanical equipment (circulating pump, heat exchanger and loop piping) would be the same for all systems. As a result, these costs are not included in the calculation. Only the costs of the actual heating devices are included.

The cost includes both equipment itself, labor for installation, and branch supply and hot water lines for each type of system. The total of these costs is divided by the greenhouse floor area to arrive at the displayed value. Details of the cost calculation are covered in the individual system screens. Equipment and labor costs are calculated separately and combined with a 20% overhead/contingency factor to arrive at the total cost.

Annual Maintenance. This value is the calculated maintenance cost for each system. Generally, mechanical equipment is calculated at 2% of capital cost and piping at 1% of capital cost. The total maintenance costs are then divided by the floor area to arrive at the displayed value.

Annual Electrical Costs. This is the cost of operating the fans associated with equipment in which fans are used (UH, FC, FC/BP and GLW). Fan horsepower is determined using manufacturers data and it is assumed the fans are cycled with the unit. (See individual system screens.) This horsepower is then converted into an electrical kW and multiplied by the number of units and the number of full load hours ([Degree Days * 24] ÷ Design Temperature Difference) to arrive at total annual electrical use. This figure multiplied by the electric rate (Input #13) yields a value for annual electric cost. This value is divided by the floor area of the greenhouse to arrive at the displayed value.

Annual Owning Cost. The value displayed is the capital cost for the system multiplied by a capital cost recovery factor and divided by the floor area of the greenhouse. Stated another way, it is the annual mortgage payment divided by the floor area. The capital cost is calculated at each system screen. The capital cost recovery factor is calculated based upon the interest rate (Input #14) and loan term (Input #15) specified in the input.

Total Annual Cost. This figure is the sum of the annual maintenance, annual electric and annual owning costs for each system. It is the basis for comparison of one system to another. The lower the annual cost per square foot, the more economical the heating system.

UNIT HEATERS

The general approach to using the Unit Heaters calculation is to first specify a number of units. The spreadsheet then calculates a required capacity per unit based on the number selected. Check to make sure that this capacity is equal to or less than the corrected capacity of the largest unit listed in the table below. If the required capacity is greater, increase the number of units. The spreadsheet then calculates the installation labor hours per unit, cost per unit and kW per unit for the size unit selected. The spreadsheet then uses the output from the sheet to generate the values for annual costs shown in the primary output.

Input

1. Number of Units. Enter the number of units desired for space heating. For greenhouses over 80 ft on the long dimension, units should be placed at both ends of the house. Spacing between individual units should not be more than 50 ft. Under certain conditions, the number of units will be affected by the capacity available from the largest unit.

Output

Capacity per Unit. This figure is the output required per unit based on the peak heating load of the greenhouse and the number of units specified in Input #1. It is important to verify that the required capacity does not exceed the corrected capacity of the largest unit (see table at bottom of screen). If this is the case, the number of units selected must be raised until the required capacity is equal to or less than the corrected capacity of the largest unit.

Cost of Selected Unit. The spreadsheet selects the cost of the unit that best matches the required capacity per unit, from the table below.

Hours per Unit. The spreadsheet selects the labor hours for the selected unit from the table below.

kW per Unit. The spreadsheet selects the kW/unit value listed for the unit size selected. This value is used to calculate the electrical costs shown in the primary output.

Indoor Design Temperature. Displayed for convenience. Value is taken from Primary Input #8.

Supply Water Temperature. Displayed for convenience. Value is taken from Primary Input #1.

Delta T. Displayed for convenience. Value is taken from Primary Input #2.

Temperature Correction Factor. Calculated from manufacturer's data. Used to calculate combined correction factor below.

Flow Correction Factor. Calculated from manufacturer's data. Used to calculate combined correction factor below.

Combined Correction Factor. Temperature Correction Factor * Flow Correction Factor. Used for calculating corrected unit heater capacities in the table below.

Total Equipment Cost. This is the total cost of the equipment, including labor, for the number of units specified. Calculated as (Cost of Selected Unit * Number of Units). This figure is used for calculation of values shown in primary output (first screen).

Total Hours. Total labor time required for installation of the number of units specified. Calculated as: Number of Units * Hours per Unit. See note at bottom of table.

