College Of Southern Idaho
Geothermal Greenhouse Modifications

Prepared by
Kevin Rafferty, PE
Klamath Falls, OR

For
Idaho Department Of Water Resources

Under contract #DWR-CON000633

12 April 2004

Contents

Introduction ……………………………………………….3

Existing Plastic Film Greenhouse Heating Systems………...3

Greenhouse Heating Requirements……………………….....4

Greenhouse heating Equipment……………………………..5

Recommended Heating Equipment……………………….....6

Aquaculture………………………………………………......8

Impact on Perrine Coulee………………..............................10

Potential Glass Greenhouse Modifications………………....10

Future Geothermal Development…………………………...10

College of Southern Idaho Geothermal Greenhouse Heating Modfications

Introduction

The college of southern Idaho is one of only two college campuses in the US using geothermal direct use technology for space heating. Two wells at slightly more than 100 degrees Fahrenheit (F) provide water to the campus heating system. In conjunction with the heating of the main campus buildings, a small complex of greenhouses is also supplied with geothermal water for heating purposes. At present, the greenhouse complex consists of a 24 x 48 ft glass house that is in regular use and three plastic film covered Quonset type houses each 18 x 50 ft that are not in use. These three structures are constructed of single plastic film roofs and double wall polycarbonate end walls. The object of this report is to identify what would be required to place the heating systems in the 3 plastic covered structures in service in such a way that suitable temperatures could be maintained for either plant or aquaculture projects. In addition, there are plans to place aquaculture facilities in at least one of the greenhouses though the specifics of the species to be grown and design of the culture apparatus is not yet defined in detail. Finally, a greenhouse may be placed to the north of the campus at some point in the future. The available heat in campus effluent near this site may be of interest in terms of heating this structure. This report addresses the issues above to the extent possible given the current level of information available.

Existing Plastic Film Greenhouse Heating Systems

Each of the three greenhouses is equipped with a floor heating system consisting of a grid of parallel 1 inch copper tubes running the length of the house and buried in pea gravel at a depth of approximately 6 inches. Water from the campus supply wells at approximately 100 F is delivered to the greenhouses for use in the heating systems. At one time each of the systems was equipped with a control valve that responded to a thermostat facilitating automatic control of the temperature in each greenhouse. It appears that some of these components have been removed. In addition, a freeze condition occurred in the middle greenhouse in the past causing a failure of some of the buried copper lines though evidently this has been repaired and all three systems are functional but must be operated manually. According to the campus physical plant personnel, the approximate amount of water available to each house is 50 gpm.

In colder climates, such as southern Idaho, it is typically not possible to fully heat a greenhouse with a floor system. The heat output of a floor heating system is a function of the temperature difference between the floor surface and the temperature in the greenhouse (air and unheated surfaces). To fully heat a greenhouse, especially small units such as these, the required floor temperature is above that recommended for occupancy. This is the case with this system as well. In fact the system was never intended to fully heat the greenhouses according to CSI physical plant staff. Based on the configuration of the floor tubes and the temperature of the water available to the system, calculations indicate that the floor system is capable of meeting only about 50% of the required heating needs (approximately 55 Btu/hr sq ft assuming a vacant greenhouse) of the structures. In fact in an operating greenhouse the existing systems would likely fall well below the 50% capacity since plants, benches and other items would compromise the performance of the floor system relative to that achieved in a vacant greenhouse. To fully heat the greenhouses to acceptable temperatures, either a new full capacity heating system is needed or a second system designed to supply the load that remains un-met by the floor system.

Greenhouse Heating Requirements

The heating requirement of a greenhouse is a function of the construction materials, desired inside temperature and outside design temperature, among other factors. Using an inside temperature of 55 F, an outside design temperature of 5 F (99% of all heating season hours in Twin Falls are above this value) and the existing single film/polycarbonate construction of the greenhouses, the peak heating requirement of each of the three greenhouses is 103,450 Btu/hr as summarized in table 1

Table 1
Greenhouse Peak Heat Loss

Roof	90,300 Btu/hr
End Walls	7,850
Infiltration	5,300
Total	103,450 Btu/hr (115 Btu/hr per sq ft of floor)

The three houses as mentioned earlier are all currently covered in single layer plastic film. The roof on the southern most house is badly damaged and requires replacement before it could be used. It is also possible to cover these greenhouses with a double layer of plastic on the roof areas. This is the standard construction used in commercial greenhouses in climates such as southern Idaho. The double layer of plastic substantially reduces heating requirements. Other than the additional plastic material, a very small fan is used to maintain the space between the two layers in a slightly pressurized condition. The inflation fan is approximately the size of a hairdryer and requires only a very small electrical input. The use of a double layer roof on these greenhouses would reduce the "U" factor for the roof from 1.15 to 0.70 Btu/hr sq ft F and the total heating requirement from 103,450 Btu/hr to 68,100 Btu/hr – approximately 34%.