Total Cost. Value shown is the sum of total Equipment cost plus total hours times cost per hour entered at Input #16.

The table shown on the unit heater screen lists the rated capacity (at 200º EWT and 60º EAT) for several models. Using the correction factor calculated above, the rated capacity is reduced to reflect the specified conditions of water temperature and delta T. Costs for the unit heaters and branch lines are listed under the Material Cost column. Installation man-hours are listed for each unit. Finally, the electrical kW is listed for each unit. Unit heater costs and labor include allowance for: 20 ft of 1-in. copper pipe, 2 1-in. ball valves, 1-in. zone valve 24V wire and thermostat, 115 V wiring, air vent and 2 1-in. unions. $255 material, 7.1 hours labor.

FINNED PIPE

Input

1. Number of Circuits. Enter the number of individual circuits of finned pipe to be installed in the greenhouse. The number of circuits should be selected to result in a velocity (Output #7) of between .75 and 3.5 ft per second.

Output

Average Water Temperature. Ratings for finned pipe are based upon average water temperature. This value is calculated from the Supply Water Temperature and delta T specified in the primary unit.

Inside Design Temperature. Displayed for convenience. Taken from primary input.

Required Length. The total length of finned pipe required to meet the peak heating load based on the corrected capacity per foot at the specified water temperature.

Temperature Correction Factor. Calculated from the average water temperature and inside design temperature. This value is used to correct the rated capacity of the finned element (shown in the table) to the corrected capacity appropriate to your particular application.

Length per Circuit. Length calculated from the number of circuits specified and the total length required. You may wish to adjust the number of circuits to arrive at a length per circuit which is a multiple of the dimension of the greenhouse in which the pipe is to be installed.

Flow per Circuit. Value is arrived at by dividing the total flow rate by the number of circuits specified in Input #1.

Velocity. The water velocity which results from the circuiting specified (Input #1) and the flow per circuit. Should be between .75 and 3.5 ft per second.

Peak Flow. Peak flow is based upon the peak heat load for the greenhouse and the delta T specified in the primary input section (#2).

Total Equipment Cost. Total cost for the finned pipe. Calculated for the total length * cost per foot from table below.

Total Hours. The total number of hours required for installation of the required length of finned pipe appearing in Output #3.

Total Cost. Value shown is the sum of the total equipment cost plus total labor hours times he cost per hour entered at Input #16.

BARE TUBE

General Procedure

The bare tube section involves an iterative approach to arrive at the correct system design Information concerning the tubing (size, length, emissivity and cost) is input along with a trial water flow rate (per tube circuit). Next the output is checked for agreement between the calculated ? T (Output #7) and the ? T specified in the primary input (#2). The sheet is rerun with new flow rates until the output #7 value agrees with the primary input #2.

Depending upon the application, it may not be possible to make bare tube calculations for larger ? Ts. To evaluate the accuracy of the calculated delta T, check the delta T values in the table at the bottom of the screen.

Input

1. Tube OD. Enter the outside diameter of the tube to be used for the system. Most systems employ polyethylene tubing of 1 in. or less for heating purposes.

2. Water Flow. Enter the trial water flow for each tubing circuit. This value will have to be adjusted several times in order to arrive at a calculated ? T (output #7) equal to the system ? T specified in the primary input section (#2).

3. Emissivity. Enter the emissivity of the tubing used for heating. This value is used in the calculation of the radiant tube output.

4. Horizontal (1.016) Vertical (1.235). Enter the value appropriate to the installation of the tubing. Most systems install the tubing horizontally on the floor or under the benches.

5. Tube Length. Enter the length of each circuit of tubing. Generally, circuits should be less than about 600 feet to limit water side pressure drop. It is also useful to make the length a multiple of the greenhouse dimension over which the tubing will be installed. For example, if the greenhouse length is 100 ft a 400 tube length would allow for 4 passes over the 100 ft dimension.

6. Tube Unit Cost. Enter the cost per foot for the tubing to be used in the system. Be careful to consider the temperature at which the system will be working. Polyethylene which is relatively inexpensive is serviceable to approximately 150°F. EPDM which is more expensive must be used for temperatures above this.

Output

Air Temperature. Displayed for convenience. This value is taken from the inside design temperature (primary input #8).

Entering Water Temperature. Displayed for convenience. This value is taken from the supply water temperature (primary input #1).

Total Unit Output. This is the calculated heat output per foot of tubing. It is the sum of outputs 4 and 5, and is used to calculate the total number of feet of pipe required.

Convective Unit Output. Calculated heat output per foot of pipe due to convection.

Radiant Unit Output. Calculated heat output per foot of pipe due to radiation.

Total Output. Calculated output per circuit. Total unit output * tube length (Input #5).

Delta T. Calculated temperature drop through each circuit. The screen should be re-run with new water flow (Input #2) until the Delta T value shown agrees with the Delta T specified in the primary input section (#2). Delta T is calculated by an iterative process in the table shown below.

Outlet Temperature. Temperature at outlet of each circuit. Calculated from supply water temperature (Primary Input #1) minus Delta T (Output #7).

Total Length. Calculated tubing length requirement based on peak load (Primary Output #1) divided by Total Unit Output (Output #3).

Number of Loops. Calculated by dividing the total length by the tubing length per circuit (Input #5).

Total Cost. Cost for tubing. Calculated by multiplying Total Length (Output # 9) times tubing cost (Input #6). Used for calculation in Primary Output section.

Total Hours. Man-hours required for installation of tubing. Calculated by multiplying .0025 hrs/ft times the total length requirement.

The table which appears at the bottom of the Bare Pipe screen is used to calculate the unit convective output, unit radiant output, total output per foot, total output per loop and delta T values which appear in the outputs above. These calculations are performed in an iterative fashion in which the average water temperature from the previous run is used as the input value for the subsequent run. In this way, the spreadsheet is able to "zero in" on the actual output values. A total of 5 runs are made to produce the values. In some cases (very long circuits or very low water flow rates), the accuracy of this calculation may be poor.

FAN COIL UNITS

The fan coil sheet contains 2 columns of input/output data: one for the fan coil system (left) and one for the Fan Coil/Bare Tube system (right). The following relates only to the fan coil system.

The general procedure for the fan coil system is to specify a number of units and a leaving air temperature. The entering and leaving water temperatures along with the inside air temperature are carried over from the primary input section. Using this input, the spreadsheet calculates the required air flow and coil configuration (rows and fins per inch). The number of rows is rounded off (for which ever fin spacing is closest to a whole number). Using the calculated nominal ton value, figures for unit cost and man-hours are selected from the nearest size unit in the table at the bottom of the screen. The spreadsheet then calculates the total equipment and labor costs and transfers these values to the primary output section.

Input

1. <u>% of Load as Fan Coil</u>. Not used for fan coil only systems,

2. <u>Number of Units</u>. Enter the number of units required. This figure will usually be less than the number of unit heaters specified. Fan coil equipment is capable of higher capacity per unit and is much less effected by low supply water temperature than unit heater equipment.

3.. <u>Leaving Air Temperature</u>. Enter the temperature of the air leaving the fan coil unit. If poly tube distribution is used, a maximum of 135ºF should be entered for this value. The figure, however, must also be considered in light of the supply water temperature available. A supply air temperature of approximately 20ºF less than the supply water temperature is generally possible with 4-row coils or less. The pricing data contained in the spreadsheet assumes that a maximum of 4-row coils would be used. For a given supply water temperature, as the required supply air temperature is increased the coil capacity in terms of more rows and closer fin spacing must be increased.

Output

<u>Capacity per Unit</u>. This is the calculated capacity required per unit based on the number of units specified (#1 above) and the peak heating load.

<u>Entering Water Temperature</u>. Displayed for convenience. Taken from Primary Input #1.

<u>Nominal Tons</u>. The calculated capacity in nominal tons of the fan coil units. Cost data for fan coil units is indexed to the air flow and cooling capacity. As a result, the nominal ton value is calculated in order to determine equipment cost.

<u>Rows Required</u>. Hot water coils transfer heat to the air based on the temperature difference between the water and the air, and the quantity of heat transfer area. Area is a function of the number of rows of tubes the coil has and the spacing of the fins. Shown here are the required rows of tubes at 3

different fin spacings which a coil must have to meet the specified performance. As mentioned elsewhere, the cost data the program uses assumes that a maximum of 4 rows will be used. If the rows required displays a value of greater than 4 rows, leaving air temperature should be reduced to decrease coil surface area requirements.