Since greenhouse personnel reported that past funding for installation of a double roof has not been available, the balance of this report is based on the existing single layer construction. The college may wish to consider a proposal to the US Department of Agriculture for the funds necessary for the costs associated with the installation of a double roof. A program for energy related projects was part of the recently passed Farm Bill.

Greenhouse Heating Equipment

The greenhouse heating equipment will be required to meet, at a minimum, the heating load beyond the capability of the present floor tubing. As an alternative a system could be selected to meet the entire heating load, assuming the existing floor system is abandoned. As current information suggests that the existing floor systems are operational, and this type of heat is an effective approach for many plant species, it seems reasonable to incorporate it into the updated system.

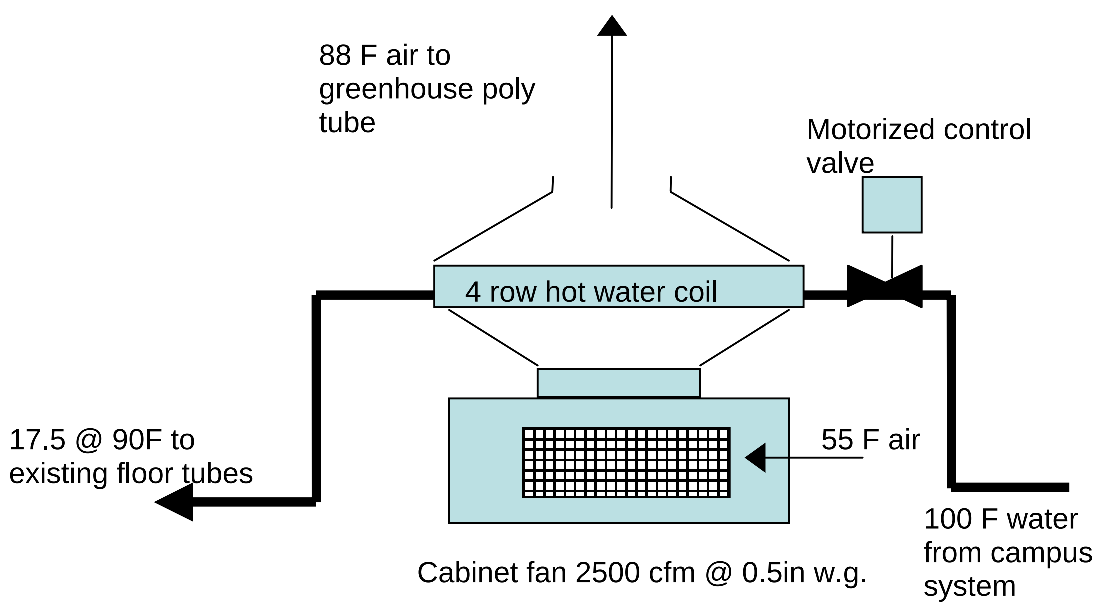
Heating of greenhouses with low temperature geothermal water less than 125 F is always a challenge. This is particularly true with small greenhouses since their surface area to volume ratio results in heating requirements (in Btu/hr sqft) of 20 to 40% more than larger facilities. In general, natural convection and radiant type equipment is not a practical approach at the low water temperatures (100 F) available in this application. Attempts to use such equipment result in excessive and impractical equipment size and cost. The most effective heating equipment for very low temperature applications is the fan coil unit. This consists of a specialized air heating coil combined with a centrifugal blower to move the air through the coil and then into the greenhouse. Somewhat similar to the unit heater type equipment currently used in the glass greenhouse, the primary differences are the custom designed coil (configured to extract a greater amount of heat from the water) and a centrifugal instead of axial fan. The fan coil unit is somewhat larger physically than an equivalent unit heater and requires a higher horsepower fan motor. For example, the unit heaters in the glass greenhouse appear to be nominally rated at 86,000 Btu/hr. This rating is based on the use of 2 psi steam as the heating medium. When the same unit heater is supplied with 100 F water, its heating capacity is only a little over 20,000 Btu/hr. At an air flow rate of 1120 cubic feet per minute (cfm), typical of units this size the temperature of the air delivered to the greenhouse is only about 72 F. A fan coil type unit with a 4 row coil operating at the same air flow would deliver 88 F air and provide a capacity of approximately 39,900 Btu per hour – roughly doubling the amount of useful heat from the same flow of 100 F water. The power requirement for the fan coil unit would amount to just under 1/2 horsepower compared to the unit heater’s 1/8hp. In terms of annual operating cost, assuming 2000 operating hours per year and $.06 per kWh, the electrical cost of operation would be $45 per year and the unit heater $22 per year.