Cost per Unit. The spreadsheet selects the cost per unit for the unit necessary to meet the required capacity. Values are found in the table at the bottom of the screen.

Labor Hours. The spreadsheet selects the man-hours labor for installation of the unit selected from the table.

Foot of Tube Required. The length of tubing required to meet the portion of the load met by the tubes (1-Input #1). The figure displayed includes both labor and material for the tubing. Calculation not required for fan coil only systems.

Cost of Tubing. Cost for tubing material and installation for the length calculated above. Calculation not required for fan coil only systems.

Total Cost. Values shown is sum of the total equipment cost plus the total labor hours times the cost per hour entered at Input #19. Also includes tubing cost for FC/BT systems.

Leaving Water Temperature. Displayed for convenience. Taken from Supply Water Temperatures (Primary Input #1) minus Delta T (Primary Input #2).

Indoor Design Temperature. Displayed for convenience. Taken from Primary Input #8).

Air Flow per Unit. The calculated air flow required at the specified supply air temperature and capacity per unit. The spreadsheet uses the value to calculate the fan horsepower and to determine the nominal tons below.

Total Equipment Cost. The total equipment cost (fan coil units) calculated from the cost per unit times the number of units.

LMTD. An intermediate value used in the calculation of the coil rows required. Calculated from entering and leaving air temperatures, and entering and leaving water temperatures.

Face Area. Calculated coil face area based upon a 500 foot per minute face velocity. All coil calculations are based on a 500 fpm face velocity.

Air Pressure Drop @ 10 FPI. Calculated air pressure drop across the coil for fan power calculations. Value is expressed in inches of water gauge (in.w.g.) And is based on a fin spacing of 10 fins per inch.

Fan kW @ 10 FPI. Calculated fan electrical energy requirement based upon a 90% motor efficiency, a 50% fan efficiency, calculated air flow and air pressure drop. This value is used for calculating annual electrical consumption for the primary output.

Total Man-Hours. Man-hours per unit times the number of units specified in the input. This value is used to calculate the total labor costs for installation of the fan coil units.

The costs and labor for the FC units includes allowance for: 2 1-in. unions, 2 l-in. ball valves, 1 1-in. zone valve, 20 ft of 1-in. copper pipe, automatic air vent, thermostat and 24v wiring, 115v wiring.

FAN COIL/BARE TUBE

The fan coil/bare tube input and output is located on the same section as the Fan Coil system. With the exception of one additional input item, the FC/BT analyses is operated the same as the FC.

The FC/BP system is one in which the greenhouse is heated the majority of the time by the bare tubing. Only during peak periods do the fan coil units operate. The use of this system greatly reduces annual electrical requirements and in some cases, the number of fan coil units required. Because the fan coil units are located in series with and downstream of the bare tubes, the supply water temperature available is less.

The comments below address only the difference between the FC/BT and FC procedures.

Input

The first input item is the percentage of the peak load which will be handled by the fan coil units. Sizing the fan coil units for 30 to 40 percent of the load would, in most locations, allow the tubes to provide 90+% of the annual heating needs. It may be useful to experiment with the value to arrive at the optimum value (lowest annual cost) for your project.

1. Number of Units. Because the fan coil units will supply only a portion of peak load, the number of units required can be lower than for the fan coil system. A minimum number will be required to achieve adequate air distribution, however.

2. Entering Water Temperature. The entering water temperature displayed is the value which results from subtracting the temperature drop through the bare pipe from the primary supply water temperature. This lower supply water temperature may necessitate a lower supply air temperature for the fan coil units under the FC/BT system compared to the FC system.

GLW UNIT HEATERS

GLW is the designation for one manufacturer's equipment line which is specifically designed for low-temperature greenhouse heating. The equipment is similar to conventional unit heater design but with an improved coil for greater heat output at low supply water temperature.

The GLW section is operated in much the same fashion as the unit heater screen. A number of units is selected. From this and the supply water temperature and Delta T, the spreadsheet calculates the capacity of the two models of GLW equipment. It then selects the appropriate unit and enters its cost, labor and electrical kW in the appropriate places. It is necessary to adjust the number of units so as to arrive at a capacity per unit close to one of the calculated capacity values in the table at the bottom of the screen. It is also useful to check the total cost associated with a small number of large units (GLW 660) compared to a larger number of small units (GLW 330).

Input

1. Number of Units. Enter the number of units selected for heating the greenhouse. Generally, due to the higher performance of the GLW equipment, the number of units required is comparable to fan coil equipment and less than conventional unit heaters. The number of units also should be coordinated with the calculated capacity per unit displayed in the table below.

Output

Capacity per Unit. Calculated capacity required per unit based upon the peak heating load and the number of units specified.

Cost of Selected Unit. The cost, from the table below, of the unit selected.

Hours per Unit. The installation labor hours, from the table below, of the unit selected.

kW per Unit. The kW, from the table below, for the unit selected. Value is used for calculating electrical costs in the Primary Output.

Indoor Design Temperature. Displayed for convenience. Taken from Primary Input.

Supply Water Temperature. Displayed for convenience. Taken from Primary input.

Delta T. Displayed for convenience. Taken from Primary Input.

Total Cost. Number of units times the cost per unit. Value is used in cost calculations for Primary Output.

Total Hours. Number of units times the hours per unit. Value is used in cost calculations for Primary Output.

Flow per Unit. Calculated water flow per unit based on the capacity per unit and the specified Delta T.

Table. Shown in the table below are the capacity, cost, installation labor and electrical requirements (kW) for the two models of GLW equipment available. The capacity is automatically calculated based on the supply water temperature and flow rate from above. The costs and labor for the GLW units includes allowance for: 2 1-in. unions, 2 1-in. ball valves, 1 1-in. zone valve, 20 ft of 1-in. copper pipe, automatic air vent, thermostat and 24v wiring, 115v wiring. Sizes of components increase to 1-1/2 for GLW660 unit.

GAS-FIRED UNIT HEATERS

Gas-fired unit heaters are sometimes used as a peaking system in greenhouses in which geothermal serves as the base-load system. This can be the case were the geothermal temperature is very low or where effluent from one house is used to heat a second facility. This section of the spreadsheet calculates the number and capacity of unit heaters required to meet a user defined percentage of the peak heating load.

Input

1. Number of Units. Enter the number of individual heating units required. As with all systems, some minimum number of units is typically necessary to assure adequate air distribution within the structure.

2. Percent of Design. Enter the percentage of the design load to be met by the gas-fired units. Any value up to 100% can be entered. Typically in base load/peak load designs, the peaking system (gas-fired) is designed to carry 40 to 50% of the peak load.

Output

Capacity per Unit. This is the required capacity (in Btu/hr) of the individual units required based on the percentage of the load to be handled and the number of units specified. This value must be equal to or less than the largest unit listed in the table at the bottom of the page.

Capacity in MBH. This is the capacity from the above output divided by 1000.

Cost per Unit. This is the cost of the unit size to most closely meet the capacity per unit value. The cost includes (as detailed in the box following the table below) the necessary flue pipe, branch gas piping and electrical connections to make the unit functional.

Hours per Unit. This is the total man-hours necessary to install the unit heater and the related components.

kW. This is the electrical demand of the motor the unit heater is equipped with. The value is used in the calculation of the operating costs for the system.

Total Equipment Costs. This is the total cost for the equipment associated with the unit heaters. It is determined by multiplying the cost per unit times the number of units.

Total Labor Hours. This is the total labor man-hours necessary to install the unit heaters and related equipment. It is determined from the hours per unit times the number of units.

Total. This is the total cost for the labor and materials for the unit heaters. It does not include the main gas piping necessary to serve the units. The length of this pipe and its cost is a function of the layout of the greenhouse.

$/sq ft. This is the total cost from above divided by the floor area of the greenhouse as entered at Input #3.

The table at the bottom of the page includes the cost, labor and electrical requirements of the unit heaters indexed to unit capacity. This data can be updated when necessary to reflect inflation. Prices indicated are current as of January 2002. The labor and equipment figures above include an allowance for: 12 ft of flue pipe, flue cap and collar, 115v wiring, 24v wiring, thermostat, shut-off valve and 20 ft of gas line.