Recommended Heating Equipment

For the plastic covered greenhouses, placing the fan coil unit in series with the existing floor tubes would allow the existing floor system to contribute a portion of the heating load with the new fan coil unit meeting the remainder of the requirement. When two types of equipment are placed in series, it is important to assure that each meets its minimum flow requirement. The geothermal flow in this case is driven by the floor tubes due to their arrangement. With approximately 18 individual 1" tubes in parallel, it is necessary to provide sufficient water flow to ensure that the velocity in the tubes is above the turbulent threshold (below which heat transfer is substantially reduced). This requires a minimum flow rate of 0.97 gpm per tube or a total flow of 17.5 gpm. Though this is greater than what would be necessary for the fan coil unit, the flow remains much less than the original flow used for the tubes alone.

Figure 1 provides a simplified diagram of the cabinet fan/ hot water coil configuration. Minor plumbing components such as shut off valves, unions, air vents, strainer etc have been omitted for clarity.

Figure 1
New Greenhouse Fan Coil Arrangement



Assuming the floor tubes are placed downstream of the fan coil unit and that plants, benches and other items cover portions of the floor and otherwise compromise 50% of the floor heating output, the resulting floor capacity would amount to 20,000 Btu/hr. As a result the fan coil unit would be sized for a capacity of 85,000 Btu/hr in order to maintain a minimum inside temperature of 55 F at the 5F outside design condition. This would require a cabinet fan capable of providing an air flow rate of 2500 cfm at 0.5 inches water gage (in w.g.), a 4-row 24" x 30" coil and sheet metal duct transitions to connect the coil and fan. Discharge air at 88 F would be delivered through an 18" diameter poly tube running along the peak of the greenhouse roof. The cabinet fan unit of this size is approximately 45 inches wide, 16 inches tall and 16 inches deep – easily mounted on the floor of the greenhouse to one side of the existing door.

The water flow to the coil would be controlled by a motorized valve responding to a thermostat. After passing through the coil the water would be reduced in temperature to approximately 90 F and would proceed to the existing floor tubes. The existing piping directing the water to disposal would remain unchanged. To accommodate the operation of the fan coil unit, electrical service would have to be provided to the three greenhouses from an adjacent building.

Costs for the arrangement appearing in Figure 1 are summarized in Table 1. These costs appear in two different formats with material only costs on the left and installed costs assuming prevailing wage and contractor overhead and profit on the right. In both cases 15% contingency is applied. Costs for the electrical connections internal to the greenhouse are included but information was not available to evaluate the costs associated with extending service from adjacent buildings. The costs in Table 1 are for a single greenhouse. The total costs for all 3 greenhouses would be 3 times the values shown.

Table 1
Estimated Greenhouse Heating Equipment Costs

	Material Only	Installed
Cabinet fan (2500 cfm@0.5in)	$800	$1100
Coil (4 row 24x30)	850	1300
Sheet metal transitions	150	400
Electrical connections	30	175
Piping/fittings	200	425
Controls	200	800
15% Contingency	350	650
Total	$2580	$4850

Aquaculture

Part of the plan for the use of the greenhouses may involve a small aquaculture lab in one of the structures. The exact configuration of the aquaculture arrangement is not known. To evaluate this potential use of the geothermal water, it was assumed that the commonly used 6 ft diameter tanks available from aquaculture suppliers would be used here. These packaged aquaculture systems (figure 2) normally consist of two 6 ft diameter approximately 500 gallon tanks linked to a small bio filter for water quality control. The use of the bio filter limits the need for make-up water to approximately 10 gal per day thus limiting the issue of water disposal. In the context of a greenhouse facility such as this, presumably the nutrient rich water removed from the tanks could be used for irrigation of the plants in the other structures.

Figure 2
Typical Educational Aquaculture Tanks

Heating of commercial aquaculture facilities is most often accomplished by adding the geothermal water directly to the tanks, ponds or raceways for heating purposes. To maintain water levels stand pipes are placed in the vessels. A primary consideration with this approach is the fact that the water exiting the facility contains fish waste products. In this particular case, due to the disposal of the water to the Perrine Coulee, it would be advisable to avoid this approach if possible in order to avoid potential environmental complications with disposal.

If the heating water is not admitted directly to the tanks, some means of external heat exchanger must be used to transfer heat out of the geothermal water to the fish culture water. Fouling is a major problem in fish culture heat exchangers. In commercial operations due to the large heat transfer requirements the use of heat exchangers is unavoidable. In a small experimental operation such as this, an alternative may be to use the tank itself as a heat exchanger.

The heat loss from a 6 ft diameter tank surface with a water temperature of 75 F at an air temperature of 55 F is approximately 4700 Btu/hr. If flexible polyethylene tubing was wound around the outside circumference of the tank, the 100 F water from the geothermal supply could be passed through the tubing effectively making the walls of the tank a heat exchanger. This approach offers the advantage of eliminating both the contaminated disposal and heat exchanger fouling issues.

Assuming the use of 80% of the available tank side wall surface (piping connections for the bio filter, recirculation etc preclude using the entire surface) a 6 ft diameter tank would have approximately 38 sq ft available as heat transfer surface area. Calculations indicate that with the thermal resistance of the polyethylene pipe, the fiberglass tank wall and the fluid films in the pipe and tank, that the available 100 F water circulated through tubing against the tank wall, should be able to maintain a temperature in the tank of 75 F. If covers are used at night on the tanks higher temperatures could be maintained.

Using ¾ in pipe around the circumference of the 6 ft tank would require approximately 450 ft of pipe per tank. With water entering at 100 F, and a 4700 Btu/hr load, the exit water temperature would be 91 F at a flow rate of 1.0 gpm. A single circuit could be used for tubing and flow would be controlled by a manual valve or a motorized valve responding to tank water temperature.

Accurate estimates of the cost of the aquaculture heating should be made subsequent to final decisions as to the specific equipment to be used. However, Table 2 presents the costs associated with the components necessary to assemble the heating system described above.

Table 2
Heating System Components for 6ft Diameter Aquaculture Tank
(material only costs)

Polyethylene pipe (3/4”) 450 ft	$100
Aquastat	50
Control valve	65
¾” ball valves (2)	20
low voltage wiring	50
misc fittings	25
15% contingency	45
Total	$355

Impact Upon Perrine Coulee

Most of the effluent from the campus geothermal heating system, including that of the greenhouse facilities, is directed to the Perrine Coulee for disposal. Substantial changes to the temperature or flow in the coulee could have an impact on downstream users of the water. The changes outlined in this report are not expected to result in a substantial impact upon the coulee.

Provided the heating system outlined in this report is implemented, the flow in the coulee will increase by 52.5 gpm (3 greenhouses @ 17.5 gpm each). The temperature of this water will be approximately 88 F. Measurements of two flows into the Coulee taken during the site visit for this work indicated current discharge temperatures of 89 F from other parts of the campus heating system. The total flow, at peak (as distinct from the average flow as reported to IDWR) entering the coulee from the campus heating system amounts to approximately 2500 gpm. The discharge from the three greenhouses would therefore result in approximately a 2.1% increase in the flow into the coulee and essentially zero impact on the water temperature.

The only user of the water in the coulee identified was the College itself (for irrigation) and the individual responsible for monitoring that use is Ross Spackman.

Potential Glass Greenhouse Modifications

Though this report focused on the re-establishment of the three plastic greenhouses, in the course of the site visit the glass house was also visited. Its heating system currently consists of the two units heaters described earlier along with back up electric resistance unit heaters. When the hot water units are unable to meet the load, the electric heat is activated. It would be possible to use the same equipment described for the plastic houses in the glass greenhouse as well. The use of the higher capacity fan coil units could eliminate the need for the electric heat currently used to back up the geothermal units and potentially reduce the geothermal flow necessary to heat the glass structure.

Future Geothermal Development

In the course of the site visit the potential for installation of an additional greenhouse in the future was discussed. This greenhouse, located at another site in the area is potentially available to the college at low cost/no cost. The question arose whether there would be some means by which campus effluent might be used to heat the greenhouse. However plans are very preliminary and only limited information was available about the structure and potential heat sources.

One option for a location would be on property owned by the college to the north of the main campus near the current photovoltaic installation. Adjacent to this location is one of the main campus geothermal discharge points. According to CSI physical plant personnel, the flow at the particular point is approximately 1200 gpm at peak heating conditions at a temperature of approximately 80 to 85F.

The greenhouse structure is reported to be 30 x 100 ft. Assuming a peal loss of approximately 100 Btu/hr sq ft, a peak heating load of 300,000 Btu/hr would result. The campus effluent stream could easily supply the heating needs of the greenhouse. In fact based on the 1200 gpm flow, the greenhouse load would only reduce the water temperature 0.5 F if the entire flow was used in the heating system.

A practical design would not employ the entire flow however. Due to the very low water temperature a heat pump assisted system or a fossil fuel peaking approach would be well suited for the application and would require less than 10% of the available flow. In fact the use of a hybrid design (heat pump or fossil fuel combined with geothermal) would be necessary since campus effluent may not be available in the more moderate temperature portions of the year (late Spring, early Fall) due to the differences in greenhouse and campus building heating needs. The use of the hybrid design would allow for both back up and peak heating requirements.